RECENT ADVANCES IN WELDING TECHNOLOGY

Soundra Prashanth
Sanjeet Kumar

ALEXIS PRESS
JERSEY CITY, USA

RECENT ADVANCES IN WELDING TECHNOLOGY

RECENT ADVANCES IN WELDING TECHNOLOGY

Soundra Prashanth

Sanjeet Kumar

ALEXIS PRESS

ALEXIS PRESS

Published by: Alexis Press, LLC, Jersey City, USA
www.alexispress.us

First Published 2022

A catalogue record for this publication is available from the British Library

Library of Congress Cataloguing in Publication Data

Includes bibliographical references and index.

Recent Advances in Welding Technology by *Soundra Prashanth, Sanjeet Kumar*

ISBN 978-1-64532-457-7

CONTENTS

CHAPTER 1

SPECIFICATION OF THE ADVANCE WELDING TECHNOLOGY

Mr. Soundra Prashanth, Assistant Professor
Department of Mechanical Engineering, Presidency University, Bangalore, India
Email Id: - prashanth.sp@presidencyuniversity.in

ABSTRACT:

The process of joining metal components together by employing heat energy is known as welding. Arc welding is a type of welding that joins materials together using an electrical current. Although less accurate, this approach is more economical.By utilizing intense heat to melt the components together and then allowing them to cool, which results in fusion, welding is a fabrication method that unites materials, typically metals or thermoplastics. Welding is separate from lower temperature processes that don't melt the base metal, such brazing and soldering.

KEYWORDS:

Brazing, Base Metal, Fabrication, Soldering, Thermoplastics.

INTRODUCTION

To perform on of the welding techniques and understand important of arc welding. Define the problem that occurs on the arc welding. Recognize the type of metal, electrode, and tools that are used in arc welding. Recognize types of arc welding and steps to create the arc welding. To know safety measure when use the welding machine along the welding process.The most widely used technique for permanently connecting all metals is welding. Although it might be regarded as a mature industry in some ways, it is still expanding. The value of the parts produced by welding, the amount of money saved by using welding over alternative metal fabrication methods, and the value of products made possible by welding should be used to determine welding's genuine influence on the metalworking industry.The expansion of the welding equipment and materials sector has been documented historically, and this growth can be used to predict future growth. The arc welding segment of the industry seems to be growing the fastest with recent years showing maximum growth.

The growth of the welding industry has been approximately 6% per year. Conventional electric arc welding equipment and filler metals represent over two-thirds of this total. Each segment of the industry and each welding process has its own growth patterns [1]–[3].In order to make a projection we must determine the past historic growth patterns, determine the present position, and consider those factors that will have an impact on the growth in the future. Future growth of the arc welding processes depends on factors that may have an impact on the industries served by welding.The future of these industries will largely determine the future of welding. It is possible to estimate the amount of each type of arc welding that is being done in the U.S.A. and how it is being applied. The most suitable approach for this analysis is to divide filler metals sold into the following categories:

1. Covered electrodes stick electrodes all types.
2. Submerged arc welding electrode wire solid steel larger than 1/16 in. 1.6mm in diameter.
3. Gas metal arc welding electrode wire solid steel wire 1/16 in. 1.6mm and smaller.
4. Covered electrodes have been decreasing steadily for the last 14 years dropping from 81% to 59% and projected to 45%.
5. Submerged arc welding has remained constant at about 5% to 7%.
6. Gas metal arc welding has almost doubled, rising from 10% to 20%, and is projected to double again in the next ten years.
7. Flux-cored welding is increasing, but at a slower rate.
8. This information shows that semiautomatic welding will greatly increase, machine and automatic welding will increase modestly, but manual welding is decreasing at least as a percentage of the total.
9. After analyzing recent trends in welding and manufacturing it becomes evident that the following must be considered with regard to the future of welding.
10. There will be a continuing trend towards the use of higher-strength materials, particularly in the steels and lighter-weight materials.
11. There will be more use of welding by manufacturing industries, probably decreasing the use of castings.
12. There will be a trend towards higher levels of reliability and higher-quality requirements.
13. The trend towards automatic welding and automation in welding will accelerate.

Welding is a fabrication process used to join materials, usually metals or thermoplastics, together. During welding, the pieces to be joined are melted at the joining interface and usually a filler material is added to form a pool of molten material that solidifies to become a strong joint.Welding is a common process for joining metals using a large variety of applications. Welding occurs in several locations, from outdoors settings on rural farms and construction sites to inside locations, such as factories and job shops. Welding processes are fairly simple to understand, and basic techniques can be learned quickly. Welding is the joining of metals at a molecular level. A weld is a homogeneous bond between two or more pieces of metal, where the strength of the welded joint exceeds the strength of the base pieces of metal.At the simplest level, welding involves the use of four components: the metals, a heat source, filler metal, and some kind of shield from the air. The metals are heated to their melting point while being shielded from the air, and then a filler metal is added to the heated area to produce a single piece of metal. It can be performed with or without filler metal and with or without pressure.There are several types of welding that are used today. Gas Metal Arc Welding GMAW or MIG, Gas Tungsten Arc Welding GTAW or TIG, Flux Core Arc Welding, and Stick Welding are the most common found types in industrial environments.

General Specification of the Advance Welding Technology was proposed by Miyamoto et al. From a scientific and technological standpoint, developments in laser welding technology for glass over the past 20 years are reviewed. These technologies include continuous wave CW, ns pulse, and ultra-short pulse USP lasers. According to a novel thermal stress model, the presence or absence of a free surface in the molten pool affects whether or not cracks in glass are prevented by laser welding. Due to the shrinkage stress and the fact that the molten pool has a free surface, crack-free welding is only possible with glass that has a low coefficient of thermal expansion CTE when using CW lasers to weld glass to glass. If the space between the glass substrates is short while welding glass to glass with a USP laser, crack-free weld-in is possible regardless of the CTE of the glass [4]–[6].Ali et al. Modern manufacturing requires complex welding techniques to combat the materials' quick growth. Engineering is becoming more difficult as a result of the new alloys and composites that are being formed in materials today. To understand how materials react to a quick temperature increase and how that affects welding performance, it is becoming more crucial to point out specific welding flaws.

The mechanical properties and microstructure creation following welding are the most characteristics that were found in the literature. These qualities describe the welding's strength. This essay discusses a few flaws in the cutting-edge welding technology that is largely utilized today in business. A discussion of welding technology is presented first, followed by a description of each approach, before each method's flaws and problems are highlighted.Salehpour-Oskoui et al. one of the intricate industrial processes is tungsten inert gas TIG welding. The metallurgical structure of welding parts has drastically changed as a result of the welding process' repeated heating and cooling cycles. These modifications degrade the mechanical qualities of the parts and result in a variety of metallurgical and mechanical flaws. The quality of welded items is influenced by a variety of welding factors in varying ways. It is vital to recognize the impact of these characteristics, be able to quantify it, and choose the best and most ideal conditions in order to produce a satisfactory weld. Therefore, an experimental investigation was carried out in this study to determine the mechanical properties of the pieces through variation of three main welding parameters, including advance.

Xu, et al. say that the subject of robotic welding is now dominated by robotic welding techniques. It has attributes including strong system redundancy, resilience, wide spatial dispersion, free cooperation, and outstanding environmental adaptability. The development of multiple robotic welding approaches, such as weld seam tracking, remote welding, off-line programming and simulation, and multi-robot cooperative welding, is reviewed in this study. Both the technical issues and the projected development trend are discussed.Uday et al. One of the most affordable and effective ways to combine metals that are similar and different is friction welding, which is already well established in the industry. It has many industrial uses in the automotive and aerospace sectors. In this area, friction welding is frequently the only practical solution to address the challenges presented by combining materials with greatly disparate physical properties. In order to weld using relative movement between the work pieces rather than electrical energy or heat from other sources, this method uses a machine that is built to transform mechanical energy into heat at the junction. The fundamental comprehension of the procedure is the focus of this review. The mechanism of friction welding, various relative motions used in the process, the effects of various parameters, and heat generation.

DISCUSSION

Welding, brazing, and soldering all result in the permanent joining of the parent materials. Welding is a fabrication process used to join materials, usually metals or thermoplastics, together. During welding, the pieces to be joined are melted at the joining interface and usually a filler material is added to form a pool of molten material that solidifies to become a strong joint.

Types of Welding

There are many types of welding used for various purposes under different situations. They are shown in Figure 1.

MIG Welding :MIG welding is one of the easier types of welding for beginners to learn. MIG welding is actually two different types of welding. The first uses bare wire and the second flux core. Bare wire MIG welding can be used to join thin pieces of metal together. Flux core MIG welding can be used outdoors because it does not require a flow meter or gas supply. MIG welding is usually the welding of choice for DIY enthusiasts and hobby welders who don't have the money to spend on expensive equipment.

Stick Welding : Stick welding, also known as Arc welding, is doing it the old fashioned way. Stick welding is a bit harder to master than MIG welding, but you can pick up a stick welding equipment for very little if you want to have a go at home. Stick welding uses a stick electrode welding rod.The below video explains the difference between Wire Feed Welding and Stick Welding.

TIG Welding: TIG welding is extremely versatile, but it is also one of the more difficult welding techniques to learn and Lincoln Electric TIG welders are skilled individuals. Two hands are needed for TIG welding. One hand feeds the rod whilst the other holds a TIG torch. This torch creates the heat and arc, which are used to weld most conventional metals, including aluminum, steel, nickel alloys, copper alloys, cobalt and titanium. TIG welders can be used to weld steel, stainless steel, chromyl, aluminum, nickel alloys, magnesium, copper, brass, bronze, and even gold. TIG is a useful welding process for bike frames, lawn mowers, door handles, fenders, and more.

Electron Beam and Laser Welding : Electron beam and laser welding are extremely precise, high energy welding techniques. Electron beams and lasers can be focused and aimed with the exceptional accuracy required to weld the smallest of implantable medical devices, and yet also deliver the tremendous amounts of power required to weld large spacecraft parts. Electron beam and laser welding are versatile, powerful, automatable processes. Both can create beautiful welds from a metallurgic and an aesthetic perspective. Both can be cost-effective.

Gas Welding : Gas welding is rarely used anymore and has been largely superseded by TIG welding. Gas welding kits require oxygen and acetylene and are very portable. They are still sometimes used to weld bits of car exhaust back together. There is currently a huge shortage of skilled welders in the US and the rest of the world, so for young people who do decide to take up a career as a welding technician, the job prospects are good.

Resistance welding: Resistance Welding is a group of welding processes in which coalescence is produced by the heat obtained from resistance of the work to the flow of electric current in a circuit and by the application of pressure *4*. Examples of resistance welding include spot welding, induction welding, and flash welding. The most common type is spot welding. Resistance spot welding is a process that produces coalescence of metals at surfaces which are made to fit closely together for the purposes of making a joint. In a structure, a resistance spot weld has mechanical characteristics much like those of a rivet, although its soundness and strength are oftentimes many folds greater.

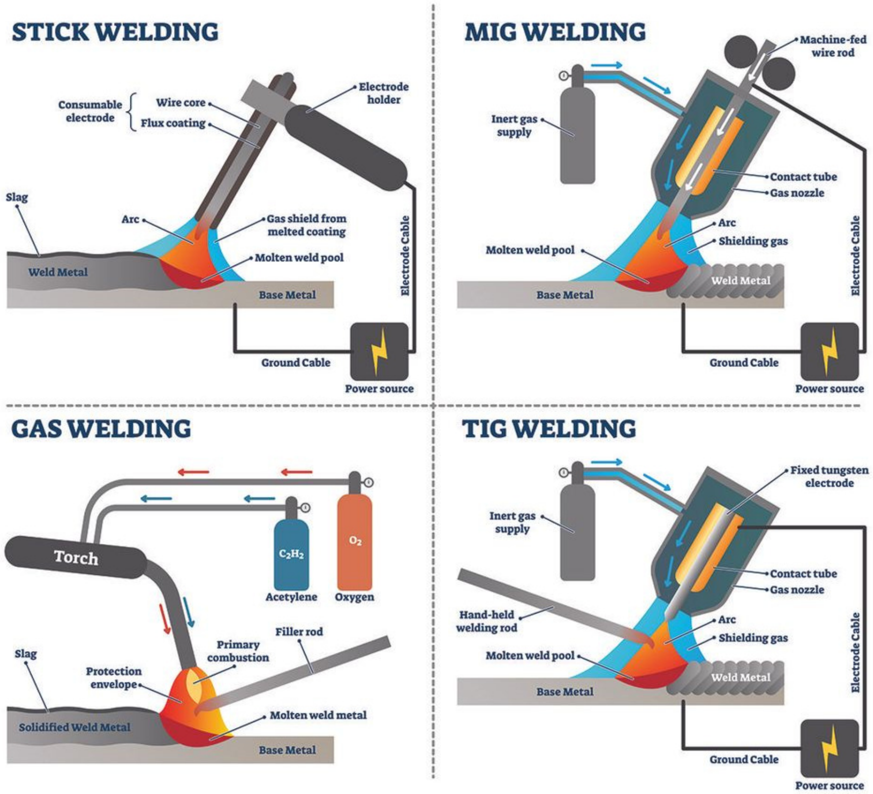


Figure 1: Represent the Types of Welding [McMahan Industrial Service].

Plasma Arc Welding:

Plasma arc welding is a precision technique and is commonly used in aerospace applications where metal thickness is 0.015 of an inch. One example of such an application would be on an engine blade or an air seal. Plasma arc welding is very similar in technique to TIG welding, but the electrode is recessed and the ionizing gases inside the arc are used to create heat [7]–[9].The normal combination of gases is argon for the plasma gas, with argon plus 2 to 5% hydrogen for the shielding gas. Helium can be used for plasma gas but because it is hotter this reduces the current rating of the nozzle.

Energy Beam Welding:otherwise referred to as electron-beam welding, is a fusion welding process. The method involves a beam of high-velocity electrons that are applied to two materials that are being joined together. The pieces melt and fuse together as the kinetic energy of the electrons is transformed into heat upon impact.

Solid-State Welding: Solid-state welding refers to joining processes in which coalescence results from application of pressure alone or a combination of heat and pressure. If heat is used, the temperature in the process is below the melting point of the metals being welded. No filler metal is utilized. Representative welding processes in this group include the following:

Diffusion Welding: Two surfaces are held together under pressure at an elevated temperature and the parts coalesce by solid-state diffusion.

Friction Welding: Coalescence is achieved by the heat of friction between two surfaces.

Ultrasonic Welding: Moderate pressure is applied between the two parts and an oscillating motion at ultrasonic frequencies is used in a direction parallel to the contacting surfaces. The combination of normal and vibratory forces results in shear stresses that remove surface films and achieves atomic bonding of the surfaces [10], [11].

Advantages and Disadvantages of Welding

Advantages

Welding establishes strong, durable, and permanent joint links. It is a simple process that results in a great finish.The technique, when used with filler material, produces a stronger weld than the base material.It can be performed at any place. It is an economical and affordable process. It is used in various sectors like construction, automobile, and many more industries.Welded joint has high strength, sometimes more than the parent metal.Different material can be welded.Welding can be performed anyplace, no need enough clearance.They give smooth appearance and simplicity in design.They can be done in any shape and any direction.It can be automated.

Disadvantages

It is hazardous when performed under the safety and security guidelines.It is a difficult task to dismantle the joined material through welding.Requires skilled labor and electric supply.It results in residual stresses and distortion of the work pieces.Welded joint needs stress relieving and heat treatment.Welding gives out harmful radiations light, fumes and spatter.Jigs, and fixtures may also be needed to hold and position the parts to be welded.

CONCLUSION

Enhancing Efficiency, Quality, Productivity, and Finish Through Modern Welding Mechanization. Leading the industry's development and expansion is Arc Welding. Significant advancements in welding techniques have revolutionized several industries. Welding's benefits have helped manufacturing grow into a booming sector of the economy. Arc welding is in the forefront because to its adaptability and accuracy, producing outstanding results that spur advancement and innovation.

REFERENCES:

[1] API, Recommended Practice for Planning , Designing and Constructing Fixed Offshore Platforms Working Stress Design, *Api Recomm. Pract.*, 2007.

[2] T. Edition, Recommended Practice for Planning , Designing and Constructing Fixed Offshore Platforms Working Stress Design, *Api Recomm. Pract.*, 2007.

[3] API, Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms-Load’and Resistance Factor Design, *Am. Pet. Institute, Washingt.*, 1993.

[4] API RP 2A-WSD 22nd Ed., Planning, Designing, and Constructing Fixed Offshore Platforms - Working Stress Design, *API Recomm. Pract.*, 2014.

[5] American Petroleum Institute, Recommended Practice for Planning , Designing and Constructing Fixed Offshore Platforms Working Stress Design, *Api Recomm. Pract.*, 2007.

[6] American Petroleum Institute [API RP2A], Recommended Practice for Planning , Designing and Constructing Fixed Offshore Platforms Working Stress Design, *API Recomm. Pract. 2A-WSD*, 2002.

[7] API-RP2A-WSD, Recommended Practice for Planning , Designing and Constructing Fixed Offshore Platforms Working Stress Design, *Api Recomm. Pract.*, 2007.

[8] American Petroleum Institute, Planning , designing and constructing fixed offshore platforms Load and Resistance Factor Design, *API Recommended Practice*. 1993.

[9] API RP 2A-WSD 21st Ed., Recommended Practice for Planning , Designing and Constructing Fixed Offshore Platforms Working Stress Design, *Api Recomm. Pract.*, 2007.

[10] A. P. Institute, Recommended Practice for Planning , Designing and Constructing Fixed Offshore Platforms Working Stress Design, *API Recomm. Pract.*, 2000.

[11] API RP2A, Recommended Practice for Planning , Designing and Constructing Fixed Offshore Platforms Working Stress Design, *Api Recomm. Pract.*, 2007.

CHAPTER 2

IMPORTANCE OF OXY-ACETYLENE GAS CUTTING

Dr. BolanthurVittaldasa Prabhu, Professor
Department of Mechanical Engineering, Presidency University, Bangalore, India
Email Id: - bvprabhu@presidencyuniversity.in

ABSTRACT:

The most common method of cutting mild steel is by an oxy-acetylene cutting process. With an oxy-acetylene cutting torch, the cutting oxidation can be confined to a narrow strip and with little effect of heat on the adjoining metal. The cut appears like a saw cut on a wooden plank. The method can be successfully used to cut ferrous metals i.e. mild steel. Non-ferrous metals and their alloys cannot be cut by this process.Oxy-acetylene gas welding is generally used for welding and cutting operations for metals and alloys. Welding is generally used to join several metals utilizing the heat generated by the combustion of fuel gasses like acetylene, hydrogen, propane or butane with oxygen mixture.Oxy-acetylene gas welding is generally used for welding and cutting operations for metals and alloys. Welding is generally used to join several metals utilizing the heat generated by the combustion of fuel gasses like acetylene, hydrogen, propane or butane with oxygen mixture.

KEYWORDS:

Acetylene, Cutting, Nozzle, Oxygen, Torch.

INTRODUCTION

The method of cutting mild steel is by an oxy-acetylene cutting process. With an oxy-acetylene cutting torch, the cutting oxidation can be confined to a narrow strip and with little effect of heat on the adjoining metal.Oxy-acetylene torches using the gascuttingmethod are one of the most popular tools for separating metals with low-alloy and low-carbon properties. The process of cutting metal consists in bringing it to a temperature at which it burns on contact with the torch and volatizes in the form of metal oxide. Such an effect is possible only thanks to the use of appropriately constructed torches that can mix oxygen with specific proportions of combustible gas [1], [2].As fuel gas, we can find materials such as acetylene and propane-butane. Due to the faster and longer reaching of high temperatures, oxygen cutting with acetylene is a very effective method. In addition, considerable advantages of oxy-acetylene torches are their mobility, ensuring cutting at various angles, good cutting quality even on thick metal sheets and the possibility of mechanizing the cutting processes with their help.

This method of metal processing is used in many industries from small workshops to large production halls. Due to its versatility, gas cutting can be used for machining cast iron, brass, bronze, steel and other metal alloys etc.The essence of gas welding is to heat the processed material to such a temperature that it is degraded by an oxygen-acetylene flame in the form of a change of state of aggregation. This method allows not only to separate steel elements up to 300 mm thick, but also to permanently join them. The obtained effects and cutting quality differ from each other due to the selection of the appropriate type of torch. The smaller the torch, the smaller the jet and the greater the cutting precision. Universal torches are used for both cutting and welding. Of course, not all metals can be processed with gas cutting. The susceptible ones include:

1. Iron.
2. Brass.
3. Bronze.
4. Cast iron.
5. Titanium.
6. Wolfram.

Oxy-acetylene burners are also perfect for machining structural, low-alloy, low-carbon and rust-covered steels. It is the foundation for all work in the field of machining, cutting and welding of various metal alloys. Due to the versatility and the possibility of adapting components such as the size of the torch, oxy-acetylene cutting finds a number of applications not only in large enterprises, but also in small companies or workshops. There is a demand for this type of service wherever it is necessary to precisely, high-quality adaptation of even thicker metal elements to the needs of a specific industry or service. Due to the wide operation of the oxy-acetylene torch, relatively low operating costs and the variety of its applications, it is used from home car workshops to large industrial or construction companies, being one of the basic elements of equipment.

Principle of Gas Cutting

When a ferrous metal is heated to red hot condition and then exposed to pure oxygen, a chemical reaction takes place between the heated metal and oxygen. Due to this oxidation reaction, a large amount of heat is produced and cutting action takes place. In oxy-acetylene cutting the combination of red hot metal and pure oxygen causes rapid burning and iron is changed into iron oxide oxidation. By this continuous process of oxidation the metal can be cut through very rapidly. The iron oxide is less in weight than the base metal. The iron oxide in molten condition is also called slag. So the jet of oxygen coming from the cutting torch will blow the molten slag away from the metal making a gap called Kerf.

Cutting Operation

There are two operations in oxy-acetylene gas cutting. A preheating flame is directed on the metal to be cut and raises it to bright red hot or ignition point 900°C app. Then a stream of high pressure pure oxygen is directed on to the hot metal which oxidizes and cuts the metal (Figure. 1). The two operations are done simultaneously with a single torch. The torch is moved at a proper travel speed to produce a smooth cut. The removal of oxide particles from the line of cut is automatic by means of the force of oxygen jet during the progress of cut.

According to Akhyan, et al., the cutting torch's impact on the mesinpemotongkontursambungan pupa's putarpermukaan is studied. Steel pipes are currently required, particularly in building activities. Cutting and connecting operations are essential when using pipe materials in construction. Large pipes are always cut using a thermal cutting technique. The goal of this investigation is to ascertain the degree to which the cutting distance affects the cutting outcomes on a pipe rotating at a constant 0.8 rpm in accordance with the contour of the corner joint. A pipe cutting tool with a diameter of 4 to 6 inches is required for the thermal cutting procedure using the Oxy Acetylene Cutting OAC process to accomplish the goals of this study [3]–[5]. R. Singh et al. describe that Oxy-acetylene welding and cutting processes are popular, easily available and one of the cheapest methods of working with metals. Welding process is used by many construction and manufacturing firms. There are several welding processes to join materials to achieve the desired purpose.

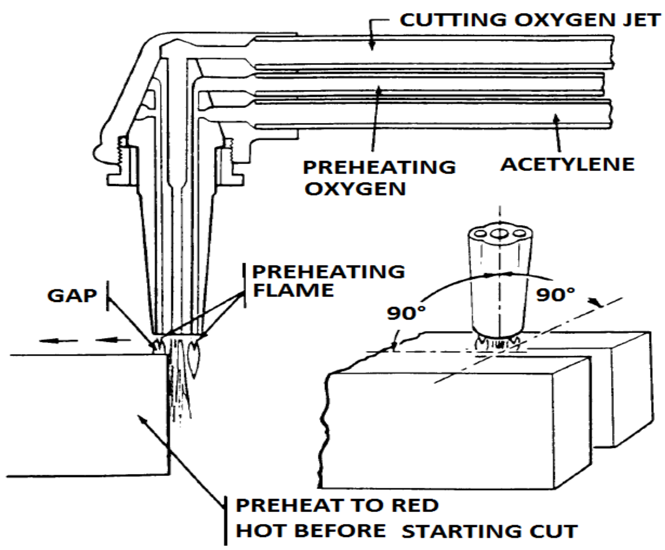


Figure 1: Represting the staring a cut with a cutting tourch [Mewelding].

Gas welding is one of the cheapest processes of welding and generally used in all the small scale works. The oxygen and the acetylene are the two gasses which produce sufficient heat and temperature which can be utilized for joining the materials. It is widely used for welding pipes and tubes and also for repair work in industries. The main object of industries is to produce better quality product at minimum cost. The joints made by gas welding should be strong enough to bear the loads applied on it. The joints fail due to several different reasons. The failure of the joints is a complicated problem and the researchers are working for the construction of optimum weld. Cutting of metals and alloys is also required in many industries which can easily be done with oxy-acetylene gas welding. In this work several important research papers on oxy acetylene gas welding were selected for analysis and investigation. The work and concept of each researcher is expressed in such a way that the future scope should be clear.

The researchers have given their own views on the performance of the gas welding process, the materials selected for their study, effect of ratio of oxygen to acetylene etc. in their researches. In this research review work different other research papers which contained the research and analysis relating input and output parameters of welding and cutting, flames, nozzle design, effects of pre and post heat treatments and snapping were included and considered while working with oxy acetylene gas welding. H. Tenkumo and colleagues describe this method. Efficient gas cutting based on drag length the consumption of oxygen and acetylene, or the economical use of gas, is the most significant issue in the practice of cutting with oxy-acetylene gas. The widespread consensus is that longer drag lengths result in decreased use of both. By examining the drag length on mild steel cutting sections with thicknesses of 12, 19, 25, and 32 mm, respectively, under various oxygen pressures and at varying cutting speeds, the authors attempted to analyses this issue. Study on Welding of Low Alloy High Strength Steel, according to Ito, Y. et al. Applying bending tests, the relationship between the crack sensitivity of the heat affected zone and the following subjects is investigated in the study of oxy-acetylene gas cutting of low alloy high strength steel. Reducing petrol quickly temperature for preheating the temperature after heating Mother steel's level of abrasion Condition of the cutting surface, steel composition, etc. In this work, experiments are conducted to determine the metallurgical makeup of the heat affected zone and how it affects the weld ability of mother steel.

These tests demonstrate the results below. An increase in bending angle during bending tests and a decrease in the maximum hardness in the heat-affected zone demonstrate that preheating to 100°C improves performancesignificantly. Controlling Hazardous Fume and Gases during Welding, a publication of the Occupational Safety and Health Administration, by melting a metal workpiece and a filler metal to create a solid junction, welding connects elements together. Visible smoke from the welding process comprises hazardous metal fume and gas byproducts. This fact sheet covers welding procedures, relevant OSHA regulations, and recommendations for shielding welders and coworkers from the several dangerous compounds included in welding smoke. Varieties of welding Fusion and pressure welding are the two categories under which welding is divided. Electric arc, gas, and hermit welding are the three different methods of fusion welding. The most common form of fusion welding is electric arc welding.

DISCUSSION

Conceptually, oxy-acetylene welding is straightforward: two pieces of metal are brought together, and the flame, with or without filler rod, melts the edges that are in contact. The oxy-fuel procedure for cutting is completely the opposite of welding. In oxygen-fuel cutting, metal is heated to a red-hot temperature using acetylene and oxygen before being burned away with pure oxygen. Since oxidation is used to achieve this, only metals that readily oxidize at this temperature can benefit from it. These metals include low alloy and mild steels. An oxygen tank, an acetylene tank, a regulator and gauges, gas hoses, a torch and a tip make up the typical oxy-acetylene equipment setup. In gas cutting, the region to be cut is heated by a flame of a fuel gas, such as acetylene burning in oxygen. A stream of oxygen is then injected around the flame, burning the steel and expelling the oxide as dross. The cutting torch can be carried in the hand or mounted to a moving machine.

In order to prevent a hard heat impacted zone from forming on the cut edge with the associated risk of cracking, the steel must be preheated as for welding depending on the thickness. Similar to how a welding procedure specification is created and validated, a cutting procedure specification can also be. The edges produced by automated cutting are smoother than those produced by hand cutting. the burners have two directions of movement that can be used to carve shapes or holes. Many copies of the same shape can be cut simultaneously by using a number of cutting heads. It should go without saying that a computer-aided manufacturing system can begin with computer control. A beveled edge can be prepared for a weld edge by setting the cutting head at an angle. Two, or even three, heads can be attached so that a double bevel with a root face can be cut in one pass. Although inclusions or laminations in steel plates can blow out gases leaving a rough edge, a gas cutter that has been adjusted properly will leave a smooth edge [6]–[8].

Equipment Used in Welding Operation

The oxyacetylene flame, which is used to weld metals, contains ethane. Acetylene is the name given to ethane in industry. Because ethanol burns easily in oxygen and produces a tremendous amount of heat, it can be used to weld and cut metal. The equipment's are used in this welding process as shown in Figure 2.

1. Oxygen Cylinder.
2. Acetylene Cylinder.
3. Welding Torch.
4. Welding Tip Nozzle.
5. Pressure Regulators.
6. Hose and Hose Fittings.
7. Goggles and Glasses.
8. Gloves and Apron.
9. Spark-Lighter, Key Set, Spanners.
10. Filler Rod and Flux Material.

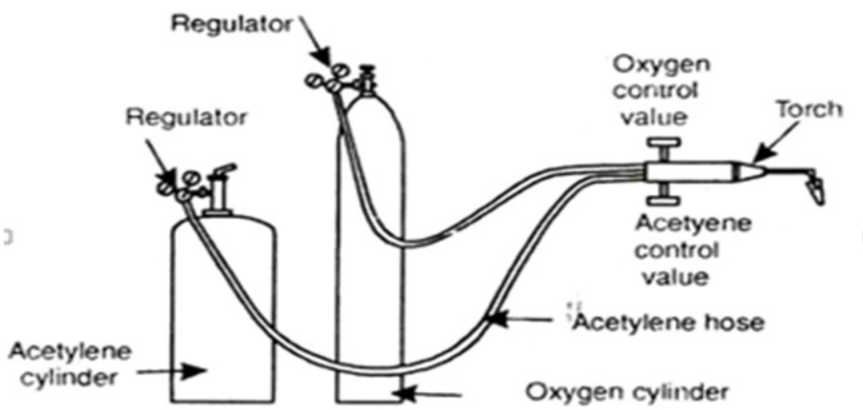


Figure 2: Represting Operational opertionial principle of oxy-Acetylene cutting torch [Bgmileakes].

Application of Cutting Torch Oxy-Acetylene Cutting Torch:

This technique is used for the welding of steel above 5mm thickness and 'LINDE' welding process of steel pipes. The oxy-Acetylene cutting is used to cut mild steel plates above 4mm thickness. The M.S. plate can be cut to its full length in straight line either parallel to the edge or at any angle to the edge of a plate. Bevelling the edges of a plate to any required angle can also be done by tilting the torch. Circles and any other curved profile can also be cut using the cutting torch by using a suitable guide or template. Figure 2 oxy-acetylene cutting equipment the oxy-acetylene cutting equipment is similar to the welding equipment, except that instead of using a welding blowpipe, a cutting blowpipe is used [9]–[11].

1. Acetylene gas cylinder.
2. Oxygen gas cylinder.
3. Acetylene gas regulator.
4. Oxygen gas regulator Heavy cutting requires higher pressure oxygen regulator.
5. Rubber hose-pipes for acetylene and oxygen.
6. Cutting blowpipe as shown in Figure. 2. cutting torch the cutting torch differs from the regular welding blowpipe in most cases. It has an additional lever for the control of the cutting oxygen used to cut the metal. The torch has the oxygen and acetylene control valves to control the oxygen and acetylene gases while preheating the metal. The cutting tip is made with an ORIFICE in the centre surrounding by five smaller holes. The centre opening permits the flow of the cutting oxygen and the smaller holes are for the preheating flame. Usually different tip sizes are provided for cutting metals of different thicknesses. Difference between cutting torch blowpipe and welding blowpipe
7. A cutting blowpipe has two control valves oxygen and acetylene to control the preheating flame and one lever type control valve to control the high pressure pure oxygen for making the cut.
8. A welding blowpipe has only two control vales to control the heating flame.
9. The nozzle of the cutting blowpipe has one hole in the centre for cutting oxygen and a number of holes around the circle for the preheating flame.
10. The nozzle of welding blowpipe has only one hole in the centre for the heating flame.
11. The angle of the cutting nozzle with the body is 60°.
12. The angle of the welding nozzle with the neck is 120°.
13. The cutting nozzle size is given by the diameter of the cutting oxygen orifice in mm.
14. The welding nozzle size is given by the volume of oxy-acetylene mixed gases coming out of the nozzle in cubic meter per hour. 4.3.3 Care and maintenance
15. The high pressure cutting oxygen lever should be operated only for gas cutting purpose.
16. Care should be taken while fitting the nozzle with the torch to avoid wrong thread.
17. Dip the torch after each cutting operation in water to cool the nozzle.
18. To remove any slag particles or dirt from the nozzle orifice use the correct size nozzle cleaner.
19. Use an emery paper if the nozzle tip is damaged to make it sharp and to be at 90° with the nozzle axis.

Advantages of Oxy-Acetylene Welding

1. Less cost per length run of the weld due to less bevel angle, less filler rod being used and increased speed. Welds are made much faster.
2. The primary advantage of oxy-acetylene welding is its versatilityit can be used for both thick and thin metals.
3. It can also join dissimilar metals, such as brass, bronze, steel, aluminum, cast iron, and even stainless steel.
4. Furthermore, oxy-acetylene welding can be used to weld in any position vertical, horizontal, or overhead.
5. Additionally, it produces minimal fumes or smoke compared to other welding processes.
6. Another advantage to using oxy-acetylene welding is its affordability. it does not require expensive equipment or materials like other welding processes. Additionally, oxy-

acetylene welders are easy to use and require minimal training for an operator to become proficient with the technique.

7. Lastly, most oxy-acetylene welds are strong enough for most applications. however, they can also be easily removed later.
8. Oxy-acetylene welding is a type of welding that uses a flame to heat and melt metals.
9. The advantage of oxy-acetylene welding over other types is that it can be used on various metals, including aluminum, cast iron, and stainless steel.
10. Oxy-acetylene welding is less likely to cause warping or distortion of the metal being welded.
11. Another advantage of oxy-acetylene welding is that it can be used in various settings, including outdoors.
12. Finally, oxy-acetylene welding is inexpensive and does not require special training to learn how to use it.

Disadvantages of Oxy-Acetylene Welding

1. One disadvantage to using this welding process is that it requires more setup time than other methods since you must adjust the regulator settings before starting each weld.
2. This type of welding requires combustible gases oxygen and acetylene, there is always a risk associated with their use in enclosed areasthis is why it's important to follow safety guidelines when performing this kind of work. Furthermore, because this type of welder produces a high-temperature flame upwards of 6300 degrees Fahrenheit, it can easily damage thin metals if not applied correctly.
3. Lastly, because the open flame produced by an oxy-acetylene welder may cause warping during certain jobs such as brazing or soldering, another method might need to be utilized instead.

CONCLUSION

Oxy-acetylene gas welding is generally used for welding and cutting operations for metals and alloys. Welding is generally used to join several metals utilizing the heat generated by the combustion of fuel gasses like acetylene, hydrogen, propane or butane with oxygen mixture. The oxy-acetylene welding is its versatilityit can be used for both thick and thin metals. It can also join dissimilar metals, such as brass, bronze, steel, aluminium, cast iron, and even stainless steel.

REFERENCES:

[1] T. Haynes, 'Welding Manual', *North*, 1994.

[2] J. Haynes and J. Storer, 'The Haynes Welding Manual', *North*, 1994.

[3] R. P. Singh, S. Kumar, S. Dubey, and A. Singh, 'A review on working and applications of oxy-acetylene gas welding', in *Materials Today: Proceedings*, 2020. doi: 10.1016/j.matpr.2020.05.521.

[4] D. Patel and P. Tandon, 'Experimental investigations of thermally enhanced abrasive water jet machining of hard-to-machine metals', *CIRP J. Manuf. Sci. Technol.*, 2015, doi: 10.1016/j.cirpj.2015.04.002.

[5] H. Tenkumo and I. Kimura, 'Economical gas cutting on the basis of drag length', *J. JAPAN Weld. Soc.*, 1952, doi: 10.2207/qjjws1943.21.43.

[6] Y. Ito, M. Kamo, Y. Araki, B. Miyanaga, and K. Nikuma, 'Study on Welding of Low Alloy High Strength Steel (Report 5)', *J. JAPAN Weld. Soc.*, 1959, doi: 10.2207/qjjws1943.28.881.

[7] V. Ganta and D. Chakradhar, 'Multi Objective Optimization of Hot Machining of 15-5PH Stainless Steel Using Grey Relation Analysis', *Procedia Mater. Sci.*, 2014, doi: 10.1016/j.mspro.2014.07.468.

[8] Nirupama Tiwari, S. N. Sahsrabudhe, Atul Tak, and P. V. A Padmanabahan, 'Measurements of Flame Temperature of Energetic Gaseous Fuels using Sodium Line Reversal Technique and Emission Spectroscopy', *Int. J. Eng. Res.*, 2015, doi: 10.17577/ijertv4is080170.

[9] Occupational Safety and Health Administration, 'Controlling Hazardous Fume and Gases during Welding', *U.S. Dep. Labor*, 2013.

[10] K. Nakamura and Y. Nakamura, 'On gas cutting (1st. Report)—Length of visible oxy-gas stream and the divergent nozzle—', *J. JAPAN Weld. Soc.*, 1952, doi: 10.2207/qjjws1943.21.105.

[11] A. C. Davies, *The Science and Practice of Welding*. 1993. doi: 10.1017/cbo9780511526695.

CHAPTER 3

A BRIEF OVERVIEW ABOUT THE TIG WELDING

Dr. SurendrakumarMalor, Professor
Department Of Mechanical Engineering, Presidency University, Bangalore, India
Email Id: - coe@presidencyuniversity.in

ABSTRACT:

Tungsten Inert Gas is the abbreviation for the USA-born moniker TIG. The metal tungsten, commonly known as wolfram, has a fusion point of more than 3300oC, which is more than twice as high as the fusion point of the typical welding metals. Inactive gas, often known as inert gas, is a category of gas that does not combine with other elements. This process is known as WIG welding in Germany, where the W stands for wolfram. The international abbreviation for this welding technique is TIG welding. A tungsten electrode is placed against the workpiece, and an electric arc burns between them to create the fusion energy used in TIG welding.In production engineering, TIG welding is a very popular technique for attaching metal components. The quality of weld joints is impacted by a variety of process variables.

KEYWORDS

Arc, Electrode, Gas, Tungsten, Weld.

INTRODUCTION

A non-consumable tungsten electrode and the workpiece are used in the TIG welding procedure to create the welding arc. Slag was employed in various welding techniques to protect the weld pool from ambient contaminants such hydrogen, oxygen, nitrogen, and other gases that can have an impact on the joint's quality. TIG welding uses an inert gas as a shield rather than slag. The technology was created by an aircraft technician in 1940s California because magnesium and aluminum alloys could not be joined using the existing techniques. It gained traction swiftly in the manufacture of ships and airplanes and played a significant role in providing the US with the edge in its military and economic pursuits. TIG welding is still widely used in aviation and aerospace engineering because it can make secure connections between uncommon materials like titanium and on very thin metals. Today, it is frequently utilized in the automobile industry and for welding on pipelines.The fact that TIG welding may be used to join a wider range of metals than any other welding method is one of its greatest advantages. It can be applied to a variety of materials, including gold, copper, nickel, titanium, magnesium, and aluminum. The fact that it uses a non-consumable electrode makes it easier to produce faultless joins because the operator can continue welding while the consumable is being changed. Additionally, this reduces downtime and operating expenses. Different from those used for MIG or stick welding, there are a few necessary components for TIG welding [1], [2].

Welding Apparatus

While each of these components is required to produce high-quality TIG welding, the most crucial component in this equation is your welding machine. This kind of welding is only possible with TIG welders [3]. The Lincoln Invertec 220TPX Welder is designed to withstand frequent use in challenging industrial environments. It provides superior arc control to enable you to accomplish flawless connections on a range of metals.

Wrought-Iron Electrode

Thoriated, zirconated, lanthanated, and ceriated tungsten electrodes are some of the different types that are offered. Ceriated electrodes are a suitable all-purpose electrode because of their strong current carrying capacity and resistance to contamination.

Wrought-Iron Grinder

To keep your electrodes sharp and clean and to assure the quality of your welds, you will require a tungsten grinding wheel. Among its other features, the Ultima TIG Benchtop Tungsten Grinder has a variable angle setting for greater versatility and a high grinding speed for precise, even grinds.

Personal Protection Gear

You will also require a set of top-notch TIG welding gloves to protect your hands and arms in addition to a welding mask to protect your face and eyes.

Torch :

Your tungsten electrode is held in place by the TIG torch. You will play around with this to make your weld pool. The TIG torch is a unique gadget. It has a collar or gas diffuser that conducts the inert gas to the work, as well as a copper electrode holder known as a collet. Due to its heat resistance, ceramic is typically used to make collars. Of course, cables and hoses connect these to the main unit. the length depends on what you want or require for your particular project. Additionally, a foot switch that controls the current within a range can be installed on TIG machines. If you need to weld unusual materials with high-quality, TIG welding is a great method. It is frequently utilized in the aerospace sector to create spaceships due to its excellent weld qualities. Tungsten serves as the material of the TIG welding electrode. The tungsten is purified if it has a green band at one end, 1% thorium is indicated by a yellow band, 2% thorium is shown by a red band, and zirconium is indicated by a brown band. The tungsten needs to be ground to a point that is linear to the rod for welding with DC, not so that the grind marks form circles around the tip.[4] The tungsten needs to be balled at the end for AC welding. Holding the torch over some scrap metal and starting the arc with the foot pedal will cause the tungsten to melt and form a ball in a matter of seconds. To accomplish this, set the machine to reverse polarity and the high frequency switch to continuous [5].

H. Rana et al [1] Describe that Flux aided TIG welding and its various applications for oxygen-free copper increase weld penetration. With the help of three new tungsten inert gas TIG welding techniques, Activated TIG A-TIG, Flux Bounded TIG FB-TIG, and Flux Zoned TIG FB-TIG, a comparative research was conducted to examine the effects of single component fluxes on the depth-to-width ratio DWR of oxygen free copper. The trials with FB-TIG and FZ-TIG using those identified DWR fluxes were conducted after the experiments to determine the fluxes delivering the greater DWRs in A-TIG welding among the thirteen different fluxes. MoO3 and MgO were the fluxes that performed best across all approaches. It was thought that reversed Maranon and arc constriction mechanisms might favour such a rise in DWR. The weld zones showed certain grain morphologies and several flaws, according to the metallurgical analysis of the weldment.

The TIG welding process variations for increasing weld penetration depth. This page discusses the many process changes that the tungsten inert gas welding method underwent over a long period of time. The typical weld penetration of the traditional TIG welding method is only up to 5 mm. The industrial applications of this method are quite limited and restricted to sheet metal processing as a result of the shallow depth of penetration. In order to enhance the process capabilities, this article focuses on the many modifications that have been made to the traditional TIG welding method. Specifically, the theories behind flux assisted TIG welding, pulse current TIG welding, keyhole TIG welding, multi-electrode TIG welding, and TIP-TIG welding processes were reviewed in order to increase weld penetration. These process variants' varied process parameters' impact on weld penetration was M. Kesse et al [2] The creation of a hybrid deep learning tig welding algorithm powered by artificial intelligence for the prediction of bead geometry.

It is now possible to envision the removal of some aspects of human mechanical effort from welding operations thanks to recent advancements in artificial intelligence AI modelling tools. In order to help human welders choose ideal end factors and produce high-quality welds during the welding process, this study proposes an AI tungsten inert gas TIG welding algorithm. The suggested model has been evaluated with data from 27 tests using welding speed, arc length, and current as control parameters to forecast weld bead width, proving its viability. The algorithm uses a fuzzy deep neural network, which combines fuzzy logic and deep neural network techniques. The AI TIG welding algorithm was used to simulate a test dataset that was used experimentally [6], [7].

The Technology for fast-frequency pulse TIG welding reviewed. The fast-frequency pulse TIG FFP-TIG welding technique has continuously advanced with the advancement of pulse TIG welding technology. FFP-TIG uses a 20 kHz ultra-high frequency UHF pulse modulation current with a clear high-frequency shrinkage effect and electromagnetic stirring effect. Traditional pulse TIG welding has a number of drawbacks that FFP-TIG welding addresses, including shallow penetration, unconcentrated current energy, a sizable heat-affected zone, and numerous welding flaws. The preferred way of joining metal in high-end manufacturing processes at the moment is FFP-TIG welding, which has a wide range of potential applications. First, this study defines the FFP-TIG welding arc characteristics and working theory, as well as the benefits of FFP-TIG welding over conventional pulse TIG welding. Second, the current state of research into the power source for FFP.

J. Siva Kumar et al [8] Effect of activated flux tungsten inert gas A-TIG welding on the mechanical properties and the metallurgical and corrosion assessment of Inconel 625. In addition to A-TIG welding and TIG welding of Inconel 625, this article tries to investigate the results of activated flux and filler wire. 6.5 mm thick plates were joined using ERNiCrMo-3, a filler that is Ni-Cr-Mo enriched. To identify the source of the observable discrepancies, secondary dendritic arm spacing measurements, mechanical property evaluation, and microstructure characterisation were performed. In both welding techniques, the weld zone experienced tensile test failures. According to Charpy impact studies, A-TIG weldments had a lower toughness value than TIG weldments. Root bend testing revealed no discontinuity in either fusion zone, proving that the weldment was created flawlessly [9]. Activated flux and fillers helped to decrease the harmful laves phase.

DISCUSSION

Principle of TIG Welding

The same basic idea that underlies arc welding also applies to TIG welding. A highly powerful arc is created between the work piece and tungsten electrode during the TIG welding process (Figure. 1). The electrode is attached to the negative terminal in this welding process whereas the work piece is typically connected to the positive terminal. This arc generates heat energy that is then used to fuse weld metal plates together. Additionally, a shielding gas is employed to prevent oxidation of the weld surface. One of my particular favorites is TIG welding, sometimes referred to as GTAW gas tungsten arc welding or tungsten inert gas welding. It comprises of a piece of tungsten the electrode held in a torch, which is used to transfer electricity to the work, and an inert gas, such as argon, flowing from the torch's nozzle to shield the weld region from ambient pollution.

Tungsten is employed because, unlike SMAW, it is not thought to be consumable as the welding process advances. A filler rod is employed even though it isn't usually required on thin materials because the electrode isn't consumed. This procedure uses a torch with a bright cone the heated tungsten and a filler rod, making it resemble ox fuel welding. Tungsten serves as the material of the TIG welding electrode. The tungsten is purified if it has a green band at one end, 1% thorium is indicated by a yellow band, 2% thorium is shown by a red band, and zirconium is indicated by a brown band. The tungsten needs to be ground to a point that is linear to the rod for welding with DC, not so that the grind marks form circles around the tip. The tungsten needs to be balled at the end for AC welding. Holding the torch over some scrap metal and starting the arc with the foot pedal will cause the tungsten to melt and form a ball in a matter of seconds. To accomplish this, set the machine to reverse polarity and the high frequency [9].

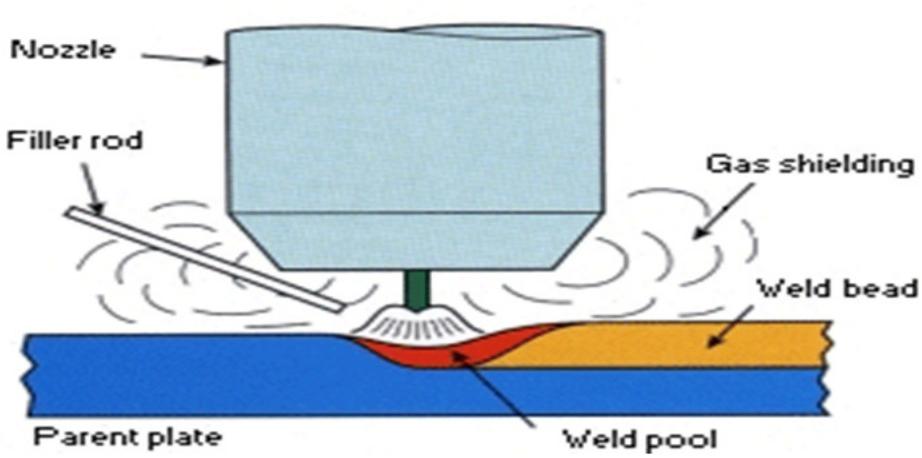


Figure 1: Represting the TIG welding process [Twi-Global].

For joining magnesium and aluminum, tungsten inert gas TIG welding experienced an overnight success in the 1940s. The procedure was a highly appealing option for manual metal arc welding and gas welding since it used an inert gas shield rather than slag to shield the weld pool.

Aluminum is now widely used for structural applications and high-quality welding thanks in large part to TIG.

Properties of the Process

In the TIG welding technique, an arc is created between the workpiece and a pointed tungsten electrode in an inert argon or helium atmosphere as shown in Figure.1. For precise and high-quality welding, the pointed electrode's narrow, powerful arc is excellent. The TIG welder does not need to balance the heat input from the arc as the metal is deposited from the melting electrode because the electrode is not consumed during welding. When filler metal is necessary, it must be put to the weld pool separately.

Power Supply

A low, constant current power supply, either DC or AC, is required for TIG welding as shown in Figure. 2. To prevent excessively large currents from being drawn when the electrode is short-circuited on the workpiece surface, a constant current power source is required. This could unintentionally occur when welding or intentionally during arc initiation. Any contact with the workpiece surface might harm the electrode tip or fuse the electrode to it if, as in MIG welding, a flat characteristic power source is utilized. In DC, the electrode is always negative polarity to prevent melting and overheating since the arc heat is distributed around one-third at the cathode negative and two-thirds at the anode positive.

Arc Beginning

By creating a short-circuit on the surface, the welding arc can be ignited. The main welding current won't flow until the short-circuit is closed. The electrode could, however, adhere to the surface and result in a tungsten inclusion in the weld. Using the lift arc technique, which forms the short-circuit at a very low current level, this risk can be reduced. The TIG arc is most frequently started using HF High Frequency. High-voltage sparks with a few thousand volts that remain for a brief period of time make up HF. The electrode-workpiece gap will collapse or ionize due to the HF sparks. Current can flow through an electron/ion cloud once it forms.

Electrodes

In order to improve arc ignition, DC welding electrodes are typically made of pure tungsten with 1 to 4% thorium. Lanthanum oxide and cerium oxide are substitute additions that promise greater performance arc starting and reduced electrode consumption. The right electrode diameter and tip angle must be chosen based on the amount of welding current. Generally speaking, the electrode diameter and tip angle are smaller the lower the current. Because the electrode in AC welding would be operating at a considerably higher temperature, zirconia-added tungsten is employed to lessen electrode erosion. It should be mentioned that it is challenging to maintain a pointed tip and the end of the electrode due to the significant quantity of heat created at the electrode.

Protective Gas

The choice of shielding gas depends on the material being welded. The following pointers could be useful. The most popular shielding gas, argon, can be used to weld a variety of materials, including titanium, steel, stainless steel, and steel. Argon + 2 to 5% H2 - Adding hydrogen to argon can slightly reduce the gas, helping to produce welds with a cleaner appearance and less surface oxidation. Higher welding speeds are possible because the arc is hotter and more constrained. The possibility of hydrogen cracking in carbon steels and the porosity of the weld metal in aluminum alloys are drawbacks. Helium and helium/argon mixturesthe temperature of the arc will increase when helium is added to argon. Higher welding rates and deeper weld penetration are encouraged by this.The process of TIG welding can be summed up as follows:

1. The power source first supplies a low voltage, high current supply to the tungsten or welding electrode. The work piece is typically linked to the positive terminal of the power source while the electrode is attached to the negative terminal.
2. This spark between the tungsten electrode and the work piece produced the current. A non-consumable electrode that produces a very powerful arc is tungsten. The heat from the arc melts the base metals to create the welding connection.
3. Through a pressure valve and a regulating valve, shielding gases like argon and helium are fed to the welding flame.
4. These gases create a barrier that prevents any oxygen and these gases create a shield that prevents oxygen and other reactive gases from entering the weld zone.
5. These gases also produce plasma, which boosts the electric arc's capacity for heat and improves welding performance.
6. There is no need for filler metal when welding thin materials, but thick joints require the manual feeding of filler rods into the welding zone by the welder.

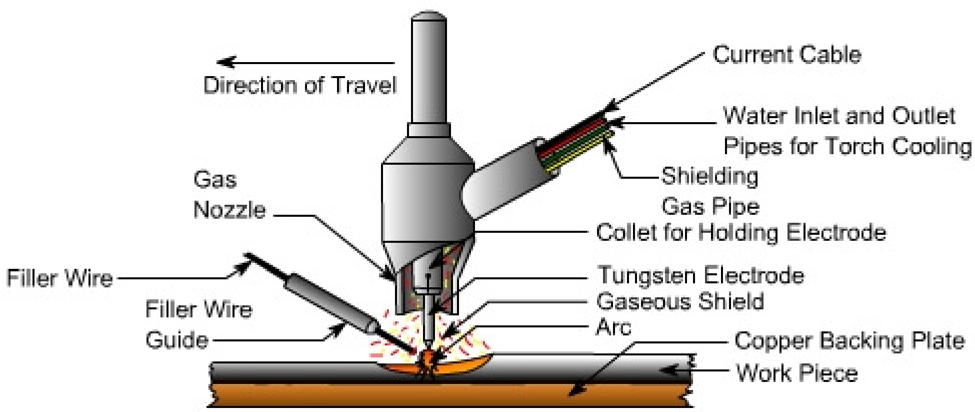


Figure 2: Represting the plasma arch welding [Learn Mech].

Applications:

The uses of tungsten inert gas welding include the following:

1. It is extensively utilized in the aerospace sector.
2. Industries, particularly nonferrous metals, use TIG welding for thin workpiece.
3. It is applied in the production of spacecraft.
4. TIG welding may be used on tubing with tiny diameters and thin walls, making it useful in the bicycle industry.
5. It is utilized to create and repair works.
6. Tools and dies, especially those composed of aluminum and magnesium, can be repaired using this method.

7. TIG welding is used on a variety of materials, including:Stainless steel, alloy steel, aluminium, titanium, copper, magnesium, nickel alloys.

Advantages and Disadvantages of TIG Welding

Advantages:

1. TIG welding has the following benefits.
2. It makes excellent welds.
3. Throughout the process, the inert gas safeguards it.
4. Slag is not produced with TIG welding.
5. It can be done while welding in any position.
6. Detailed Precision.
7. Extremely Complex Metal Welding.
8. Non-consumable Electrodes.

Disadvantages:

1. Provides A Laborious Welding Method.
2. High-Skilled Workers Are Required.
3. Operation Costs Are Very High.
4. Exposure Of Welders To Intense Lighting.
5. A Time-Consuming Process.
6. Complicated Appliances.
7. The Cost Of Inert Gas.

CONCLUSION

TIG welding is an extremely skilled arc welding technique that yields welds of the highest caliber. Modern TIG equipment allows for customizing the heat and arc input and guides the arc with a non-consumable electrode. In contrast to MIG welding, it can be slower and more challenging to master. Despite this, because of its visual appeal and cleanliness, TIG welding is still favored for some tasks. On the other hand, MIG welding is a quicker and simpler form of arc welding. While both TIG and MIG welding have advantages, TIG is typically regarded as the superior choice for producing faultless, attractive welds.

REFERENCES:

[1] H. Rana, V. Badheka, P. Patel, V. Patel, W. Li, and J. Andersson, ‘Augmentation of weld penetration by flux assisted TIG welding and its distinct variants for oxygen free copper’, *J. Mater. Res. Technol.*, 2021, doi: 10.1016/j.jmrt.2020.12.009.

[2] M. A. Kesse, E. Buah, H. Handroos, and G. K. Ayetor, ‘Development of an artificial intelligence powered tig welding algorithm for the prediction of bead geometry for tig welding processes using hybrid deep learning’, *Metals (Basel).*, 2020, doi: 10.3390/met10040451.

[3] D. Pandya, A. Badgujar, and N. Ghetiya, ‘A novel perception toward welding of stainless steel by activated TIG welding: a review’, *Materials and Manufacturing Processes*. 2021. doi: 10.1080/10426914.2020.1854467.

[4] P. Omoniyi, M. Mahamood, T. C. Jen, and E. Akinlabi, 'TIG welding of Ti6Al4V alloy: Microstructure, fractography, tensile and microhardness data', *Data Br.*, 2021, doi: 10.1016/j.dib.2021.107274.

[5] M. Cheepu, C. I. Lee, and S. M. Cho, 'Microstructural Characteristics of Wire Arc Additive Manufacturing with Inconel 625 by Super-TIG Welding', *Trans. Indian Inst. Met.*, 2020, doi: 10.1007/s12666-020-01915-x.

[6] N. Jeyaprakash, A. Haile, and M. Arunprasath, 'The Parameters and Equipments Used in TIG Welding: A Review', *Int. J. Eng. Sci.*, 2015.

[7] H. Li, J. Zou, J. Yao, and H. Peng, 'The effect of TIG welding techniques on microstructure, properties and porosity of the welded joint of 2219 aluminum alloy', *Journal of Alloys and Compounds*. 2017. doi: 10.1016/j.jallcom.2017.08.157.

[8] J. Sivakumar, M. Vasudevan, and N. N. Korra, 'Effect of activated flux tungsten inert gas (A-TIG) welding on the mechanical properties and the metallurgical and corrosion assessment of Inconel 625', *Weld. World*, 2021, doi: 10.1007/s40194-020-01061-4.

[9] J. H. Jun, J. H. Park, M. Cheepu, and S. M. Cho, 'Observation and analysis of metal transfer phenomena for high-current super-TIG welding process', *Sci. Technol. Weld. Join.*, 2020, doi: 10.1080/13621718.2019.1637172.

CHAPTER 4

UNLOCKING THE POWER OF EFFICIENT MIG WELDING

Mr. Gangaraju, Assistant Professor
Department of Mechanical Engineering ,Presidency University, Bangalore, India
Email Id: - gangaraju@presidencyuniversity.in

ABSTRACT:

A continuous solid wire electrode is heated and fed into the weld pool from a welding gun in the Metal Inert Gas MIG welding process. The connection is created by melting the two basic materials together that is called MIG welding. In This Paper discussed about the MIG welding technology that is used to joint two or more metal pieces together with the help of this technology.A continuous solid wire electrode is supplied into the weld pool by a welding gun during the MIG welding process, which unites the two base materials.Due to its adaptability, simplicity, and high productivity, MIG Metal Inert Gas welding is a well-liked welding process. MIG welding has a bright future because it is still a dependable and affordable welding method.

KEYWORDS:

Gas, Metal, Welding, Wire, Welder.

INTRODUCTION

A continuously fed wire electrode and a shielding gas are used in the MIG welding technique, commonly referred to as Gas Metal Arc Welding GMAW, to produce an electric arc between the wire and the base material. The base material and the wire are both melted by the electric arc, forming a fusion bond. The weld is shielded from ambient contamination and oxidation by the shielding gas, which is typically a mixture of argon and carbon dioxide. Due to its adaptability, simplicity of usage, and capacity to weld a wide range of metals, including aluminum, stainless steel, and mild steel, MIG welding is widely employed in the manufacturing industry, automotive repair, and metal fabrication. Compared to conventional procedures, it is also a faster welding process since it permits continuous [1]–[3].

A continuous solid wire electrode is heated and fed into the weld pool from a welding gun in the Metal Inert Gas MIG welding process. The connection is created by melting the two basic materials together. Metal inert gas MIG and metal active gas MAG are two of the subtypes of gas metal arc welding GMAW, which is a welding process in which an electric arc forms between a consumable MIG wire electrode and the workpiece metal or metals, heating them to the point of fusion melting and joining. A shielding gas that passes through the welding cannon with the wire electrode protects the procedure from ambient contamination as shown in Figure. 1. A continuous solid wire electrode is supplied into the weld pool by a welding gun during the MIG welding process, which unites the two base materials. Additionally, a shielding gas is delivered through the welding gun to guard against contamination of the weld pool. Actually, MIG is an acronym for metal inert gas.

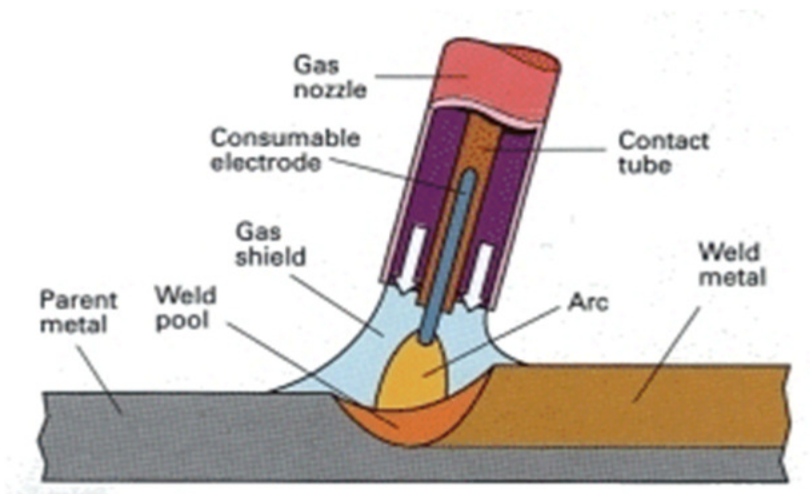


Figure 1: Represting the metal active gas welding [Science Direct].

Working Principle: MIG Welding uses the same basic principal as TIG or arc welding. It operates under the fundamental tenet that an electric arc generates heat. The metal of the foundation plates and consumable electrodes is also melted using this heat, and once solidified, they form a sturdy junction. In order to shelter the weld zone from additional reactive gases, shielded gases are also provided through nozzles. A stronger joint results, as well as a high surface polish.The versatile MIG/MAG welding process can be used for both thin sheet and thick section components as shown in Fig.1. In order to create a weld pool, an arc is created between the workpiece and the end of a wire electrode. Through the arc at the wire tip, the wire acts as both a heat source and filler metal for the welding junction. A copper contact tube contact tip is used to feed the wire, and this carries welding current into the wire.

A shielding gas is delivered through a nozzle encircling the wire to shield the weld pool from the atmosphere. The choice of shielding gas depends on the application and the material being welded. A motor drive feeds the wire from a reel, and the welder moves the wire as it is fed.The welding flame is moved along the joint line as the wire is fed from a reel by a motor drive. Wires can be cored composites made from a metal sheath with a powdered flux or metal filler or solid basic drawn wires. When compared to those used in other operations, consumables are typically priced fairly. Given that the wire is fed continuously, the process has a high production level [4], [5]. Because the wire feed rate and arc length are controlled by the power source but the travel speed and wire position are manually controlled, manual MIG/MAG welding is frequently referred to as a semi-automatic method. When none of the process parameters are directly within the control of a welder, the process can also be automated, albeit manual adjustments may still be necessary.

MIG welding is a flexible method appropriate for components with thick and thin sections. An electric arc melts the workpiece or base materials during the welding process to create a weld pool, which cools to form a solid bond and unite the metals. A consumable heated wire electrode and shielding gas are continually fed through a welding torch by the welder while the metal is being joined. The electrode wire is positively charged and connected to a power source to produce a consistent voltage in order to operate the welding process. Alternating current and a steady current system are also options.The wire electrode is brought into contact with the portion of the workpiece that has to be welded to begin the welding process. As a result, an electric arc is created between the electrode's tip and the metal surface. The wire electrode and metal surface are both melted by the heat from the electric arc, creating a weld pool. A solid weld joint is created when the molten weld pool cools. To screen the molten weld pool from moisture and other airborne pollutants, a shielding gas from the welding torch nozzle is injected alongside the electrode. The application and the metal being welded determine the best shielding gas to use. As a result, an electric arc is created between the electrode's tip and the metal surface.

The wire electrode and metal surface are both melted by the heat from the electric arc, creating a weld pool. A solid weld joint is created when the molten weld pool cools. To screen the molten weld pool from moisture and other airborne pollutants, a shielding gas from the welding torch nozzle is injected alongside the electrode. The application and the metal being welded determine the best shielding gas to use. The welding flame is gradually moved along the joint line of the welding region by the welder as the welding process progresses. The diameter of the wire electrode, which ranges from 0.6 mm to 1.6 mm, can be either solid or cored. It functions as filler metal for the welding joint as well as a heat source through an electric arc at the contact point. The consumable electrode melts and is used in the welding procedure. The copper contact tube at the torch's contact tip, which carries welding current into the wire electrode, is fed the wire during welding. The power source controls the wire feeding rate and arc length in semi-automatic MIG/MAG welding. However, the wire position and travel speed are manually adjusted by the welder. There is no need for manual assistance while using automatic MIG/MAG welding.

DISCUSSION

Equipment's used in MIG Welding

Unless you have a dedicated MIG welding machine, MIG welding requires the appropriate equipment. This article provides a general overview of the tools required if you intend to use a power supply and require or desire the bells and whistles. A CV, or constant voltage power supply, is a MIG welder. They are only the power source that generates the necessary polarity, voltage, and amperage for MIG welding. After obtaining a power source, you will require:

1. Ground Clamp, Gas Regulator Hoses and Wire Feeder for MIG Gun
2. MIG welder wire feeder ESAB
3. MIG welder wire feeder ESAB
4. MIG Welding Guns by ESAB
5. MIG Welding Guns by ESAB
6. MIG Welder MIG Welder MIG Welder MIG Welder Gas Regulator Prest O Line Cable Feed Systems.

There are three types of wire feeders for MIG welding. Case for Add-on Wire Feeding Systems Spool feed guns with a wire feed system. Include mig cable feed systems Add-on wire feeders are just wire feeders that are attached to a power supply's top or side. These are typically found in production areas and factory floors where welds on heavy plate call for high duty cycles and lots of electricity. This is more of a specialty piece than anything else, not something for regular welding. The quickest wire feed speeds are found in add-on systems, which are utilized for high production welding. Mig wire feeder with lincoln flex feed. Case for a lincoln flex feed add on mig wire feeder wire feed systems for mig welders. Most multi-process welders use suitcase wire feed systems. Simply connect the gas and MIG wire, then plug them into the power source. I have had some really positive personal encounters with them, and they are fantastic. They take the shape of a suitcase with a MIG gun strapped to the front and three cordsa power cord, a remote wire, and a shielding gas hosehanging out of the back. They are waterproof and operate perfectly under unusual circumstances. I appreciated how the wire is protected from dust and debris by the covered box. The fact that the cable on these wire feeders is short means that running wire, such as stainless steel, is not a problem. Most shipyards use these suitcase wire feeders, and I have to say they perform better than any other feeders I have ever used! Suitcase Wire Feed Miller MIG Welder Miller Wire Feed for a MIG Welder Suitcase

MIG Welder Wire Feeder Miller Suitcase

ESA B Suitcase MIG Welding Wire Feeder ESA B Suitcase MIG Welding Wire Feeder

Torches or MIG Guns

The MIG gun is the center of MIG welding. To create a weld, you only need to squeeze the trigger and get everything to work as it should. There are three MIG gun options, and they are as follows:

1. The Common MIG Guns.
2. MIG Spool Feed Guns.
3. MIG Push-Pull Guns.

There are many different kinds of welder accessories available. these are only the basic sorts of MIG welding equipment.

1. Traditional MIG Welding Guns.
2. Traditional MIG Welding Guns.
3. MIG Spool Feeder MIG Spool Feeder.
4. MIG Push Pull Python Gun MIG Push Pull Python.

The Common MIG Guns

The typical MIG gun is simply a cable attached to a gas feed system with a remote wire attached to the trigger. The majority of the time, this simple piece of machinery works well, with the exception of soft filler metals like aluminum.

1. Traditional MIG Welding Guns.
2. Common Pistol Grip MIG Gun with Water Cooling.
3. Water-cooled, standard pistol-grip MIG gun.
4. MIG Gun Typical with Cable and Liner.
5. Standard MIG Gun with Liner Spool and Cable Supply MIG Guns.

The easiest to use MIG guns are those that use a spool feed! They are not the most affordable or effective to utilize. Due to the short distance the wire needs to travel from the spool to the joint, these are the preferred aluminum MIG welders. The wire would jam and break in a standard MIG welder because aluminum is so soft. The size of the wire that can fit into the cannon is a drawback. Even though it just has a 4 inch maximum spool size, it is as trouble-free as they come [6]–[8].

MIG gun with ESAB spool feed ST 23A spool gun

Aluminum Spool Gun MIG Welding ESAB Spool Feed MIG Gun ST 23A Spool Gun MIG Welding Spool Gun MIG Welding for Aluminum MIG Welding Aluminum Spool Gun Rollers Rollers for aluminum spool guns

MIG Push-Pull Guns

The push pull feed mechanism works well when welding aluminum, stainless steel, or when a lot of liner or wire is required between you and the MIG welding equipment. The most typical use for the push-pull system is aluminum welding. Factory floors and other locations where a lot of MIG welding of aluminum and stainless steel is required employ push-pull wire feed systems. My first welding job was to weld aluminum with a Cobra Push Pull Feed system in a factory. As long as everything is properly configured, it works fine. Making things right is a different matter. ESAB Push Pull MIG Gun PP36 plus ESAB Push Pull MIG Gun PP36 plus Millermatic 350P Millermatic 350P Python Push Pull MIG Gun Millermatic 350P Double Roller Aluminum Push Feed Aluminum Push Feed MIG Welding with a Double Roller Gas Controls. A gas regulator is required if you are MIG welding. They are all readily available and each one functions equally well. A gas regular and a gas hose are required to connect to the MIG welder.

MIG Welding Gas Regulator for Prest O Line

MIG Welding Gas Regulator for Prest O Line MIG Welding Gas Regulator for ESAB MIG welding using shielding gas Gas Shielding for Welding

Floor Clamp

Last but not least, a ground clamp is required to secure the piece to the power supply. Because the ground only needs to transmit the same voltage and amperage as the MIG gun, don't go wild getting a thick gauge of wire [9]–[11].

Application of MIG Welding

1. Welding of sheet metal.
2. Automobiles, home improvement, and the automotive sector.
3. Pressure vessels and steel structures are being constructed.
4. Heavy structures like bridges and building supplies.
5. Pipelines being welded.
6. The fixing of automobiles.
7. Used for the majority of sheet metal welding types
8. Construction of steel structures and pressure vessels
9. Vehicle manufacturing and house improvement

Advantages of MIG Welding

1. Due to constant feeding of the wire throughout the process, MIG welding offers excellent productivity.
2. MIG welding creates high-quality welds more quickly than TIG or SMAW welding, which use tungsten inert gas or shielded metal arc welding, respectively.
3. It is simple to use MIG welding to join a variety of metals and alloys, including copper, aluminum, nickel, and iron.

4. Diverse metals can be joined using this procedure.
5. Metal is transferred across the electric arc while the arc is shielded by a gas. As a result, the loss of alloying elements is minimal.
6. Faster weld times
7. Higher rates of deposition
8. Less cleaning after welding e.g., less slag to chip off the weld.
9. Increased visibility of the weld pool
10. No stub end losses or lost man hours due to electrode changes
11. MIG/MAGS welding torch operation requires little skill.
12. When compared to other procedures, positional welding presents no issues. Transfer in a pulsed or dip fashion
13. Automating the procedure is simple.
14. In many circumstances, no fluxes are necessary.
15. The technique of very low hydrogen
16. Weld spray from the welding process is minimal and easily cleaned up.

Disadvantages of MIG Welding

1. MIG welding is not recommended for vertical or overhead welding locations due to the high heat input and fluidity of the weld puddle.
2. In comparison to equipment used for shielded metal-arc welding, MIG welder equipment is more complicated.
3. higher setup costs at first
4. This procedure can only be used in draught-free environments since the atmosphere surrounding the welding process needs to be stable thus the shielding gases.
5. Increased maintenance expenses brought on by more electrical components
6. Setting plant variables demands a high level of ability.
7. Less effective when a high duty cycle is required.
8. The consequences of radiation are more severe

CONCLUSION

In this Chapter discussed about the MIG Welding technology that can used for joint two metal together.Sheet metal welding is one use for MIG welding. Automobiles, home improvement, and the automotive sector. Pressure vessels and steel structures are being constructed.AC and DC power sources can both be used for TIG welding. The ability to weld non-ferrous metals like aluminum, copper, magnesium, copper, nickel, titanium, etc. is one of TIG welding's major advantages.

REFERENCES:

[1] T. L. (Head Office), 'Metal Inert Gas (Mig) Welding - Process And Applications', *Twi Ltd (Head Off.*, 2021.

[2] K. R. Madavi, B. F. Jogi, And G. S. Lohar, 'Metal Inert Gas (Mig) Welding Process: A Study Of Effect Of Welding Parameters', In *Materials Today: Proceedings*, 2021. Doi: 10.1016/J.Matpr.2021.06.206.

[3] A. Khoshroyan And A. R. Darvazi, 'Effects Of Welding Parameters And Welding Sequence On Residual Stress And Distortion In Al6061-T6 Aluminum Alloy For T-Shaped Welded Joint', *Trans. Nonferrous Met. Soc. China (English Ed.*, 2020, Doi: 10.1016/S1003-6326(19)65181-2.

[4] R. R. Mishra, V. K. Tiwari, And R. S, 'A Study Of Tensile Strength Of Mig And Tig Welded Dissimilar Joints Of Mild Steel And Stainless Steel', *Int. J. Adv. Mater. Sci. Eng.*, 2014, Doi: 10.14810/Ijamse.2014.3203.

[5] P. Kumar, H. Pathak, And A. Singh, 'Fatigue Crack Growth Behavior Of Thermo-Mechanically Processed Aa 5754: Experiment And Extended Finite Element Method Simulation', *Mech. Adv. Mater. Struct.*, 2021, Doi: 10.1080/15376494.2018.1549294.

[6] H. B. Sektiawan And A. Fahruddin, 'Analysis Of Tensile Strength Of Inert Gas Metal Welding On Aluminum 5083 With Variations In Argon Gas Current And Discharge', *Indones. J. Innov. Stud.*, 2021, Doi: 10.21070/Ijins.V14i.541.

[7] H. Wibowo, M. N. Ilman, And P. Tri Iswanto, 'Analisa Heat Input Pengelasan Terhadap Distorsi, Struktur Mikro Dan Kekuatan Mekanis Baja A36', *J. Rekayasa Mesin*, 2016, Doi: 10.21776/Ub.Jrm.2016.007.01.2.

[8] J. A. Ikimi, A. A. Momodu, And E. Totore, 'Investigating The Effect Of Metal Inert Gas Welding Parameters On Aa10119 Mild Steel Quality By Taguchi Method', *J. Eng. Res. Reports*, 2021, Doi: 10.9734/Jerr/2021/V20i617327.

[9] G. C. Da Silva Costa And A. A. De Resende, 'Evaluation Of The Tig–Mig/Mag Welding Process In Direct Polarity', *Sn Appl. Sci.*, 2020, Doi: 10.1007/S42452-020-1953-7.

[10] A. Benoit, S. Jobez, P. Paillard, V. Klosek, And T. Baudin, 'Study Of Inconel 718 Weldability Using Mig Cmt Process', *Sci. Technol. Weld. Join.*, 2011, Doi: 10.1179/1362171811y.0000000031.

[11] M. Tümer, T. Mert, And T. Karahan, 'Investigation Of Microstructure, Mechanical, And Corrosion Behavior Of Nickel-Based Alloy 625/Duplex Stainless Steel Uns S32205 Dissimilar Weldments Using Ernicrmo-3 Filler Metal', *Weld. World*, 2021, Doi: 10.1007/S40194-020-01011-0.

CHAPTER 5

IDENTIFYING AND PREVENTING COMMON WELDING DEFECTS

Mr. AravindaTelagu, Assistant Professor
Department Of Mechanical Engineering, Presidency University, Bangalore, India
Email Id: - aravinda@presidencyuniversity.in

ABSTRACT:

A bad weld causes a weld flaw, which weakens the joint. It is described as the location in the welding process that is outside of the allowable tolerance. Dimensional imperfections could lead to an unsatisfactory outcome. They might also manifest as a material property or a discontinuity. Common reasons of welding faults include poor welding technique, material choice, inexperience, or wrong machine settings for welding speed, current, and voltage. In this paper discussed about the welding defects. In this paper discussed about that how to reduce the defect during the welding operation.

KEYWORDS:

Arc, Engineers, Defects, Metal, Weld.

INTRODUCTION

The term defects in the weld refers to irregularities in the weld metal created by using the incorrect welding settings, welding techniques, or filler and parent metal combinations. Defects introduced during welding beyond the acceptance limit that can cause a weld to fail is a brief definition that applies to all cases. A flaw prevents the completed joint from withstanding the necessary strength load [1], [2]. Introduction length can be as per the nature of the topic. Hence it can be prepared as per the discretion of the author. The research work already done in this particular field has to be discussed here, in this specific section.

DISCUSSION

Weak or poor welding techniques performed by unskilled or untrained welders, as well as structural issues during the welding process, can result in welding defects. Or you could say that the size and shape of the metal structure are altered during the welding process. It can be the result of using the improper welding approach or the inappropriate welding process. A good or ideal weld must have adequate fusion between the filler metal and the edge preparation and goodpenetration. You can click on them to learn more about various welding techniques such arc welding, resistance welding, gas welding, laser beam welding, and plasma arc welding. Let's talk about the many welding flaws that can occur during welding for the sake of this essay [3], [4].

Types of Welding Defects:

Following are the types of welding defects can:

1. Porosity and Blowholes.
2. Undercut.

3. Weld crack.
4. Incomplete fusion.
5. Slag inclusion.
6. Incomplete penetration.
7. Spatter.
8. Distortion.
9. Hot Tear.
10. Mechanical damage.
11. Misalignment.
12. Excess reinforcement.
13. Overlap.
14. Lamellar tearing.
15. Whiskers.

Now, we will discuss in detail about all types of defects in the welding:

1. **Porosity and Blowholes:**
   A blowhole is a very big concealed hole or pore, whereas porosity is a collection of tiny bubbles. Gases that have been trapped are the main cause. The presence of weld metal contamination leads to porosity as shown in Figure. 1.

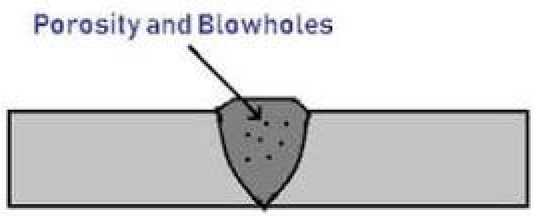


Figure 1: Represting the Porosity and Blowholes [The Engineers Post].

Causes and Remedies of Porosity:

1. The Roots of Porosity Treatment for Porosity not using enough electrode DE oxidant.
2. The selection of appropriate electrode and filler materials.
3. Applying an excessive gas flow.
4. Examining the gas flow meter to make that it has been modified as necessary with the proper pressure and flow settings. Utilizing a wider arc.
5. Verify the accuracy of the arc distance.
6. Moisture being present during the process.
7. Before starting the welding process, clean the metal.
8. Inadequate gas shield.
9. It will slow down welding, allowing the gas to escape.
10. Dirty task surface, which refers to the presence of scales, rust, oil, grease, etc. on the job surface.
11. Cleaning each component separately and preventing contaminants from entering the welding area.

2. **Undercut:**
   In welding, undercutting causes imperfections by creating grooves in the weld toe as shown in Figure. 2, which reduces the base metal's cross-sectional thickness. The workpiece and weld both weaken as a result.

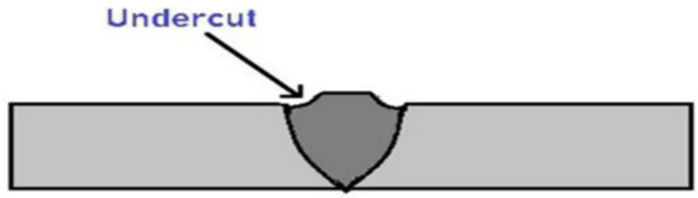


Figure 2: Represting the Undercut section of welding [The Engineers Post].

Causes and Remedies of Undercut:

1. Incorrect usage of angle, which causes the free edges to receive more heat.
2. An appropriate electrode angle is used, and bulkier components receive more heat delivery.
3. Due to an excessive welding speed.
4. Decreasing the electrode's travel speed, but not too slowly.
5. Using subpar welding techniques.
6. Using the multitasks method.
7. Use of filler metal and improper gas shielding.
8. Choose a shielding gas that is structurally appropriate for the material you are welding.
9. Using an excessive weld current.
10. Use a suitable stream to decrease thin sections and free edges as you approach them.
11. Using electrodes with a bigger diameter.
12. Reducing the length of the arc.

3. Weld Cracks:

These kinds of welding faults are the riskiest ones. By practically all production norms, it is not permitted. It might show up on the surface, in the metal used to weld, or in a hot spot. Depending on the temperature, numerous kinds of cracks might form during welding [5].

a. Hot Cracks

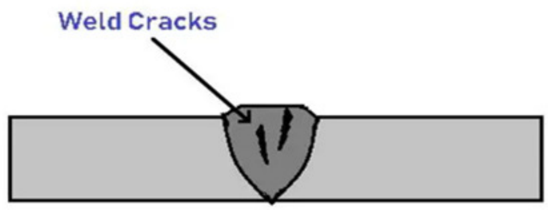
During the welding process or the crystallization of the weld joint, hot cracks might form. At this stage, temperatures can rise above 10,000C.

b. Frosty Cracks

After the weld is formed and the metal temperature has lowered, these fissures appear. They can also be produced after welding steel, hours or days later. Most often, this happens when a steel structure is deformed.

4. Crater Crack:

Before the operator completes the weld joint, these cracks appear at the conclusion of the welding operation. They are often produced close to the end of the procedure. The weld must have enough volume to overcome metal shrinkage when the weld pool cools and freezes. It will create a crater fracture as shown in Figure. 3.



. **Figure 3: Represting the Crater Cracks in weld [The Engineers Post].**

Causes and Remedies of Crater Crack:

1. Welding ferrous metals while using hydrogen.
2. Using appropriate metals.
3. Using a modest current and welding quickly.
4. Using the proper welding current and speed.
5. The design idea is subpar.
6. Using appropriate design principles.
7. Not preheating before beginning to weld.
8. Before beginning to weld, preheating the metal.
9. Base metal contamination.
10. The metal surface should be cleaned before welding.
11. Shrinkage-induced residual stress solidification.
12. Allowing the weld region to be adequately cooled.
13. The metal's significant sulphar and carbon content.
14. Utilizing the ideal ratio of carbon and sulphar in the metal.
15. Incorrect crater filling while welding.
16. To avoid crater cracks, make sure the crater is correctly filled.

5. Incomplete Fusion:

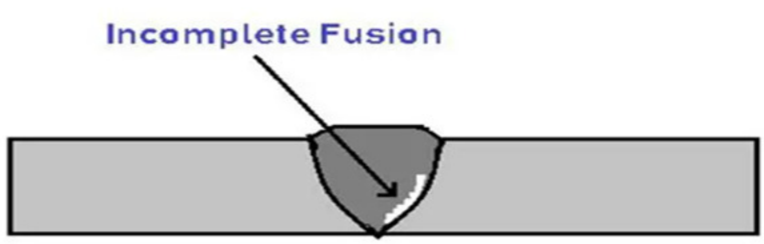


Figure 4: Represting the Incomplete fusion in weld [The Engineers Post].

These kinds of welding flaws develop when there is insufficient fusion between the metal and the weld as shown in Figure. 4. Additionally, it might be seen between adjacent weld beads. As a result, there is a space inside the joint that is not occupied by molten metal.

6. Slag Inclusion:

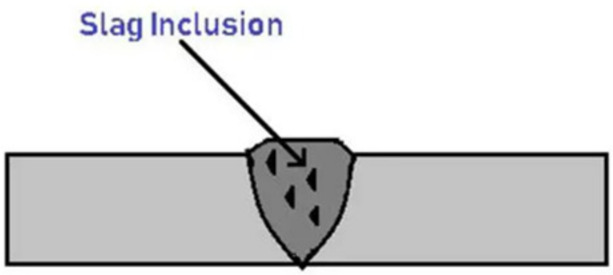


Figure 5: Represting the Slag Inclusion in weld [The Engineers Post].

Slag inclusion is a type of weld fault that is typically apparent as shown in Figure. 5. Stick welding, flux-core arc welding, and submerged arc welding all result in the toxic material known as slag. It can happen when the flux, a solid shielding material used during welding, melts within the weld or on the weld region's surface. Slag inclusion weakens the joint by reducing the joint's strength [6], [7].

7. Incomplete Penetration:

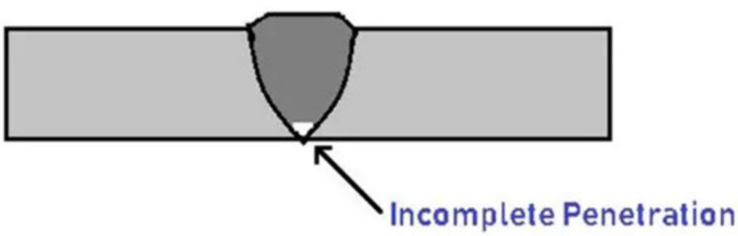


Figure 6: Represting the Incomplete Penetration in weld [The Engineers Post].

When it comes to these kinds of welding flaws, penetration is referred to as the distance between the base plate's highest surface and the weld nugget's largest possible extent (Figure. 6). When the metal groove is not completely filled, the weld metal does not completely distribute through the joint thickness, which results in incomplete penetration.

8. Spatter:

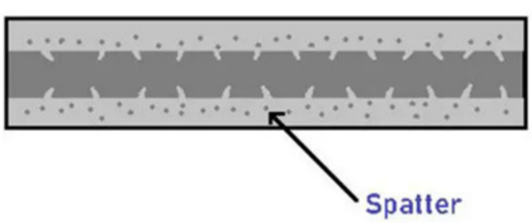


Figure 7: Represting the Spatter in Welding [The Engineers Post].

When welding, microscopic metal particles called spatters are released from the arc and collect on the base metal along the length of the weld bead (Figure. 7). This frequently occurs during gas-metal arc welding.

9. Distortion:

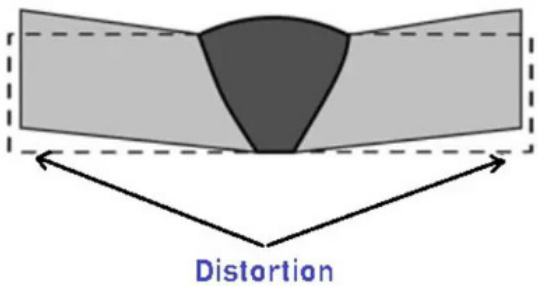


Figure 8: Represting the Distortion in welding [The Engineers Post].

Due to the temperature gradient existing at various spots along the weld joints as shown in Figure. 8, distortion is the variation in size and location between the two metal plates' positions before and after welding.

10. Hot Tear:

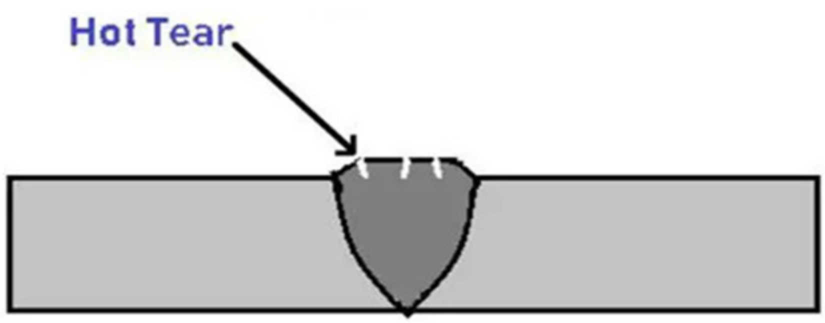


Figure 9: Represting the Hot Tear in Welding [The Engineers Post].

In these kinds of welding flaws as shown in Figure. 9, the deposited metal begins to crack from a neighboring edge, solidifying the crack growth. Due to the weld metals grain boundaries being torn while it is still flexible and before it freezes. It is also called as solidification cracking as a result.

11. Mechanical Damage:

Mechanical damage is a depression in the parent metals or the weld's surface brought on by harm sustained when welding. It happened as a result of improper welding tool use, including the use of hammers, grinders, and other instruments.

12. Misalignment:

Sometimes, filler metals decompose in the welded seam. this is probably due to misalignment. On the surface, it appears to be wavy or curved.

13. Excess Reinforcement:

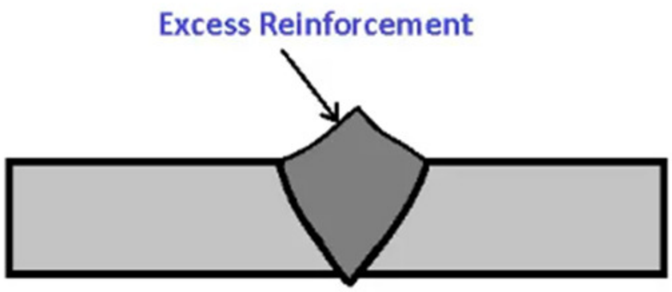


Figure 10: Represting the Excess Reinforcement in welding [The Engineers Post].

It is a typical form of welding problem that occasionally happens. This happens when there is too much filler material in the welding joint, as opposed to under fill faults. Additionally, the extra fortification is jagged and uneven Figure. 10.

14. Overlap:

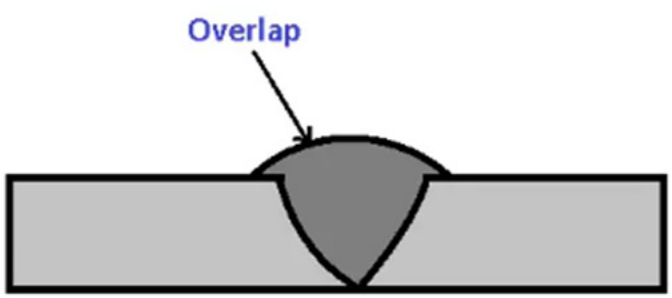


Figure 11: Represting the Overlap in welding [The Engineers Post].

A welding problem known as overlap occurs when the filler material at the weld's toe covers the base metal without adhering as shown in Figure. 11. In other words, there is a surplus of weld metal flowing.

15.Lamellar Tearing:

It is a cracking flaw that mostly affects the fabrication of rolled steel plate and happens near the bottom of the weld. Always occurring parallel to the weld fusion boundary, the ripping frequently takes place outside the heat-affected zone and is always contained within the parent plate.

16.Whiskers:

In MIG welding, whiskers are little segments of electrode wire that are bonded through the weld on the root side of the joint. This is a result of the electrode wire sticking out from the weld pool's leading edge.

17. Burn Through:

The metal may blow a hole through the middle if excessive heat is used during the welding process. This flaw is known as burn-through. When welding thin parts that are less than 1/4 inch thick, this is a typical welding flaw.

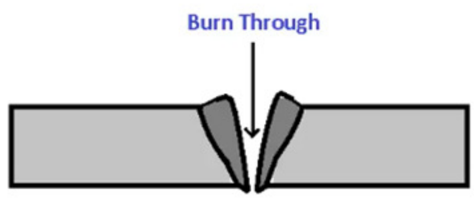


Figure 12: Represting the Burn Through in welding process [The Engineers Post].

If there are no results involved in your paper e.g. graphs, plots, charts, tables etc., then change the title of this section to simply discussion'[8].

CONCLUSION

In this Chapter discussed about the welding defects that occurs during the welding operation on the metallic pieces.The flaw could be different from the intended weld bead form, size, and quality. Defects in welding can happen on the exterior or inside of the metal being welded. Some flaws might be permitted if they fall within acceptable bounds, however flaws like cracks are never accepted.

REFERENCES:

[1] H. Pan, Z. Pang, Y. Wang, Y. Wang, and L. Chen, 'A New Image Recognition and Classification Method Combining Transfer Learning Algorithm and MobileNet Model for Welding Defects', *IEEE Access*, 2020, doi: 10.1109/ACCESS.2020.3005450.

[2] L. Yang, H. Wang, B. Huo, F. Li, and Y. Liu, 'An automatic welding defect location algorithm based on deep learning', *NDT E Int.*, 2021, doi: 10.1016/j.ndteint.2021.102435.

[3] Z. Jia *et al.*, 'Effect of pulse shaping on solidification process and crack in 5083 aluminum alloy by pulsed laser welding', *Opt. Laser Technol.*, 2021, doi: 10.1016/j.optlastec.2020.106608.

[4] M. Sokolov and A. Salminen, 'Improving Laser Beam Welding Efficiency', *Engineering*, 2014, doi: 10.4236/eng.2014.69057.

[5] P. Amirafshari, N. Barltrop, M. Wright, and A. Kolios, ‘Weld defect frequency, size statistics and probabilistic models for ship structures’, *Int. J. Fatigue*, 2021, doi: 10.1016/j.ijfatigue.2020.106069.

[6] P. Podržaj, B. Jerman, and D. Klobčar, ‘Welding defects at friction stir welding’, *Metalurgija*, 2015.

[7] S. J. Oh, M. J. Jung, C. Lim, and S. C. Shin, ‘Automatic detection of welding defects using faster R-CNN’, *Appl. Sci.*, 2020, doi: 10.3390/app10238629.

[8] F. Duan, S. Yin, P. Song, W. Zhang, C. Zhu, and H. Yokoi, ‘Automatic Welding Defect Detection of X-Ray Images by Using Cascade AdaBoost with Penalty Term’, *IEEE Access*, 2019, doi: 10.1109/ACCESS.2019.2927258.

CHAPTER 6

UNDERSTANDING THE UNDER WATER WELDING TECHNOLOGY

Mr. B Muralidhar, Assistant Professor
Department of Mechanical Engineering, Presidency University, Bangalore, India
Email Id: - muralidhar@presidencyuniversity.in

ABSTRACT:
The underwater welding refers to the hyperbaric welding, commonly referred to as underwater welding, and involves welding under intense pressure. Underwater welding is employed on a variety of marine infrastructure, including ships, dams, oil rigs, pipelines, bridges, and more. Applications involving nuclear power plants, rivers, canals, and other structures also make use of underwater welding technology.Diverse methods have been devised to create underwater welding that exhibit both wet and dry processes. In the wet process, your weldment is deposited in a wet environment alongside water, but in the dry process, the specific area the joint to be welded is made dry with the aid of several containers or chambers.

KEYWORDS:

Arc, Depth, Melt, Weld, Welding.

INTRODUCTION

Underwater welding is the practice of doing welding in a dry or wet environment at a specific depth below the water's surface.Since welds are done deep beneath the water, where pressure doubles compared to the atmosphere on land, this method is also known as the hyperbaric process. Large structures might be built underwater using this method, which is sometimes challenging to do on land. Working under pressure calls for a high level of competency, which is why scuba welders receive professional training to fulfil their jobs as both skilled welders and divers. Wet underwater welding refers to the practice of performing the welding process directly in the water without the need of an insulation barrier to keep the ambient water from coming into touch with the work area, the weld pool, the electric arc, the filler material, and the welder. It is obvious that under such circumstances, a variety of factors affect both the effectiveness of the welding process and the quality of the welded joints. Because the weld pool and electric arc are separated by a mechanical barrier that maintains a dry environment at atmospheric or hyperbaric pressure, depending on the water depth and the shape or type of the involved objects, dry underwater welding avoids direct contact with the surrounding water. In order to find offshore hydrocarbons, the oil industry has had to venture into deeper waters. In the 2000s, activity in the Gulf of Mexico, Brazil, West Africa, northwest Europe, and the Mediterranean Sea extended beyond the continental shelf. Oil is already being produced from fields far deeper than 1000 m of water, and field developments to double these depths are ongoing.

The value of underwater welding and inspection technology has been amply demonstrated in countless instances involving the installation, maintenance, and repair of naval objects. Additionally, the technical sophistication of such procedures calls for additional expenditures and development as the extraction of oil and gas appears to be moving into deep waters.

Although it is obvious that automation cannot be avoided, conventional diving is indispensable in some operations, and as a result, the field of education and training of human resources is given significant weight. Additionally, it is clear that development has advanced to the point where these technologies can be used in a variety of contexts. It is commonly known that numerous programmers were profiled over the past 30 years in an effort to improve undersea technology to a fit-for-service level. While some of those programmers produced positive benefits, others failed because of high costs and limited flexibility. For a very long time, the underwater wet welding technique was misunderstood and was associated with bad welds that were porous, had cracks, and had poor mechanical qualities including low ductility and were susceptible to cracking because of micro structural problems. Companies that did not comprehend all underwater welding concerns were lacking in expertise and understanding, which led to the development of ineffective welding techniques, subpar welder technique, and incorrect filler materials. That position has altered through time, and today underwater welding projects, both dry and wet, are utilized in the majority of challenging and complex products with a high degree of quality assurance [1], [2].Groupings for Underwater Welding

The two primary categories of underwater welding can be further broken down into the following subcategories Underwater welding while wet is defined as welding at atmospheric pressure when there is no mechanical barrier separating the diver-welder from the water.

1.Dry Underwater Welding

Dry underwater welding is defined as welding in a dry environment at atmospheric or hyperbaric pressure, where the welder-diver is separated from the water by a mechanical barrier. This mechanical barrier could be designed in accordance with AWS D 3.6 in a number of different ways. Dry welding at one atmosphere is when the pressure is decreased to one atmosphere regardless of the water depth in a pressure vessel. Dry welding in a habitat is the process of welding at atmospheric pressure in a sizable chamber in which water has been removed and where an atmosphere is created such that the welder does not require diving gear. Dry chamber welding is the process of welding at ambient pressure in a straightforward, open-bottomed dry chamber that can at least fit a diver-welder's head and shoulders when they are wearing their full diving gear. Dry spot welding, which involves the diver-welder working underwater in a small, clear container while welding at atmospheric pressure. While MMAW-manual metal arc welding is frequently used in underwater wet welding, the selection of the welding process is more flexible in dry underwater welding, where MMAW, TIG-tungsten inert gas, FCAW-flux cored arc welding, and MAG-metal active gas are all options depending on water depth, material type, thickness, and other object requirements.

2.Under Water Wet Welding

Wet underwater welding is adaptable and may be used on a variety of underwater constructions. Diver-welders and electric arcs are in direct contact with water, which has a number of detrimental effects on both weld quality and welder safety. When considering the operational accessibility of wet welding techniques, the depth is a limiting factor because these issues increase proportionally with depth. On the other hand, compared to underwater dry welding methods, equipment and other technical facilities are far more sophisticated and affordable, therefore underwater wet welding is frequently the best technology to employ for maintaining underwater structures and repairing ships.

DISCUSSION

Under Water Welding also known as hyperbaric welding is the practice of joining materials under high pressure, typically underwater. It is possible for hyperbaric welding to be done dry inside a specially designed positive pressure container or wet in the water itself as shown in figure 1. When employed in a dry environment, it is commonly referred to as hyperbaric welding and when utilized in a wet setting, as underwater welding. Hyperbaric welding has many uses, including pipeline repair, ship repair, and maintenance on offshore oil installations. The most often welded material is steel. When high-quality welds are required, dry welding is preferred to wet underwater welding because it allows for more precise control of the environment, such as through the use of pre- and post-weld heat treatments. An overall far higher quality weld than a comparable wet weld is the direct result of this improved environmental control over the operation. Therefore, dry hyperbaric welding is typically used when a weld of extremely high quality is required. Ongoing research is being done on the use of dry hyperbaric welding at depths of up to 1,000 meters 3,300 feet. Generally speaking, ensuring the integrity of underwater welds can be challenging though it is achievable utilizing various nondestructive testing applications, particularly for wet underwater welds because faults are challenging to identify if they are below the surface of the weld [3], [4].

Figure 1: Represting the Under Water Welding process [Make Money Welding].

Process of Underwater Welding:

In practically every manufacturing industry and for structural applications metal skeletons of buildings, welding technologies have grown in importance. Most of the various techniques for welding in the atmosphere cannot be used in applications involving contact with water in offshore and marine environments. The majority of offshore repair and surfacing work is carried out in the splash zone, which is the area intermittently covered by water (Figure.1). The most technologically difficult task, nevertheless, is repair at higher depths, particularly for pipeline building and the patching up of rips and breaches in marine structures and boats. Because it avoids the need to remove the structure from the water and saves both money and important time during dry docking, underwater welding may be the least expensive choice for marine maintenance and repair. It also makes emergency repairs possible, allowing the damaged structure to be moved securely to dry locations for long-term repair or demolition. Although seasonal weather prevents offshore underwater welding in the winter, underwater welding is used in both inland and offshore situations. The most popular diving technique for underwater welders in both locations is surface supplied air.Ships, submarines, nuclear reactors, offshore infrastructure, and pipelines can all be repaired underwater. Wet underwater welding and hyperbaric welding are currently popular procedures.It is usually used for the repair of ships, offshore oil platforms, and pipelines.

Types of Underwater Welding:

Different Underwater Welding Styles. Underwater welding often takes place in one of two ways:

1. Wet Welding.
2. Dry Welding.

1.Underwater Wet Welding

This procedure is executed underwater as shown in Figure. 2. The same procedure as in conventional welding is performed here, along with specially specialized welding rods. When welding underwater while wet, the diver and electrode are exposed to the environment's elements and water. Divers weld using a variety of arc welding techniques and charge their electrodes with 300–400 amps of DC power. Since hydrogen cracking occurs, the method is typically only applicable to low-carbon equivalent thefts, especially at higher depths. The same tools used for dry welding are used for wet welding, however the electrode holders for wet welding are heavier and more insulating with a water cooling design.The diver and electrode are immediately exposed to the water and environment when doing wet underwater welding. Divers often supply their electrode with 300–400 amps of direct current and weld utilizing a variety of arc welding techniques. This procedure frequently makes use of a waterproof electrode and a shielded metal arc welding variation.

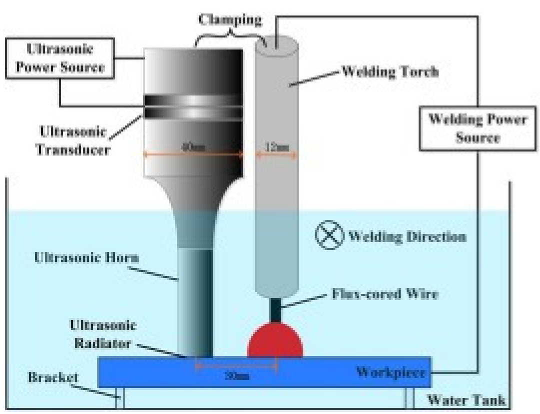


Figure 2: Represting the Wet Under water welding [Science Direct].

Friction welding and flux-cored arc welding are two additional techniques employed. In each of these scenarios, cables and hoses are used to link the welding power supply to the welding apparatus. Due to hydrogen-caused cracking, the procedure is typically restricted to low carbon equivalent steels, especially at larger depths. The equipment used for dry welding is also utilized for wet welding with a stick electrode, but the electrode holders are more extensively insulated and built for water cooling. If utilized outside of water, they will get too hot. Manual metal arc welding is done with a constant current welding machine.

In order to enable the ability to disconnect the welding current when not in use, direct current is employed, and a heavy duty isolation switch is installed in the welding cable at the surface control position. The surface operator is given instructions by the welder on how to create and break contact as needed throughout the procedure. Only when actually welding should the connections be closed. otherwise, especially when switching electrodes, they should be left open. The workpiece and welding rod are heated by the electric arc, and molten metal is transported through the gas bubble surrounding the arc. The electrode's flux coating, which contributes to the formation of the gas bubble, is typically polluted to some extent by steam. A trained operator can weld in place by transferring metal droplets from the electrode to the workpiece through the use of current flow. Rapid cooling is one of the main challenges in creating a high-quality weld, although slag deposition on the weld surface helps to slow it down [5], [6].

2. Under water dry welding

Hyperbaric welding involves sealing a chamber around the target structure before beginning. A gas often a mixture of helium and oxygen, or argon is then pumped within, forcing water outside the hyperbaric area. This enables the welding to be done in a dry atmosphere.In dry hyperbaric welding as shown in figure 3, the structure being welded is enclosed in a chamber that is filled with a gas mixture and operated at a high pressure. While most arc welding techniques, including shielded metal arc welding SMAW, flux-cored arc welding FCAW, gas tungsten arc welding GTAW, gas metal arc welding GMAW, and plasma arc welding PAW, may be used at hyperbaric pressures, all of them suffer as the pressure rises. The most used type of welding is gas tungsten arc. As the gas flow regime surrounding the arc changes and the arc roots shorten and become more mobile, the deterioration is linked to physical changes in the arc's behavior. It is noteworthy that the rise in pressure is accompanied by a sharp rise in arc voltage. Overall, as the pressure builds, competence and efficiency deteriorate. Although dry hyperbaric welding has been operationally limited to less than 400 m 1,300 ft. water depth by the physiological capability of divers to operate the welding equipment at high pressures and practical considerations regarding construction of an automated pressure / welding chamber at depth, special control techniques have been applied that have allowed welding down to 2,500 m 8,200 ft. simulated water depth in the laboratory.

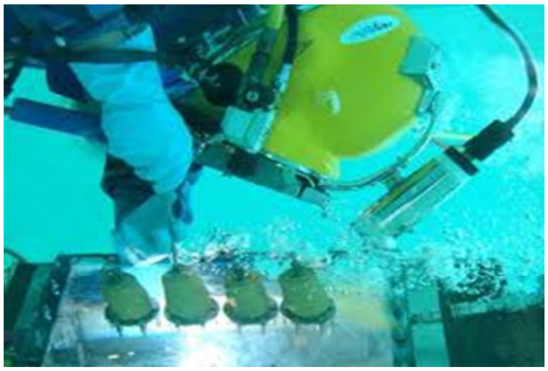


Figure 3: Represting the Dry under water welding [Global under hub].

Risks and hazards:

Electric shock to the welder is one of the risks associated with underwater welding. To avoid this, welding equipment must be suitable for use in a marine environment, suitably insulated, and with controlled welding current (Figure. 3). Commercial divers must also take into account the occupational safety concerns that divers confront, particularly the possibility of developing decompression sickness because of the heightened gas pressure in the air that they breathe. The galvanic breakdown of dental amalgam is thought to be the cause of the metallic taste that many divers have noticed. Underwater welding may have long-term impacts on the brain and potentially the musculoskeletal system [7], [8].

Equipment for Submarine Welding

Commercial divers utilize five to six major tools to properly weld underwater:

1. Diving helmet.
2. Accessories.
3. Diving suit.
4. Electrodes.
5. Stinger.
6. Power supply.

Advantages Of Underwater welding:

Dry Welding

1. The entire procedure takes place in a well-lit chamber that can withstand ocean currents. It has a system for controlling the environment. It guarantees the total safety of the workforce.

2. Non-destructive testing, sometimes referred to as non-destructive evaluation, is based on the examination of procedures, components, structures, welding flaws, etc. without causing damage to the original component.
3. Due to the optimal conditions and low quantities of H2, high-quality welds are formed.
4. It is possible to achieve permanent welds with improved structural strength.
5. Pipe alignment, NDT inspection, and other items to be watched.
6. The tools are more quickly and easily moved.
7. For urgent repairs, they are the best option.
8. Greater precautions are taken to reduce the threat of explosion.
9. Complex structures will require customization to encompass the full welding area. It is more affordable and simple to obtain.
10. Heat can be distributed evenly in an environment that is controlled.
11. Even at greater depths, gas is delivered at a pressure greater than that of water. Dryness is maintained over the repair area.
12. At and below the sea's surface, it is feasible.
13. For optimal outcomes, dry hyperbaric welding circumstances are compared to underwater ones.

14. It is utilized frequently and all around the world due to its affordability.
15. Wet welding can be completed quite quickly. It so saves time.
16. High-quality welding equipment is used.
17. Enclosure construction might take time. Enclosures are not necessary. So, using reasonably priced technology and equipment, the process is carried out fast and effectively.
18. When offshore structures need to be repaired but other methods are ineffective, it is employed to weld them.
19. At a depth of 100,000 feet, welding is possible because to special methods.

Disadvantage of Underwater Welding:

Dry Weld

1. The chamber is intricate.
2. It requires expensive heavy equipment, which is required.
3. The price is high and fluctuates with depth.
4. At larger depths, the arc constricts and higher voltages are needed.
5. A chamber that is used for one job cannot be used for another.
6. A different one is built each time.

Wet Welding

1. The metal weld is continuously quenched by water.
2. Although quenches are known to concurrently increase the tensile strength of the weld, they also reduce ductility.
3. It makes the metal harder and more porous.
4. Existence of water is a big concern.
5. The outcome is impacted by the welder's poor vision.

6. A significant amount of hydrogen is present in the welding area as a result of water vapor dissociation in the arc zone. When this H2 enters the metal, it causes embrittlement, minute fissures, and cracks in the heat-affected zone HAZ.
7. The embrittlement may cause the structure significant harm.

CONCLUSION

Underwater welding, also known as hyperbaric welding, is the process of welding under high pressures. Wet welding takes place in the water, while dry welding takes place in a dry, pressured enclosure, with steel being the most typically welded material.Underwater welding is a specialized sort of welding that requires substantial training as well as specific abilities. Underwater welders usually operate on offshore oil rigs and offshore pipelines that need to be repaired. While the labor might be highly rewarding, it is also the most hazardous employment in the nation.

REFERENCES:

[1] A. Shukla and H. Karki, 'Application of robotics in offshore oil and gas industry-A review Part II', *Rob. Auton. Syst.*, 2016, doi: 10.1016/j.robot.2015.09.013.

[2] M. Luo, R. Hu, Q. Li, A. Huang, and S. Pang, 'Physical understanding of keyhole and weld pool dynamics in laser welding under different water pressures', *Int. J. Heat Mass Transf.*, 2019, doi: 10.1016/j.ijheatmasstransfer.2019.03.129.

[3] Y. J. Hu, Y. P. Sun, S. P. Zhou, J. M. He, and C. Y. Yang, 'Effect of a cooling method on the structural and mechanical properties of friction stir spot welding with a 2524 aluminum alloy', *Mater. Res. Express*, 2021, doi: 10.1088/2053-1591/abe5ff.

[4] D. Fydrych, G. Rogalski, and J. Łabanowski, 'Problems of Underwater Welding of Higher-Strength Low Alloy Steels', *Inst. Weld. Bull.*, 2014.

[5] V. Y. Kononenko, 'Underwater welding and cutting in CIS countries', *Pat. Weld. J.*, 2014, doi: 10.15407/tpwj2014.06.08.

[6] K. Wang, C. Shao, X. Jiao, J. Zhu, Z. Cai, and C. Li, 'Investigation on microstructure and properties of duplex stainless steel welds by underwater laser welding with different shielding gas', *Materials (Basel).*, 2021, doi: 10.3390/ma14174774.

[7] T. Garg, P. Mathur, V. Singhal, C. Jain, and P. Gupta, 'Underwater Friction Stir Welding: An Overview', *Int. Rev. Appl. Eng. Res.*, 2014.

[8] S. Han, D. Cai, Z. Luo, and Y. Yi, 'Research on water-air plasma cutting process of carbon steel', *Zavar. i zavarene Konstr.*, 2021, doi: 10.5937/zzk2102053h.

CHAPTER 7

WELDING SAFETY FOR JOINING TO METALLIC PIECES

Dr. Udaya Ravi Mannar, Professor
Department Of Mechanical Engineering, Presidency University, Bangalore, India
Email Id: - udayaravim@presidencyuniversity.in

ABSTRACT:

Metals are joined together by the welding process, which employs pressure, heat, flame, or an electric arc. A filler metal, the work piece, and an electric arc or combustion gas are heated during the welding process to form the weld. In this paper discussed about the welding safety. Welding gloves and dungarees should be clean and dry at all times. The quantity of exposed skin, especially on the arms and legs, should be kept to a minimum by wearing dungarees or other garments. Electric shock cannot be prevented by welding PPE, but it does offer some protection. The main objective of welding safety is to avoid the hazard by using the right process during the welding of the metallic pieces. With the help of suitable equipment welding can avoid dangerous conditions.

KEYWORDS:

Arc, Equipment, Gloves, Protection, Safety.

INTRODUCTION

During the welding operation the worker or welder should be wearing the proper safety clothes. Wearing the proper PPE, such as a welding helmet and goggles, will protect the eyes and head of the worker from hot slag, sparks, and bright light, and chemical burns. To make sure there are no shouldering flames, welding workers should stay in the work area for at least 30 minutes after welding is complete.Elderly people should put on clean, dry welding dungarees and gloves. The quantity of exposed skin, especially on the arms and legs, should be kept to a minimum by wearing dungarees or other garments. Electric shock cannot be prevented by welding PPE, but it does offer some protection [1]–[3].

Personal Protective Equipment:

Electrical Safety - Welding

To avoid electrical risks, adhere to the electrical welding safety guidelines.

There are three different types of electricity that can be used for welding:

1. Single phase 120 or 240 volts.
2. Triple phase 575 volts V in Canada.
3. 480 volts V in the United States.

Never connect a Canadian triple phase voltage input to an American triple phase power source directly. You risk hurting yourself or others when destroying the transformer.

Power Resources

All power supply must adhere to the requirements set out by ANSI/NFPA 70 2011 or CSA standard C22.1 Canadian Electrical Code, 19th edition in Canada.

Typical Electrical Risks

Shock Electric

The human body is an electrical conductor. Even small currents can have a serious impact on your health. Depending on how much current is passing through the body, where it goes, and how long it is exposed for, the effects may include spasms, burns, paralysis of the muscles, or even death.

Completion of the Body's Circuit

When someone touches a live conductor, current may pass through their body and shock them if it does so.

1. The risk of shock rises with more electrical contact with the ground.
2. Avoid standing in water, using wet surfaces, working with wet hands, and do not wear perspiration-soaked clothing.
3. Small shocks could catch you off guard and make you trip and fall.

How to react if you get an electric shock

1. Request medical assistance.
2. AVOID touching the victim with your bare hands until after they have been removed from the live electrical source.
3. At the circuit breaker panel or fuse box, turn off the electricity. Unplug the appliance or piece of electrical equipment and turn it off if you can do so safely. Simply turning off the machinery is insufficient.
4. Determine whether you should transfer the victim or push the wire away from the victim if the electricity cannot be shut off and the victim is still in contact with the electrical source call for emergency assistance if the wire is a high voltage power line.
5. If you must move a victim away from a live contact, insulate yourself by donning dry gloves or covering your hands with fabric. You should also stand on anything dry and insulating, such as cardboard, wood, or clothing. Ensure your footing is secure so you can move the victim without tripping or falling.
6. Push the victim away from the live wire or power source by using a piece of dry wood, a broom handle, or another dry, insulating object or material.
7. Introduction length can be as per the nature of the topic. Hence it can be prepared as per the discretion of the author.

DISCUSSION

Over 500,000 workers in the United States alone are exposed to health and safety concerns each year as a result of the hazardous industrial activity of welding. The purpose of welding safety regulations is to safeguard workers from welding risks. To reduce the risk of health and safety injuries, welding safety can be implemented by completing appropriate training, monitoring welding equipment, and making sure personnel are informed of safety procedures before performing welding activities [4]–[6]. The complexity of the individual task and the environment on the job site, among other things, influence safety work practices in welding. Welders should generally observe several fundamental safety precautions based on industry norms, such as the following:

1. Unless exposure tests show exposure levels below the applicable exposure limits, welding operators should always wear an authorized respirator.
2. Before beginning work, check the electrode holder and welding equipment.
3. The metal components of the electrode holder should not be touched by damp or oily skin by welders.
4. Wearing the proper PPE, such as a welding helmet and goggles, will protect the eyes and head of the worker from hot slag, sparks, and bright light, and chemical burns.
5. To make sure there are no shouldering flames, welding workers should stay in the work area for at least 30 minutes after welding is complete.

Tips and Cautions:

Actions that welders can take to prevent welding-related events or injuries, such as burns, eye injuries, other skin injuries, and even deaths from explosions, electrocutions, and asphyxiation, are known as safety measures. Welders should put these safety measures and advice into practice in order to eliminate or limit the most typical welding risks:

6. To keep fumes and gases out of the breathing zone and the surrounding region, provide sufficient ventilation and local exhaust.
7. Inform a supervisor of any concerns you have so that your exposure to welding fumes and other toxins can be evaluated.
8. Workers can be protected from heat, flames, electrocution, and burns by wearing fire and electrical resistant clothes, hand shields, welding gloves, aprons, and boots. Be aware that repeated washings will reduce the effectiveness of flame retardant coatings. The tops of the boots must be covered by the pant legs, which cannot have cuffs. Sparks can gather in cuffs.
9. Additionally, workers might be shielded from noise using earplugs and earmuffs.
10. When doing repairs, follow lockout and tag out procedures. Equipment maintenance and repair should only be performed by qualified experts.
11. While welding, keep a sufficient Class ABC fire extinguisher close by. A full extinguisher gauge should be present. Have access to fire hoses, sand buckets, or other items that contain a fire if an extinguisher is not accessible.
12. When welding within 35 feet of flammable materials, cover the flammable material with a piece of metal or a fire-resistant blanket, and have a fire watcher nearby to keep an eye out for sparks.

Personal Protective Equipment for Welding Operation:

Personnel protective equipment PPE used appropriately significantly lowers the risk of harm and lessens the impact of toxins as shown in Figure. 1. The welding lab at Laney College requires protective gear. You won't be allowed in the lab if you don't have the proper PPE on.You must bring your own personal protective equipment to the lab. The PPE that is mandatory designated with an R and optional designated with an O is listed in the following table. The list below includes descriptions of each item as well as suggestions [7], [8].

Figure 1: Represting the Personal Protective Equipment for welding operation [Canadian Metal working].

Welding Cap:

To shield the head from hot metal and slag spray, wear a welder's cap. A welding jacket should also be worn inside long hair that is tied back. It's acceptable to wear cotton baseball caps. Hats made primarily of polyester or with a large amount of plastic are prohibited. Cotton doo-rags or cotton welding hats are suggested.

Figure 2: Represting the Welding Cap for the protection during welding [Laney College].

A welding helmet is a type of personal protective equipment used in performing certain types of welding to protect the eyes, face, and neck from flash burn, sparks, infrared and ultraviolet light, and intense heat as shown in Figure. 2. The modern welding helmet used today was first introduced in 1937 by Wilson Products. Welding helmets are most commonly used in arc welding processes such as shielded metal arc welding, gas tungsten arc welding, and gas metal arc welding. They are necessary to prevent arc eye, a painful condition where the cornea is inflamed. Welding helmets can also prevent retina burns, which can lead to a loss of vision. Both conditions are caused by unprotected exposure to the highly concentrated infrared and ultraviolet rays emitted by the welding arc. Ultraviolet emissions from the welding arc can also damage uncovered skin, causing a sunburn-like condition in a relatively short period of welding. In addition to the radiation, gases or splashes can also be a hazard to the skin and the eyes. Most welding helmets include a window covered with a filter called a lens shade, through which the welder can see to work. The window may be made of tinted glass, tinted plastic, or a variable-density filter made from a pair of polarized lenses. Different lens shades are needed for different welding processes. For example, metal inert gas MIG and tungsten inert gas TIG welding are low-intensity processes, so a lighter lens shade will be preferred.

Protective Lenses:

While in the lab, approved eye protection must be worn at all times. Goggles or safety glasses can be used for this. Eye protection needs to be well-fitting and in good condition. It must be worn correctly at all times to shield the user's eyes. Mirrored or brightly colored lenses are not permitted for use in welding labs since they don't protect the eyes (Figure.3). Eye protection must adhere to ANSI Z87.1-1989 standards, which block 99% of UVA and 60% of UVB rays. Safety glasses constructed of polycarbonate that are clear and ANSI 87.1 compliant. Prescription safety glasses with side shields are advised when prescription glasses are required to be protected.

Figure 3: Represting the height=166″ Safety glasses for use over glasses[Amazon].

Protection for Hearing:

The welding lab has a variety of noise-producing equipment that can harm your hearing as shown in Figure. 4, and there are some situations when debris can go into the ear canal. You must use earplugs to protect your ears from loud noises and injury from foreign objects. To further reduce noise, ear muffles can be worn. Washable Silicon earplugs on a string are advised.

Figure 4: Representing the hearing plug used for the Protection for Hearing [Moldex].

Gloves:

In order to protect the hands when welding, welding gloves are necessary. They ought to be compatible with the welding procedure you're using. For SMAW and FCAW, thick leather welding gloves are advised (Figure. 5). For FCAW, high-temperature welding gloves are advised. For GMAW, medium-weight welding gloves are advised. For GTAW and OAW, thinner welding gloves with greater dexterity are advised. Gloves shouldn't be worn in situations where they could catch on revolving equipment, particularly pedestal grinders.

Figure 5: Representing the Welding Gloves for safty during the welding process [India MART].

Breathing protection:

Welding and its related procedures produce a lot of fumes and gases. For welding and grinding, it is strongly advised that a filter mask or a half-mask respirator be worn as shown in Figure. 6. Grinding, SMAW, and FCAW all generate fumes and particles. As a bare minimum of protection, nuisance filter masks of type N95 with charcoal are advised. The charcoal filter lowers the amount of ozone O3 produced during welding while the N95 filter removes 95% of particles measuring 0.3 micrometers and greater. A half-mask respirator with a P100 filter and charcoal filter is strongly advised for situations where there is considerable particle formation and hazardous compounds such as chromium 6+. Particles 0.3 micrometers m and larger are completely filtered by a P100. High efficiency particle absorption HEPA filters are another name for P100s. Ozone O3 is lessened by the charcoal filter, same like with N95s.

Figure 6:Represting the Breathing protection mask during the welding process [laney.edu].

Clothing:

The right gear can offer a lot of protection. Students who are learning to weld must dress in natural fibers like cotton or wool. Long trousers and long-sleeved shirts are also necessary. A welding jacket is strongly advised. Fleece coats, pants, or pantyhose made of nylon or polyester are prohibited items. Cuffs on pants shouldn't be able to catch hot slag or sparks. For the same reason, sagging is prohibited. It is forbidden to wear clothing that is torn or holes in it.

Shoes:

Your feet will be shielded from scorching sparks and flying debris by the right footwear. Here are some recommendations for selecting safety footwear. You should make sure that the safety shoes you select adhere to the American Society for Testing and Materials ASTM standard F2413-05, which classifies safety shoes into groups based on their resistance to compression and impact. Toe caps are built into impact and compression resistant footwear to shield your foot from falling objects that could shatter or crush your toes [9]–[11].

CONCLUSION

Welding is a joining method that involves heating, melting, and mixing metals or polymers to create a junction with qualities identical to the materials being joined. A weld is composed of three major components. They are as follows An electric arc, a flame, pressure, or frictional heat source.Metal joining is a method of melting or heating metal slightly below the melting point. Fusion welding is the process of joining metal through fusion. The procedure is known as solid-state welding because it does not involve fusion.

REFERENCES:

[1] Y. Zhu *Et Al.*, 'A Lightweight Multiscale Attention Semantic Segmentation Algorithm For Detecting Laser Welding Defects On Safety Vent Of Power Battery', *Ieee Access*, 2021, Doi: 10.1109/Access.2021.3064180.

[2] Y. Yusmita And H. Hasanah, 'Penerapan Ergonomi K3 Dalam Proses Pengelasan', *J. Tek. Ind. Terintegrasi*, 2021, Doi: 10.31004/Jutin.V3i2.1348.

[3] Y. Yang *Et Al.*, 'A Lightweight Deep Learning Algorithm For Inspection Of Laser Welding Defects On Safety Vent Of Power Battery', *Comput. Ind.*, 2020, Doi: 10.1016/J.Compind.2020.103306.

[4] K. Čolić, S. Petronić, M. Jarić, N. Budimir, And D. Nasradin, 'Welding Safety By Using A New Model Of Welders' Recertification In The Oil And Gas Industry', *Struct. Integr. Life*, 2021.

[5] Sugiarto, M. Yenni, And T. S. Hilal, 'Factors Affecting Occupational Safety And Health Behavior In Welding Workshop Workers', *Kesmas Uwigama J. Kesehat. Masy.*, 2021, Doi: 10.24903/Kujkm.V7i2.1175.

[6] K. Singh And A. Anand, 'Safety Considerations In A Welding Process: A Review', *Int. J. Innov. Res. Sci. Eng. Technol.*, 2013.

[7] M. Pankratz, 'Welding Safety.', *Occup. Health Saf.*, 1999, Doi: 10.1007/978-3-662-11049-2_9.

[8] P. Kah, 'Welding Safety And Training', In *Advancements In Intelligent Gas Metal Arc Welding Systems*, 2021. Doi: 10.1016/B978-0-12-823905-6.00009-X.

[9] C. T. Mgonja, 'The Effects Of Arc Welding Hazards To Welders And People Surrounding The Welding Area', *Int. J. Mech. Eng. Technol.*, 2017.

[10] R. Pramitasari, H. Haikal, M. C. Yuantari, K. I. K. Dwi, And C. Treesak, 'Job Safety Analysis And Hazard Identification Of Welding Process In Semarang - Jsa Method As/Nzs 4360:2004', *Dis. Prev. Public Heal. J.*, 2021, Doi: 10.12928/Dpphj.V16i1.4613.

[11] Hse, 'Safety In Gas Welding, Cutting And Similar Processes', *Heal. Saf. Exec.*, 2012.

CHAPTER 8

A BRIEF OVERVIEW ABOUT PIPE WELDING TECHNOLOGY

Mr. Sagar Gorad, Assistant Professor
Department of Mechanical Engineering, Presidency University, Bangalore, India
Email Id: - Goradsagarramachandra@presidencyuniversity.in

ABSTRACT:

A technique for connecting two pipes is pipe welding. Arc welding procedures like MIG welding and TIG welding are utilized for welding pipes. Some distinguish between pipeline welding and pipe welding, with pipeline welding referring to those used to transport gas, water, oil, and other liquids over great distances. In this Chapter discussed about the Pipe welding refers to metal pipes at factories and refineries. Pipe and pipeline welders work in a variety of settings, including the building trade, oil and gas fields, the water sector, fabrication shops and nuclear power plants. Pipe welding is often carried out in accordance with pertinent laws and standards, whether it is to connect new pipes or repair damaged ones.

KEYWORDS:

Basic, Metal, Pipe, Pool, Weld.

INTRODUCTION

A technique for connecting two pipes is pipe welding. Arc welding procedures like MIG welding and TIG welding are utilized for welding pipes. Pipe and pipeline welders work in a variety of settings, including the building trade, oil and gas fields, the water sector, fabrication shops and nuclear power plants. Pipe welding is often carried out in accordance with pertinent laws and standards, whether it is to connect new pipes or repair damaged ones [1], [2].

Welding Techniques Used

An arc welding method, such as the following, is frequently used to weld pipes and pipelines:

1. SMAW, or shielded metal arc welding

Shielded Metal Arc Welding SMAW is sometimes referred to as Stick Welding, Flux Shielded Arc Welding, and Manual Metal Arc Welding MMA or MMAW.By adopting SMAW for pipe welding, sometimes referred to as stovepipe welding, no flux or shielding gas is required during the welding process, making the welding apparatus straightforward and portable. By melting the electrodes with the heat produced by an electric arc, the metal is joined together. SMAW offers several benefits, but because of its sluggish travel speed, it is less effective than other approaches.

2. GMAW Gas Metal Arc Welding

Metal Inert Gas MIG Welding and Metal Active Gas MAG Welding are two types of gas metal arc welding GMAW. While these procedures are more productive than SMAW, they do necessitate superior welding variable control to produce high-quality, effective work. GMAW enables high deposition rates with minimal fume emission and is often carried out using semi- or completely automatic equipment.

3. FCAW, or Flux-Cored Arc Welding

FCAW flux-cored arc welding, including gas- and self-shielded FCAW. Although windy conditions might perturb the shielding gas and result in porosity problems, gas-shielded FCAW uses semi-automatic machines to provide a high productivity welding option for pipes. Although self-shielded FCAW has lower deposition rates, it avoids this by not requiring a shielding gas.

4. Generation Arc Welding

The arc is hidden during the semi-automatic process of submerged arc welding, which might make tracing challenging. However, it delivers surfaces free of flaws and has the highest deposition rates of any pipeline welding technique.

5. TIG Welding Tungsten Inert Gas

Gas tungsten arc welding GTAW, also referred to as tungsten inert gas TIG welding. TIG welding is more expensive in terms of equipment and has lower deposition rates than other pipe welding techniques. However, it is ideal for important and high-precision welding applications since it creates welds of extremely high quality based on welder expertise.

Introduction length can be as per the nature of the topic. Hence it can be prepared as per the discretion of the author.

Tools Required for Pipe Welding:

Modern pipe and pipeline welding jobs are sophisticated and call for the best tools both on the job site and in the shop. Tools including pipe welding stands:

1. Pipe jacks.
2. Pipe alignment clamps.
3. Pipe chain alignment clamps.

These all tools are helpful during the pipe welding process. These tools all contribute to higher productivity as well as a more comfortable and secure working environment. The best equipment available for producing a flawless pipe weld.

DISCUSSION

A pipeline welder, sometimes referred to as a pipe welder, joins metal components using specialized flame torches to assemble and fix pipes. As a pipeline welder, you can work on oil rigs, in refineries, for utility companies, in construction, and in the manufacturing sector.A minimum of two manual arc welding processes, such as Tungsten Inert Gas TIG, Plasma Arc Welding PAW, Manual Metal Arc MMA, Metal Inert Gas MIG/Metal Active Gas MAG, and Flux Cored Arc Welding, are used to manually weld tubes and pipes to high standards of quality and integrity [3], [4].

Basic Guidelines and Process for Welding Pipes:

Open root welding, which is the most typical method used for welding pipes, is a welding joint that does not utilize a tacked backing plate. Because you'll essentially be welding across a gap although a small one, this is very challenging. It's crucial to apply the proper method to avoid messing up the entire project (Figure. 1).

1. Whether they are left- or right-handed, every welder will have a good side and a bad side when it comes to welding. When you man oeuvre around the pipe, your hand will eventually obstruct your vision. The issue for right-handed welders is the left side of the pipe, whereas for left-handed welders, the challenge is the right side of the pipe. It is best to anticipate this challenge and understand how to deal with it in order to consistently produce welds that are extremely strong and well-formed. The bottom half of the pipe will likely be more difficult than the top depending on which hand is you're stronger because gravity will affect the weld pool.
2. Starting by tacking your materials together is a good option because it will keep them firmly in place and allow you to take your time and do the welding right. Your tacks should be removed and feathered because doing so will lessen the number of flaws in the finished weld.
3. Never begin or end a pipe welding session in the gap. always do it on the side wall. Start the arc, let the weld pool form, and then travel slowly and delicately to the other side of the open root. For the first piece of the pipe, slowly zigzag your way along the exposed root until you have to switch positions.
4. Divide the pipe into portions by imagining it as a clock face. Start at the 12 o'clock position and work your way around to the 3 o'clock position. Stop and make sure you're comfortable and ready for the following part. do sure all of your tacks are tied in correctly as you go, and if you need to do numerous passes, stagger the tie-ins rather than keeping them all at the same location around the pipe.
5. Because of the open root structure of the welds and the frequent use of fairly thick, heavy-duty materials, pipe welding might result in subpar penetration. On difficult, industrial pipe welding jobs, leaving poorly penetrated welds can be disastrous. Since it's doubtful that you'll be able to weld from both the inside and outside of the pipe, you'll need to make sure you accomplish full penetration, but you can avoid this possible issue by employing a groove weld.

Figure 1: Represting the overview about Pipe welding [Australian General Engineering Vietnam].

Steps for Pipe Welding:

There are a number of stages that need be taken, as with all welding work, beginning with process selection, which entails taking into account things like:

1. Pipe material Pipe wall thickness and pipe diameter.
2. Location for welding.
3. Welding direction uphill or downhill welding qualities.
4. Necessary welding standard.
5. Monetary considerations.
6. Safety and health.

Once these issues have been resolved, you can analyses which tools are most appropriate for the job by looking at:

1. Power output Duty cycle.
2. Portability Safety.

Once the procedure and equipment have been chosen, it is time to start welding, which usually entails the following steps. Joint preparation should adhere to the rules specified by the applicable standard [5]–[7].

1. Pipe End Cleaning: Eliminate any unwelcome moisture or coatings, such as varnish, paint, rust, or oil. By doing this, flaws and expensive repairs or rewarding will be avoided.
2. Welding: After choosing the appropriate materials, including electrodes, and conditions, such as preheat needs, the welding can start with the root passes. Before the welding fill and final cap passes, hot passes come next.
3. Repairs: Ideally, you'll be able to avoid this part, but it's still important to verify the weld and fix any flaws that you find.

Welding Pipe Passes

Pipe welds necessitate numerous weld passes

Root Passes: The space between the two pieces of piping should be filled by these initial passes.

Hot passes: These connect the groove faces to the root weld. Before the final cap passes are made, the groove is mostly filled with these passes.

Cap Passes: During these last passes, the weld should be finished with the least amount of buildup outside the pipe's surface. Before applying a final, finishing cap pass, you can grind this layer back if necessary to enhance the weld beading and remove impurities.

Positions for Welding Pipe:

The four pipe welding position types are 1G, 2G, 5G, and 6G. Each position specifies whether the pipe is fixed in situ or moving, as well as whether it is positioned vertically, horizontally, or at an angle.

Pipe-Welding-Positions-Info Graphic

1G Position: Pipe is horizontal in this position for 1G welding. The pipe can be turned while the welder is still in place along the horizontal X axis. The top of the pipe is where the weld is finished, making it the simplest pipe welding position.

2G Position: Using 2G welding, the pipe is held vertically and upright in this position. The pipe can be turned while the welder is still in place along the vertical Y axis. The pipe's side is where the welding is done horizontally.

5G Position: In contrast to the 1G position, the pipe cannot be rotated during 5G welding, which sets it horizontally. Instead, to generate the weld, the welder must move vertically around the stationary pipe.

6G Position: This position for 6G welding tilts the pipe at a 45° angle to produce a sloping surface. Similar to 5G, the pipe is fixed, thus the welder must man oeuvre around it. The pipe welder must have a higher level of proficiency for this role, which is the most advanced of the four.

The easiest to master and the most challenging positions for welders to learn are 1G and 6G, respectively. A welder must become certified in each position in turn. as a result, someone who is qualified to weld in 1G positions cannot weld in 2G, 5G, or 6G positions, but someone who is competent to weld in 6G positions can weld in any of the other positions. When executing pipe welds, these criteria maintain the safety of the working environment [8].

Advantages of Pipe Welding:

When joining pipes, welding offers a number of benefits over alternative methods, such threaded fittings. These benefits consist of:

1. Reduced Fittings

Straight pipe sections can be joined without fittings by welding. While welding can quickly join pipes after thorough preparation of the component pieces, screwed pipes require fittings at every joint.

2. Reduced Prices

For long lines and larger operations, welded pipe can use thinner wall pipe than with bolted connections, saving significantly on costs. Along with the greater costs of the threaded fittings themselves, screwing pipes together might also result in higher work costs.

3. Enhanced Flow

Screwed fittings cause fluid resistance and turbulence in the pipe's flow. For better flow, welded solutions can produce streamlined, smooth surfaces.

4. Repair Ease

Systems that are welded rather than screwed are typically simpler to repair. A screwed system needs to be disassembled and reassembled for maintenance, whereas a welded pipe can frequently be fixed in place. This inevitably results in higher staff expenses and longer pipe system downtimes.

5. Less Leakage

A welded pipe is typically more resilient to vibration than a screwed system, making leaks less likely.

6. Simpler Insulation

Welded pipes are simpler to insulate because there are no threaded connections to provide challenging bumps that need to be covered.

7. The area

Threaded pipes require more room so that wrenches and other equipment may be used than welded pipes, which can be positioned close together.

8. Labour

While the amount of manpower needed to weld or screw smaller pipes is roughly the same, as pipe size increases, so do labour costs and installation times for the screwed pipe. While a professional welder may use the same welding machine for a variety of pipe sizes, a screwed pipe also needs separate tools for various pipe sizes.

Common Problems

Understanding the procedure and the associated working circumstances is the best method to prevent common mistakes in pipe welding.

1. First, the pipes that need to be linked must be well prepared, with clean and straight edges. If this is not done properly, issues could arise such as hydrogen inclusion, slag traps, and a lack of fusion in the weld.

2. The working environment for welders provide a variety of difficulties in addition to the preparation. If the proper safety measures are not performed, the process itself may result in a risk of injury. The heat produced by the welding equipment, the intense light produced by the arc, and the emission of particles or gases are among the concerns.

3. Due to the operating conditions involved with pipes, pipe welding might introduce additional risks. This includes working in awkward or even hazardous positions and environments, such as below ground or underwater. Other considerations can include working in extreme heat or cold, depending on where the pipe is located, as well as risks related to the pipe's contents, such as oil or sewage.

Applications and Illustrations of Pipe Welding:

There are many uses for this ability because pipe welding is the process of joining metal pipes. Since welding is one of the most economical ways to join multiple sections of pipe, the number of applications grows.

1. Pipe welding is therefore employed in a variety of industries, including the transportation of raw materials to oil refineries, via national or international pipelines, and to mineral processing facilities.

2. Along with providing infrastructure for water and gas providers, the construction sector, and more, pipe welder’s work in factories that process chemicals, produce food and beverages, generate electricity, and more.

CONCLUSION

In this Chapter discussed about the pipe welding technology and many welding technic performed such as Arc welding is used for pipe welding to connect metal pipes. While there are some differences between pipe welding and pipeline welding, there are also many commonalities. Pipe welders, also known as pipefitters, work in a variety of sectors, including the building industry, oil and gas fields, the water sector, fabrication shops, and power generation. Pipe welding can be a challenging skill and may require working in uneasy or potentially dangerous conditions, but with the right knowledge, safety precautions, and standards, welding is frequently preferred to alternative pipe joining methods.

REFERENCES:

[1] J. Górka, M. Przybyła, A. Chudzio, D. Ładak, and M. Szmul, 'Qualifying the TIG orbital welding technology of titanium pipes with a perforated bottom', *Weld. Technol. Rev.*, 2020, doi: 10.26628/wtr.v92i3.1098.

[2] B. Y. Lee, J. S. Kim, S. Y. Lee, and Y. K. Kim, 'Butt-welding technology for double walled Polyethylene pipe', *Mater. Des.*, 2012, doi: 10.1016/j.matdes.2011.10.014.

[3] Y. Jiang, L. Chen, Z. Li, and Y. Cui, 'Study on Welding Technology of Nuclear Power Main Pipe', *Hedongli Gongcheng/Nuclear Power Eng.*, 2020, doi: 10.13832/j.jnpe.2020.S2.0163.

[4] Suyitno and U. A. Salim, 'Fabrication of Bicycle Frame of A356 Aluminum Alloys by Using Sand Casting', *Appl. Mech. Mater.*, 2015, doi: 10.4028/www.scientific.net/amm.758.131.

[5] Y. Feng *et al.*, 'Research progress and prospect of key technologies for high-strain line pipe steel and pipes', *Nat. Gas Ind. B*, 2021, doi: 10.1016/j.ngib.2020.09.015.

[6] H. Arora, R. Singh, and G. S. Brar, 'Numerical simulation on residual stresses of stainless steel SS-304 thin welded pipe', *Meas. Control (United Kingdom)*, 2020, doi: 10.1177/0020294020917173.

[7] R. H. G. e. Silva, M. B. Schwedersky, and Á. F. da Rosa, 'Evaluation of toptig technology applied to robotic orbital welding of 304L pipes', *Int. J. Press. Vessel. Pip.*, 2020, doi: 10.1016/j.ijpvp.2020.104229.

[8] B. Huang *et al.*, 'Study on arc welding technology of 316L/X65 clad pipe', *Cailiao Daobao/Materials Rev.*, 2016, doi: 10.11896/j.issn.1005-023X.2016.06.024.

CHAPTER 9

AN OVERVIEW ABOUT PLASMA ARC WELDING PROCESS

Mr. MadhusudhanMariswamy, Assistant Professor
Department of Mechanical Engineering, Presidency University, Bangalore, India
Email Id: - madhusudhan@presidencyuniversity.in

ABSTRACT

Similar to gas tungsten arc welding GTAW, plasma arc welding PAW is a type of arc welding. An electrode, which is typically but not always constructed of sintered tungsten, and the workpiece come together to generate the electric arc. The primary distinction between PAW and GTAW is the placement of the electrode within the torch's body, which separates the plasma arc from the shielding gas envelope. In this Chapter discussed about plasma arc weldingKey whole and non-key whole welds are both made using plasma welding. Making a non-keyhole weld the procedure can make non-keyhole welds on work parts that are 2.4 mm in thickness and under. The procedure of plasma arc welding is mostly utilized for tools, dies, and moulds, etc. Many industries, including the marine and aerospace industries, use plasma arc welding. Welding stainless steel pipes and tubes with plasma arc welding is another option. It is utilized for turbine blade welding.

KEYWORDS:

Argon, Hydrogen, Plasma, Shielding, Welding.

INTRODUCTION

An electric plasma arc and a non-consumable electrode are used in the plasma arc welding PAW method to fuse metals together. The electrode is often constructed of throated tungsten, just as TIG. It is a superb option for welding both thin metals and producing deep, narrow welds because of its distinctive torch design, which provides a more focused beam than TIG welding. Compared to conventional techniques, plasma welding is frequently used to join tough metals such stainless steel, aluminum, and others. This method, which can cut metal using plasma like oxy-fuel welding, makes it a flexible tool for fabricators and manufacturers [1]–[3].

Plasma arc Welding Process:

The idea behind plasma arc welding is to create an arc between a non-consumable tungsten electrode and the workpiece. The electrode for the plasma nozzle is situated inside the torch's body, which is a distinctive design element. As a result, the shielding gas envelope and arc plasma can depart the torch independently. In addition, the nozzle's restricted opening speeds up the flow of plasma gas, enabling deeper penetration. While the leading edge of the weld pool is generally where filler metal is supplied, this is not the case when making root pass welds. Compared to gas tungsten arc welding, the plasma welding torch is more complicated. It is necessary for plasma welding torches to always be water-cooled since they operate at extremely high temperatures that risk melting away their nozzle. Although these torches can be controlled by hand, the majority of contemporary plasma welding guns are made for automatic welding.

Tungsten inclusions and undercutting are the two plasma welding flaws that occur most frequently. When the welding current exceeds the tungsten electrode's capabilities, tiny tungsten droplets become caught in the weld metal and form tungsten inclusions. Keyhole mode PAW welding is typically associated with undercuts, which can be prevented by utilizing active fluxes. Plasma arc welding is a type of welding in which the temperature that results from the setup between a tungsten alloy electrode and the workpiece is used to create a coalescence. There are three different types of gas sources utilized in plasma arc welding, including:

1. **Plasma Gas:** As it flows through the nozzle, plasma gas becomes ionized.
2. **Shielding Gas:** This gas serves the exterior nozzle and shields the weld from ambient pollution.
3. **Back Purge Gas:** The back purge gas is mostly utilized when welding certain types of materials.

   In order to produce an additional pilot arc and separate the plasma and shielding gases, the equipment can be purchased as an add-on unit to traditional TIG equipment. The plasma arc is generated by the specific torch arrangement and system controller. Alternately, specialty plasma equipment is accessible.

DISCUSSION

In plasma arc welding PAW, an electric arc is created between an electrode and the workpiece during the welding process. In most cases, but not always, the electrode for plasma arc welding is comprised of sintered tungsten. Robert Merrell Gauge made the discovery of plasma arc welding in 1957. The plasma arc can be separated from the shielding gas envelope by placing the electrode inside the welding torch's body. The arc is then constrained when the plasma is forced through a fine-bore copper nozzle, and the plasma exits the nozzle orifice at high speeds and a temperature close to 2000 °C. A non-consumable tungsten electrode is used in plasma arc welding, and an electric arc is constrained through a fine-bore copper nozzle. The majority of industrial metals and alloys can be welded using a plasma arc [4]–[6]. The plasma arc welding process can be varied in a number of ways by altering the welding current, plasma gas flow rate, and nozzle orifice width, including:

1. When welding current is less than 15 A, micro plasma is used.
2. Melt-in Mode 15 to 400 A for welding current
3. For welding currents more than 100 A, use keyhole mode.

Principle of Operation

Tungsten inert gas TIG welding has evolved into plasma arc welding. While plasma employs a particular torch with the nozzle employed to confine the arc while the shielding gas is supplied independently by the torch, TIG uses an open arc shielded by argon or helium. A water-cooled small diameter nozzle is used to constrict the arc, which squeezes it and intensifies its pressure, temperature, and heat to improve its stability, form, and heat transfer properties. Laminar low pressure and low flow and turbulent high pressure and high flow gases are used to create plasma arcs. Argon, helium, hydrogen, or a combination of these gases are employed. To prevent the molten metal from being blasted beyond of the weld zone when plasma welding, laminar flow low pressure and low flow of plasma gas is used.

When plasma welding, the non-transferred arc pilot arc is used to start the welding process. The electrode - and the water-cooled constricting nozzle + are where the arc is created. By introducing a high-frequency unit into the circuit, a non-transferred arc is triggered. After the first high-frequency start, a modest current is used to create the pilot arc between the elect. The nozzle is neutral after the main arc is struck, or in the case of welding-mesh employing micro plasma, an option to have a continuous pilot arc may be provided. A transferred arc has a fast plasma jet and high energy density. It can be used to cut and melt metals depending on the current used and gas flow. Foils, bellows, and thin sheets can be employed with micro plasma,

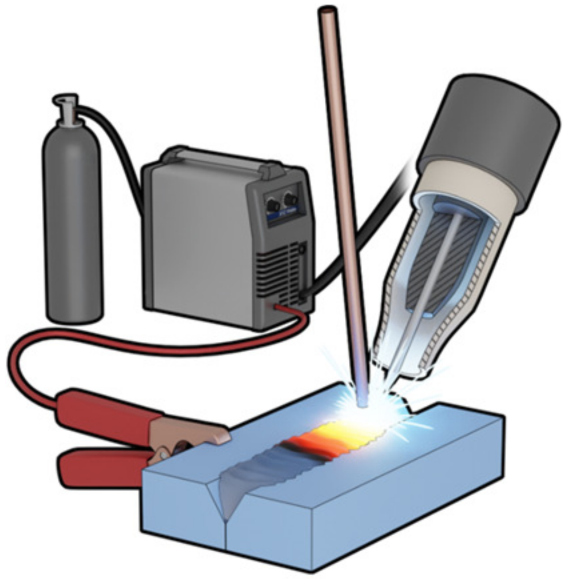


Figure 1: Represting the TIG Welding process [Manufacturing Guide].

Which uses current between 0.1 and 10 amps. Since this is an autogenously process, filler wire or powder are typically not used. For higher-thickness plate welding with filler wire or autogenously up to 6 mm 0.24 in plates as well as metal deposition hard facing utilizing specialized torches and powder feeders PTA using metal powders, medium plasma employs current between 10 and 100 amps. High travel speeds are utilized to weld filler wires while using high-current plasma above 100 amps. Other uses for plasma include heating, deposition of diamond films, material processing, metallurgy the manufacture of metals and ceramics, plasma-spraying, and underwater cutting Kithara et al. 1989. The plasma and shielding gases are turned on after the equipment is set up and the welding cycle is started. The arc is transported from the electrode to the workpiece through the opening in the copper alloy nozzle when the torch is brought close to the workpiece or when the chosen welding current is started, at which point a weld pool is created Figure. 2. The melt-in mode and the keyhole mode, which are the two separate operating modes for the PAW process, are frequently used terms.The term melt-in-mode describes a weld pool that resembles the one that frequently forms during gas-tungsten arc welding GTAW, in which a bowl-shaped section of the workpiece material that is under the arc is melted.

Gases For Shielding and Plasma Orifice:

The shielding gas is used to protect the weld metal pool while it cools and hardens, whereas the plasma gas is utilized to create the arc. Argon is often the plasma gas. For micro plasma welding, the flow rate can range from 0.1 L/min to 10 L/min for keyhole plasma welding.

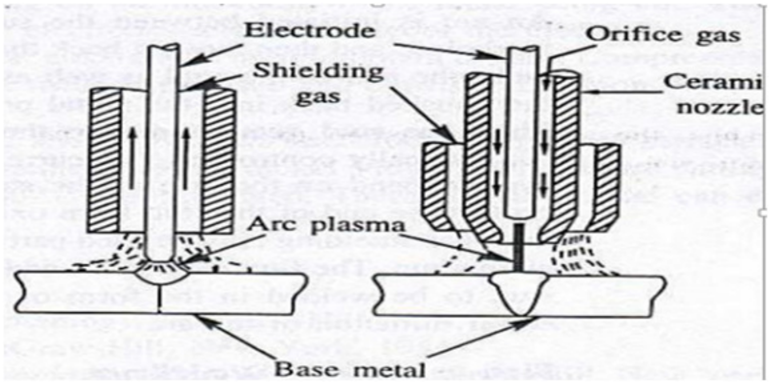


Figure 2: Represting the Comparison of the torch tips of tig and paw Process [Intechnologies].

GAS PLASMA

In more than 90% of all applications, argon is employed as the primary plasma gas. It is completely inert, which means that it won't interact with other substances at any temperature or pressure. Its low ionisation potential ensures a dependable pilot arc and arc initiation [7]–[9].

Argon: Argon supplies the tungsten electrode with exceptional protection and arc stability.

The flow rates are between.25 SCFH .18 lpm and 5.0 SCFH 2.4 lpm.

Argon/Hydrogen: Up to 3% Hydrogen Argon/Hydrogen

There are situations when adding a little hydrogen to argon is advised. This raises the weld puddle's heat input. A hotter arc produced by argon/hydrogen will help with weld penetration and weld puddle fluidity. When compared to argon, utilising Argon/Hydrogen mixes will reduce the life of torch parts. Tip Using a hydrogen gas mixture results in a 50% reduction in current ratings. The flow rates are between.25 SCFH .18 lpm and 5.0 SCFH 2.4 lpm.

Shielding Gas

Argon: All metals can be utilised with argon. At lower current levels less than 20 amps, it offers good arc stability and efficient cleaning. Additionally, it is advised for usage while welding reactive metals, copper alloys, titanium, and aluminium. Due to the higher arc voltages required in plasma welding 18–32V, Argon could occasionally function less than satisfactorily. A weld may experience slight undercutting or show signs of surface oxidation when the weld puddle is not flowing. It might be essential to employ argon/hydrogen, helium, or argon/helium mixes.

Hydrogen/argon 95/5%:

Argon/hydrogen mixes are utilised to increase the weld's heat input. Increased travel speeds arise from the reduction of surface tension in the molten pool caused by the addition of hydrogen to argon. Degassing of the weld pool is made easier by lowering the surface tension of the molten metal, which also lessens the risk of gas inclusions in the form of porosity. Undercutting is also prevented and a better weld surface is attained at faster welding speeds.

Hydrogen has a fluxing action that lowers the quantity of oxides generated when connecting stainless steels, nickel, and high nickel alloys in addition to increasing arc heating efficiency. The presence of hydrogen actually aids in welding nickel or nickel alloys by preventing porosity. The hydrogen reduces the nickel oxides that are created when oxygen from the air enters the system. Any stray oxygen is attacked by the hydrogen before it can become nickel oxides. The maximum amount of hydrogen that is allowed is 15%. It is tangentially connected to the thickness of the welding substance. The hydrogen can get trapped in the weld with higher current welding and slower travel speeds on thicker materials. The weld becomes embrittled as a result of this. In general, the higher the permitted amount of hydrogen in a gas combination that can be employed, the thinner the work-piece must be. In automated welding, using thinner materials .062, 1.6 mm or less, a larger hydrogen content can speed up travel.

Helium:

The weld heat is increased by around 25% when helium is used instead of argon. This is caused by helium's increased ionisation potential, which also raises the arc voltage. When welding aluminium alloys, copper alloys, and thicker parts of titanium, helium is frequently employed. These materials will lose heat more quickly and require the help of the helium. The range of flow rates is from 15 SCFH 7.1 lpm to 40 SCFH 18.8 lpm.

Argon/Helium 75/25%:

For a given welding current, an arc gets hotter when helium is added to argon. Before a significant shift in heat can be felt, a mixture must have at least 40% helium in it. The arc tends to be stabilised by the argon. Results from mixtures containing more than 75% helium will be fairly comparable to those from pure helium. Thicker sections of titanium or copper alloys are employed in applications where a combination of 75% helium and 25% argon is utilised.

Equipment Used in Plasma Arc Welding:

The following is a list of the tools required for plasma arc welding and their respective roles:

1. **Current:** Control of current and gas decay is necessary to adequately seal the keyhole and finish the weld in the structure.
2. **Fixture:** Important to keep the molten metal inside the bead from being contaminated by the atmosphere.
3. **Materials:** Materials include aluminum, steel, and other substances.
4. **High-Frequency:** Arc igniting is accomplished using a high-frequency generator and current limiting resistors. Arc-starting systems can be standalone or integrated into larger systems. Used for transferred arc or non-transferred arc types, the plasma torch. It can be mechanized or operated by hand. Almost all applications today call for an automated system. To prolong the life of the nozzle and electrode, the torch is water-cooled. Depending on the metal to be welded, the shape of the weld, and the required penetration depth, the size and type of the nozzle tip are chosen.
5. **Power Source:** Plasma arc welding requires a direct-current power supply generator or rectifier with drooping characteristics and an open circuit voltage of at least 70 volts. In general, rectifiers are preferred over DC generators. Open circuit voltage exceeding 70 volts

is necessary when using helium as an inert gas. The arc can be started with argon at the typical open-circuit voltage and then helium can be turned on. This greater voltage can also be achieved by operating two power sources in series.

The following are typical welding parameters for plasma arc welding:

Direct current electrode negative DCEN is typically used for plasma arc welding, with the exception of when welding aluminum, in which case water-cooled electrodes, or direct-current electrode positive DCEP, are preferred. Other parameters for plasma arc welding include currents of 50 to 350 amps, voltages of 27 to 31 volts, and gas flow rates of 2 to 40 liters/minute lower range for orifice gas and higher range for outer shielding gas.

1. **Shielding gas:** Two inert gases or gas mixes are used as shielding gases. The plasma arc is created by orifice gas flowing at a lower pressure and flow rate. Although the orifice gas pressure is purposefully kept low to prevent weld metal turbulence, this low pressure cannot adequately protect the weld pool. The same or another inert gas is fed through the outer shielding ring of the torch at considerably greater flow rates to have enough shielding protection. The majority of materials can be joined together using inert gases or gas mixes such as argon, helium, argon hydrogen, and argon helium. It's common to use argon. Where a broad heat input pattern and flatter cover pass are required without a key-hole mode weld, helium is preferable. Keyhole mode welding in nickel-base alloys, copper-base alloys, and stainless steels are possible when argon and hydrogen are combined because the thermal energy produced is larger than when argon is used alone. A combination of argon and hydrogen 10–30% or nitrogen may be used for cutting. Due to its atomic dissociation and subsequent recombination, hydrogen produces temperatures higher than those reached by employing argon or helium alone. Furthermore, hydrogen creates a reducing environment that aids in preventing oxidation of the weld and its surroundings. Attention must be paid since some metals and steels can become embrittled as a result of hydrogen leaking into the metal [10]–[12].
2. **Voltage control:** Voltage regulation is necessary for contour welding. A voltage control is not thought to be necessary for standard key-hole welding because an arc length change of up to 1.5 mm has no discernible impact on weld bead penetration or bead form [13], [14].

Application of Plasma Arc Welding:

The following list includes several plasma arc welding applications. The procedure of plasma arc welding is mostly utilized for tools, dies, and moulds, etc. Many industries, including the marine and aerospace industries, use plasma arc welding. Welding stainless steel pipes and tubes with plasma arc welding is another option. It is utilized for turbine blade welding. Additionally suitable for the electrical sectors is plasma arc welding.

Advantage of Plasma Arc Welding:

The following are the main benefits of plasma arc welding:

1. Compared to other arc welding procedures, plasma arc welding has a higher energy concentration.
2. Depending on the material, a maximum depth of 12 to 18 mm can be reached using the plasma arc welding process.

3. Greater arc stability in plasma arc welding enables significantly longer arc lengths and much higher tolerance for arc length variations.
4. The plasma arc welding uses very little power.
5. Plasma arc welding allows for rapid welding.
6. When compared to other procedures, such GTAW, thicker metal can be pierced in a single pass.
7. Less joint preparation is necessary due to the higher penetration.
8. The method can result in good weld integrity similar to GTAW, reducing the number of welding passes and, consequently, the number of welding hours and labour costs.
9. Better visibility of the weld pool is made possible by the longer arc length, which is crucial for manual welding.

Disadvantage of Plasma Arc Welding:

The following are some drawbacks of plasma arc welding:

3. It's noisy when plasma arc welding.
4. Welders with advanced skills are necessary.
5. The orifice needs to be replaced for plasma arc welding.
6. The complicated and expensive plasma arc welding equipment is employed.
7. There is more radiation produced.
8. The welding processes used in plasma arc welding are typically more intricate and less forgiving of fit-up variances, etc.
9. The cost of the equipment is higher than with the GTAW method.
10. Compared to the wider, conical arc of the GTAW process, high arc constriction yields higher penetration but also limits the method's tolerance to joint gaps and misalignment.
11. The PAW torch design is more complex and has more parts, necessitating more periodic maintenance.

CONCLUSION

In This Chapter discussed about the plasma arc welding technology that is used to join the metal workpiece together.The process of plasma arc welding is mostly used for tools, dies, and moulds, among other things. Plasma arc welding is used in numerous industries, including the marine and aerospace sectors. Plasma arc welding stainless steel pipes and tubes is an additional option. It is used to solder turbine blades. Plasma arc welding is also appropriate for the electrical industries.

REFERENCES:

[1] J. Qiao, C. Wu, and Y. Li, ‘Numerical analysis of keyhole and weld pool behaviors in ultrasonic-assisted plasma arc welding process’, *Materials (Basel).*, 2021, doi: 10.3390/MA14030703.

[2] C. S. Wu, L. Wang, W. J. Ren, and X. Y. Zhang, ‘Plasma arc welding: Process, sensing, control and modeling’, *J. Manuf. Process.*, 2014, doi: 10.1016/j.jmapro.2013.06.004.

[3] Z. M. Liu, S. L. Cui, Z. Luo, C. Z. Zhang, Z. M. Wang, and Y. C. Zhang, ‘Plasma arc welding: Process variants and its recent developments of sensing, controlling and modeling’, *Journal of Manufacturing Processes*. 2016. doi: 10.1016/j.jmapro.2016.04.004.

[4] T. Q. Li, L. Chen, Y. Zhang, X. M. Yang, and Y. C. Lei, ‘Metal flow of weld pool and keyhole evolution in gas focusing plasma arc welding’, *Int. J. Heat Mass Transf.*, 2020, doi: 10.1016/j.ijheatmasstransfer.2019.119296.

[5] C. S. Rao and K. S. Prasad, ‘Advances in Plasma Arc Welding : A Review’, *J. Mech. Eng. Technol.*, 2012.

[6] Y. Li, C. Wu, and M. Chen, ‘Numerical analysis of the ultrasound induced arc pressure increment in plasma arc welding’, *J. Phys. D. Appl. Phys.*, 2019, doi: 10.1088/1361-6463/aae96d.

[7] A. V. Nguyen, D. Wu, S. Tashiro, and M. Tanaka, ‘Undercut formation mechanism in keyhole plasma arc welding’, *Weld. J.*, 2019, doi: 10.29391/2019.98.018.

[8] R. Zhang, F. Jiang, and S. Chen, ‘Comparison of energy acted on workpiece among Twin-body Plasma Arc Welding, Non-transferred Plasma Arc Welding and Plasma Arc Welding’, *J. Manuf. Process.*, 2016, doi: 10.1016/j.jmapro.2016.08.009.

[9] D. Wu, S. Tashiro, X. Hua, and M. Tanaka, ‘Numerical study of keyhole behaviors and thermal fluid flow in high current plasma arc welding’, *Yosetsu Gakkai Ronbunshu/Quarterly J. Japan Weld. Soc.*, 2021, doi: 10.2207/QJJWS.38.40S.

[10] Z. Lu, W. Zhang, F. Jiang, S. Chen, and Z. Yan, ‘A primary study of variable polarity plasma arc welding using a pulsed plasma gas’, *Materials (Basel).*, 2019, doi: 10.3390/MA12101666.

[11] A. Sahoo and S. Tripathy, ‘Development in plasma arc welding process: A review’, in *Materials Today: Proceedings*, 2019. doi: 10.1016/j.matpr.2020.09.562.

[12] T. Qing Li, X. M. Yang, L. Chen, Y. Zhang, Y. Cheng Lei, and J. Chun Yan, ‘Arc behaviour and weld formation in gas focusing plasma arc welding’, *Sci. Technol. Weld. Join.*, 2020, doi: 10.1080/13621718.2019.1702284.

[13] D. Wu, S. Tashiro, X. Hua, and M. Tanaka, ‘Analysis of the energy propagation in the keyhole plasma arc welding using a novel fully coupled plasma arc-keyhole-weld pool model’, *Int. J. Heat Mass Transf.*, 2019, doi: 10.1016/j.ijheatmasstransfer.2019.07.008.

[14] C. S. Wu, C. Y. Zhao, C. Zhang, and Y. F. Li, ‘Ultrasonic vibration-assisted keyholing plasma arc welding’, *Weld. J.*, 2017.

CHAPTER 10

FILLER RODS FOR GAS WELDING AND ITS SIGNIFICANCE

Mr. Sandeep Ganesh Mukunda, Assistant Professor
Department of Mechanical Engineering, Presidency University, Bangalore, India
Email Id: - sandeepgm@presidencyuniversity.in

ABSTRACT:
If a filler rod is used, it should be slowly dabbed into the leading edge of the weld pool at an angle of 10–20°. Since this usually results in spatter and could unintentionally contaminate the electrode, it shouldn't be fed straight into the arc column. The welder's vision of the weld pool is restricted at angles steeper than 10–20°. To avoid oxidation, the filler rod's tip should be held inside the gas shield while it is still hot. In this Chapter discussed about the filler rods for gas welding. When welding, soldering, or brazing, filler metals are used to fill the space between two closely fitting components. When heated, these metalsalloyed or unalloyedmelt and flow into the spaces between two closely abutting components to form a weld, soldered, or brazed joint

KEYWORDS:

Filler, Gas, Joint, Metal, Rod,Welding.

INTRODUCTION

In gas welding, brazing, and some types of electric welding, a filler metal that is not a component of the electrical circuit is referred to as a filler rod. The filler rod's sole purpose is to provide the junction with filler metal. In the shape of wire or rods, filler rod is frequently referred to as welding rod. With the exception of a thin covering left over from the production process, filler rods are typically uncoated. Steel welding filler rods are frequently copper-coated to prevent corrosion while being stored. The majority of rods are supplied in 36-inch lengths and come in a wide range of diameters, from 1/32 to 3/8 inch. Cast iron welding rods are typically square rather than circular and range in length from 12 to 24 inches. The thickness of the metal you are connecting determines the rod diameter for a certain job.You choose the filler rod based on the requirements of the metals being joined, with the exception of rod diameter. These requirements could come from the government, the military, or the Navy. In other words, they are applicable to the Military Establishment, the Navy, or all government institutions. Currently, one or more of these three categories of criteria apply to filler metals. All Navy specifications will eventually be converted to military MIL specifications. As a result, some of the welding material standards described in this section may eventually be published as military specifications rather than Navy specifications [1], [2].

To weld ferrous and nonferrous metals, numerous varieties of rods are produced. Typically, welding facilities simply have a few basic types on hand that can be used in all welding situations. General-purpose rods are the name for these fundamental varieties. The 1100 and 4043 rods are two different kinds of welding rods that can be used to gas weld aluminum alloys. When highest corrosion resistance and great ductility are crucial, the 1100 rod is employed. Only welding 1100 and 3003 type aluminum alloys is permitted with the 1100 rod. The 4043 rod is utilized because it has a lower tendency to crack and is stronger. Additionally, it is applied to all other castings and wrought aluminum alloys.These rods serve as filler material for gas welding, which produces a high-temperature flame at the tip of a gas welding torch using a mixture of fuel and oxygen gas. To form a weld on the workpiece, heat from the flame melts and fuses the material from the workpiece and a gas welding rod. Unlike arc welding, gas welding does not require electricity. The research work already done in this particular field has to be discussed here, in this specific section.

DISCUSSION

The junction between the base metal elements is formed by adding a filler metal to the joint during the brazing and soldering procedures. With soft soldering, a filleroften a lead-tin solder alloyis used that melts at a lower temperature than the workpiece. A higher temperature filler is used in brazing and hard soldering that melts at a temperature that may be close to the base metal's melting point and may create a eutectic alloy with the base metal. Because filler alloys have a lower melting point than base metal, the joint can be formed by heating the entire assembly up separately from the base metal. Complex joints can be constructed in stages using filler metals with progressively lower melting points, typically for jewelry or live steam boiler making. By heating to the higher temperatures, early joints are spared destruction [3], [4]**.**

Filler Rod

The term filler rods or welding rods refers to pieces of wire or rod with a standard diameter and length that are used as filler metal in the joint during the gas welding process. Metal, either ferrous or non-ferrous, is used to make these rods.High grade filler rods should be used for the greatest results. When compared to the cost of the job, labour, gases, and flux, the actual cost of welding rods is quite low. To decrease oxidation the result of oxygen, control the mechanical characteristics of the deposited metal, and Compensate for the loss of some elements from the weld metal brought on by fusion. At the joints of thin section metals, a cavity or depression will occur during welding. At the joint, a groove is made for heavy/thick plates. This groove is required to achieve a better full-thickness metal fusion and achieve uniform strength at the junction. Metal needs to be inserted into this produced groove. A filler rod is also required for this function. There must be a proper filler rod for each metal.

Sizes According to IS: 1278-1972

The diameter of the filler rod, which ranges from 1.00 to 1.20 to 1.60 to 2.00 to 2.50 to 3.15 to 4.00 to 5.00 to 6.30 mm, determines its size. Up to 4 mm diameter filler rods are employed for the leftward procedure. For rightward method, diameters up to 6.3 mm are used. Filler rods with a diameter of 6 mm or greater are used for cast iron welding.

Filler Rods Come in Lengths of 500 mm or 1000 mm

For welding mild steel, filler rods larger than 4 mm in diameter are not frequently utilized. Mild steel filler rods typically come in sizes between 1.6 mm and 3.15 mm in diameter. All mild steel filler rods are coated with a small layer of copper to prevent oxidation rusting while being stored as shown in Figure 1. The name copper coated mild steel C.C.M.S. filler rods refers to these filler rods. Before being utilized, all filler rod types must be kept under sealed plastic covers.

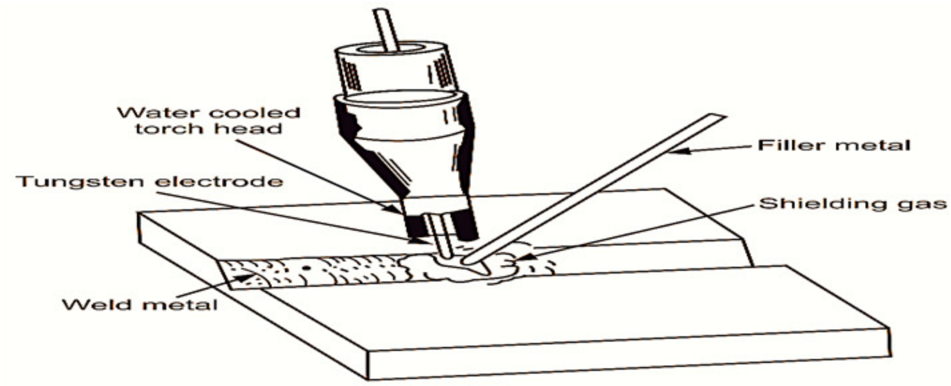


Figure 1: Represting the Filler rods come in lengths of 500 mm or 1000 mm [Electrical workbook].

Welding Using Hot Gas

In hot gas welding, a weld or filler rod and the joint area are covered by a heated gas . In order to make the weld, the weld rod is typically utilized to fill a single- or double V-groove or bevel T joints. Except in situations where the substance might easily oxidize, nitrogen or inert gases are utilized instead of air. The weld rod and the components are typically scraped before welding to remove any contaminated surface layers shown in Figure 2. Prior to welding, the components are typically tack welded with a tacking tip. Then, while pressing the weld rod to force the melt into the joint, the operator oscillates the hot gas tip back and forth from the weld rod to the component surface in a fanning motion to heat both sides. You can quicken the procedure by using a high speed tip, which contains a hot gas channel to heat the surface of the part, a weld rod channel to heat and extrude the filler rod and a pressure foot.

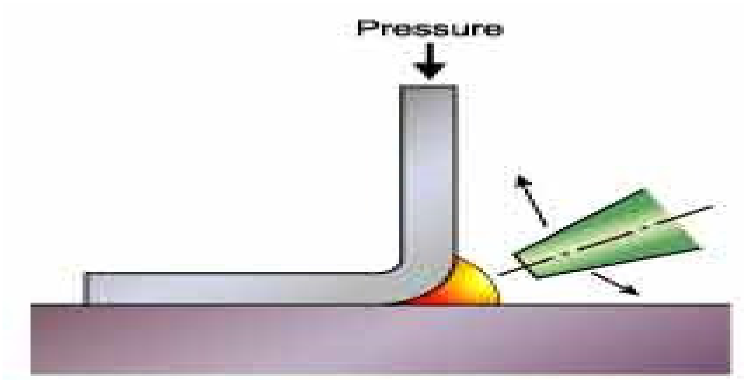


Figure 2: Represting the Hot Welding process overview [TWI Global].

Hot Gas Welding Cadillac Plastic and Chemical Company: Cadco Heavy sections of Cadco actual can be joined by hot gas welding. A hot nitrogen welding gun, pressure regulator, filler rods of actual and appropriate jigs and fixtures are needed for this technique. Use of a nitrogen blanket is recommended to avoid oxidation leading to low weld strength. The outlet temperature of the welding gun should be approximately 332°C 630°F. For maximum joint strength, both the parts to be welded, and the filler rod should be heated so that all surfaces to be joined are melted.

Tungsten Arc TIG Welding with Gas Shielding

In this method, a weld pool is formed between a tungsten electrode and the parent metal and filler rod is typically put into it by hand Figure. 3 . The filler wire can be fed by automated devices, and the welding head can travel along the joint line automatically. The tungsten electrode is non-consumable, and an inert shielding gas such as argon, helium, or combinations of these gases prevents air from contaminating the weld pool. The welder must possess a high level of ability and be able to precisely regulate penetration. Because of this, the method is especially well suited for pipe root runs and thin section welding.

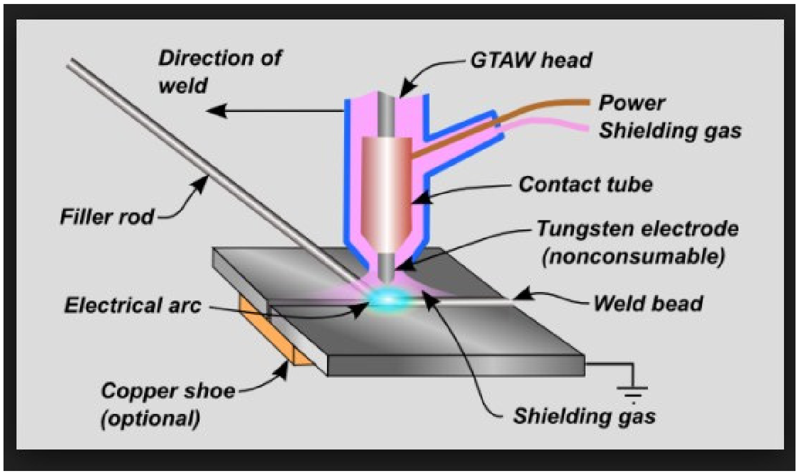


Figure 3: Represting the Tungsten arc TIG welding with gas shielding [Weldingis].

Joints In The Butt

When welding open butt joints, a filler rod is required to close the root gap and provide a penetration bead without compromising complete fusing of the root faces. The 'keyhole' technique is the method utilized to create the root run in open butt joints. By melting the root faces until a distinct hole is created, the keyhole is created. When the keyhole forms, a filler rod is inserted into the arc to cover the space left by the molten root. After the root faces have been connected by a bridge, the TIG torch is merely shifted forward enough to recreate the keyhole. As welding proceeds around the joint, filler rod is gradually added to fill the hole and is then added again each time the keyhole is produced [5]–[7]. When an arc with open butt joints is put out, it leaves a keyhole that is already there. In these circumstances, the restart is the same as it is for close butt joints. Care must be taken to prevent remelting the leading edge and causing it to enlarge once at the keyhole. The existing keyhole is filled with a tiny quantity of filler rod, which is then reshaped and filled appropriately to finish the root run. However, the keyhole does not need to be reformed when using the continuous filler rod technique.

Various Filler Rod Types

Gas welding includes the following categories of filler rods:

1. Ferrous and non-ferrous filler rods
2. Filler rod of the alloy type for ferrous metals
3. Filler rod of the alloy type for non-ferrous metals
4. A ferrous filler rod contains a large percentage of iron.

The filler rod of the ferrous kind is made up of iron, carbon, silicon, sulphar, and phosphorous. Iron, carbon, silicon, and one or more of the following elementsmanganese, nickel, chromium, molybdenum, etc.are all present in the alloy type filler rod. Non-ferrous filler rods are filler rods that include non-ferrous metal components. Non-ferrous filler rods have a similar chemical makeup to other non-ferrous metals like copper and aluminum. Metals like copper, aluminum, tin, etc. are found in non-ferrous alloy filler rods together with zinc, lead, nickel, manganese, silicon, etc.

Choosing the Filling Rod

For successful welding, choosing the appropriate filler rod for a given task is a crucial step. The metallurgical requirements of an element are taken into special account while choosing the filler metal composition. Making the incorrect decision owing to ignorance or erroneous economic considerations might result in costly failures. The standard IS: 1278-1972 outlines the specifications that filler rods for gas welding must meet. A different specification, IS: 2927-1975, is available for brazing alloys. It is highly advised to utilize filler material that adheres to these requirements. It may be essential in very unusual circumstances to utilize filler rods of a composition not covered by these criteria in these circumstances, filler rods having a track record of reliable performance should be used. The filler rod must have the same composition as the base metal to be welded in order to be chosen in relation to that metal. The following factors should be taken into account when choosing a filler rod.

1. The type and composition of the base metal.
2. The thickness of the base metal.
3. The method of edge preparation.
4. The weld is deposited as a root run, intermediate runs, or final covering run.
5. Welding position.
6. If the welding has caused any corrosion or material loss from the base metal.

Maintenance and Upkeep

1. To avoid degradation, filler rods should be stored in a clean, dry environment.
2. Don't combine several filler rod types.
3. Ensure that labels and packages are arranged properly for quick and accurate selection.
4. If it is not practical to keep filler rods in warm circumstances, the storage area may be equipped with a moisture-absorbing material, such as silica gel.
5. Check to make sure the rod is clean and free of contaminants including rust, scale, oil, grease, and moisture.
6. Make sure the rod is largely straight to facilitate welding manipulation.

Different Filler Metals and Fluxes For Gas Welding

Additionally, they comply with ISO standards almost always as well as the requirements of the American Welding Society AWS, The American Society for Testing Materials ASTM, and other organizations. Tin, lead, silver, lead-free, cadmium-free, sylphs, copper, aluminum, nickel, and jeweler’s gold are examples of common filler metals.

Issues with Quality

i. Filler rods need to be made of the same thermoplastic as the base material.
ii. The filler rod's force must remain constant throughout the process in order to promote mixing of the softened material.
iii. Incomplete softening, oxidation, and heat degradation of plastic material weaken joints.
iv. The hot gas temperature, pressure from filler rod or fixtures, and welding speed are process factors.
v. Filters are needed to remove impurities and extra moisture from hot gas.
vi. The strength of the weld varies from 50% to 100% of the base material.
vii. A scraper can be used to make the recast plastic filler at the joint flush with the base material.
viii. Prior to beginning the welding process, the pieces that will be linked should be tacky welded.
ix. For big pieces, it is recommended to use additional fittings in order to apply additional pressure and facilitate joint formation.
x. The weld's surface finish is fair to good.
xi. Typical fabrication tolerances are 0.5 mm.

Joints at Corners:

In the proper placements for the torch and filler rod are indicated for a corner junction. The pool should remain on the joint centerline and both of the adjacent pieces' edges should be melted. Deposit enough filler metal to produce a convex bead when adding it. A throat thickness that is smaller than the metal thickness is caused by a flat bread or concave deposit. If the fit-up is particularly good, this joint design lends itself to fusion welding on thin materials without filler. For autogenously welding, a different corner configuration is displayed [8]–[10].

CONCLUSION

In this Chapter discussed about the filler rod for gas welding to join the metal work pieces together. These rods serve as filler material for gas welding, which produces a high-temperature flame at the tip of a gas welding torch using a mixture of fuel and oxygen gas. To form a weld on the workpiece, heat from the flame melts and fuses the material from the workpiece and a gas welding rod.

REFERENCES:

[1] A. Sabetghadam-Isfahani, M. Abbasi, S. M. H. Sharifi, M. Fattahi, S. Amirkhanlou, and Y. Fattahi, 'Microstructure and mechanical properties of carbon nanotubes/AZ31 magnesium composite gas tungsten arc welding filler rods fabricated by powder metallurgy', *Diam. Relat. Mater.*, 2016, doi: 10.1016/j.diamond.2016.08.017.

[2] S. H. Saheb and A. Chandrashekhar, 'Experimental study on influence of filler rods in gas Tungsten Arc welding', in *AIP Conference Proceedings*, 2019. doi: 10.1063/1.5131594.

[3] M. Fattahi, M. Rostami, F. Amirkhanlu, N. Arabian, E. Ahmadi, and H. Moayedi, 'Fabrication of aluminum TIG welding filler rods reinforced by ZrO2/reduced graphene oxide hybrid nanoparticles via accumulative roll bonding', *Diam. Relat. Mater.*, 2019, doi: 10.1016/j.diamond.2019.107518.

[4] S. O. Sada, 'Optimization of weld strength properties of tungsten inert gas mild steel welds using the response surface methodology', *Niger. J. Technol.*, 2018, doi: 10.4314/njt.v37i2.15.

[5] S. Senthur Vaishnavan and K. Jayakumar, 'Performance analysis of TIG welded dissimilar aluminium alloy with scandium added ER5356 filler rods', *J. Chinese Inst. Eng. Trans. Chinese Inst. Eng. A*, 2021, doi: 10.1080/02533839.2021.1940298.

[6] R. Bendikiene, S. Baskutis, J. Baskutiene, and L. Kavaliauskiene, 'Monitoring of welding process parameters in gas tungsten arc welding of carbon steel weldments', *Mechanika*, 2019, doi: 10.5755/j01.mech.25.1.22158.

[7] M. Khan, M. W. Dewan, and M. Z. Sarkar, 'Effects of welding technique, filler metal and post-weld heat treatment on stainless steel and mild steel dissimilar welding joint', *J. Manuf. Process.*, 2021, doi: 10.1016/j.jmapro.2021.02.058.

[8] M. Hindsén and M. Bruze, 'Welding', in *Kanerva's Occupational Dermatology*, 2019. doi: 10.1007/978-3-319-68617-2_197.

[9] M. Sarkari Khorrami, M. A. Mostafaei, H. Pouraliakbar, and A. H. Kokabi, 'Study on microstructure and mechanical characteristics of low-carbon steel and ferritic stainless steel joints', *Mater. Sci. Eng. A*, 2014, doi: 10.1016/j.msea.2014.04.065.

[10] M. V. Patil, 'Multi response simulation and optimization of gas tungsten arc welding', *Appl. Math. Model.*, 2017, doi: 10.1016/j.apm.2016.10.033.

CHAPTER 11

BASIC INTRODUCTION OF FRICTION WELDING

Mr. Vijaykumar Lingaiah, Assistant Professor
Department of Mechanical Engineering, Presidency University, Bangalore, India
Email Id: - vijaykumarsl@presidencyuniversity.in

ABSTRACT:

Friction welding FWR is a solid-state welding technique that uses lateral force known as upset to plastically displace and fuse the materials. It creates heat through mechanical friction between workpiece that are moving relative to one another. In this Chapter discussed about the friction welding that is used to join the two or more metallic pieces together. Friction welding is not a fusion welding procedure because no melting takes place. instead, it is a solid-state welding method more akin to forge welding.This phenomena is used in friction welding for joining purposes. Friction welding creates heat through the induced mechanical action, which makes the materials being welded pliable and viscous.

KEYWORDS:

Friction, Heat, Inertia, Materials, Welding,Weld.

INTRODUCTION

A solid-state joining technique called friction welding uses the heat generated between surfaces as a result of a combination of mechanically produced rubbing motion and applied stress to cause coalescence in the materials. The joint that is produced has forged quality. Normal circumstances prevent the faying surfaces from melting. With this method, filler metal, flux, and shielding gas are not necessary [1], [2].

Different Materials

Friction welding can be used to unite even metal alloys that aren't often thought to mix well, like nickel alloys to steel, copper to aluminum, titanium to copper, and aluminum to steel. All forgeable metallic engineering materials, such as tantalum, managing steel, tool steel, and automobile valve alloys, can typically be friction welded. Numerous castings, powder metals, and metal matrix composites can also be welded.

Cost, Time, and Material Savings

Due to the fact that incompatible materials can be linked, bimetallic parts can be created by engineers that only employ pricey materials when necessary. Less expensive forgings can be welded on bar stock, tubes, plates, and other similar materials to substitute costlier forgings and castings. As a result of the procedure being substantially quicker than more traditional welding techniques, significant time savings are realized.

Manufacturing Technology

A business that specializes in friction welding, was established in 1976. At that time, MTI purchased from Caterpillar Tractor Company all applicable patents, technical details, and product development data for Inertia Welders and AMF's Flywheel Friction Welders. In 1985, a new addition was made when MTI purchased the rights to New Britain's Direct Drive Friction Welder line. Inertia, Direct Drive, and Hybrid Direct Drive Friction Welders are all available from MTI today. MTI, which has equipment in operation all over the world, is a global leader in the design and construction of inertia and direct drive friction welders by assisting key industries in resolving many of their most challenging manufacturing issues. Applications for friction welding often include spindle blanks, bimetallic materials, and waste canisters, oil field pieces, cutting tools, agricultural machinery, automobile parts and spindle assemblies. In addition to adding complementary technologies to our product line and maintaining contract welding services for sectors with variable or low volume needs, we continue to grow in knowledge, equipment size, and volume.

The joints produced by friction welding are of forged quality, with a 100% butt joint weld through the contact area. The tiny heat-affected weld zone and accompanying flash are visible in this solid segment. Friction welding is a solid-state welding technique that joins two pieces of metal by applying frictional heat and pressure. High axial force is applied while one part is rotated rapidly against the other in this operation. The heat produced by the friction softens the materials, and the pressure that results in forging results from the pressure. The rotation is halted once the necessary heat has been produced, and the two pieces are kept under pressure until they have cooled and fused together into a single piece. High-speed friction welding can create sturdy welds across incompatible metals and materials that are challenging to weld using other techniques. It is frequently used to attach components including engine parts, drive shafts, and axles in the manufacturing, automotive, and aerospace industries. In comparison to other welding techniques, it has various benefits such as low heat input, less distortion, and no requirement for filler material or shielding gas [3], [4]. The research work already done in this particular field has to be discussed here, in this specific section.

DISCUSSION

A group of solid-state welding techniques known as friction welding FRW use mechanical friction between moving and stationary components to generate heat. At the same time, a lateral force known as upset is provided to the parts, which causes the material to be plastically displaced and fused.Through mechanical friction and pressure, two components are bonded together during the solid-state welding process known as friction welding. While exerting axial pressure on both components, one of the components is rotated during the process. As a result, heat is produced at the point where the two parts meet, softening and joining the material as it cools [5]–[7].

Inertia Friction Welding

Inertia friction welding is a form of friction welding in which the welding machine's rotational kinetic energy, which is stored, provides the majority of the energy needed to make the weld. One of the workpiece is attached to a flywheel in inertia welding, while the other is prevented from rotating. The required energy is stored while the flywheel is accelerated to a predetermined spinning speed. Workpiece are welded together by friction when the driving motor is deactivated. The pressure from this causes the faying surfaces to rub against one another. As the flywheel speed slows, the kinetic energy contained in the revolving flywheel is released as heat through friction at the weld interface. Before rotation ends, a greater friction welding force forge force may be applied. After rotation stops, the forge force is kept for a predetermined period of time. The diagram shows the link between the Inertia Friction Welding parameter features.

Advantages

In comparison to Direct Drive Friction Welding, Inertia Friction Welding provides a number of benefits:

1. Heat-affected zones that are smaller.
2. Less time spent welding.
3. Weld strength can be improved by helical flow lines and hot working at the end of the welding cycle.
4. Simplicity of monitoring, as there are only two parameters that affect welding: energy RPM and pressure.
5. Before the signal to weld is provided, energy can be measured, limiting the number of variables during welding to one.
6. For the majority of materials and geometries, pre-calculable parameters.
7. As a result, the procedure can be numerically scaled, allowing for the production of massive parts using small samples.
8. No brakes or clutches.
9. The rate of spindle speed change is used to indirectly estimate weld torque.
10. Complies with Military Standard 1252 and the welding requirements of many major American corporations.
11. The largest inertia friction welder has a forging force of 2250 tones.

Drive 7 and Hybrid FrictionWelding

The energy needed to create the weld is supplied by the welding equipment through a direct motor connection for a predetermined amount of the welding cycle in direct drive friction welding. One of the workpiece is attached to a motor-driven unit while the other is restricted from rotating while using direct drive friction welding. A predetermined constant speed is used to rotate the workpiece driven by the motor. After forcing the workpiece that need to be fused together, a friction welding force is used. As the faying surfaces weld interfaces rub against one another, heat is produced. This keeps going for a certain period of time or until a predetermined quantity of axial shortening upset occurs.

By applying a braking force or by the weld itself inertia welding, the rotary driving force is stopped, and the revolving workpiece is stopped. After rotation stops forge force, the friction welding force is kept constant or increased for a predetermined period of time. The diagram illustrates the link between the Direct Drive Friction Welding parameter features. The hybrid direct drive friction welders from MTI don't need brakes or clutches because they use AC or DC variable speed drives. Smooth up and down force control is ensured by proportional hydraulic controls. Welds that range from classic Direct Drive Friction welds to close to Inertia Friction welds can be produced by adjusting deceleration times and forging force ramp up timings.

Advantages

Compared to inertia friction welding, direct drive friction welding provides a number of advantages. Reduced welding pressure for solid items. On the same tonnage equipment, larger components can be welded.

1. If brake is engaged at the end of the welding cycle, weld torque will be reduced. Therefore, there are less strict standards for tooling.
2. RPM reductions for solid parts.
3. With parts that have a wider tolerance before welding i.e.,.050 in. [1.27 mm], weld directly to a completed length of.015 in. .38 mm or better.
4. After welding, angular orientation of 1° or greater is feasible between the two components.
5. No change in the flywheel between settings.
6. Never compromise weld quality to achieve dimensional accuracy or angular orientation.

Flash 9 Uninstall:

The flash curl generated during welding is coherent, will not flake off, and can often be left intact if design and engineering considerations allow. Alternately, parts can frequently be designed to accommodate the flash curl in a recess flash trap. In many cases, if the weld flash must be removed, this can be accomplished on the welder as an integrated part of the machine cycle. Part geometry and accessibility of the flash are the two major factors which determine whether on-machine flash removal can be incorporated, and which system can be employed. Available systems include Shearing–outside and Shearing–inside. Plunge Cut–one axis. Plunge Cut–two axis. The customer must determine if the increase in machine cycle time and additional complexity of the machine are warranted.

Safety Options:

The custom-designed guarding on the newest machines includes a front sliding door for manual loading and unloading of parts and movable, stationary guards for the back and sides. The sliding door and all removable guarding have physical locks installed. Programme interlocks safeguard people and equipment by demanding that specific criteria be satisfied before enabling machine movement. Older machines might have the same safety features retrofitted or rebuilt onto them. There are sound enclosures available to reduce the motors' noise levels. On smaller machines, they can be mounted directly on the hydraulic unit, whereas on very large machines, a whole chamber is constructed around the hydraulic unit.

MTI 10 Welding Services

Friction welding is a type of welding that combines two or more components using the friction welding technique. In order to perform different types of friction welding, such as rotary friction welding, linear friction welding, or friction stir welding, friction welding service providers often use specialized equipment (Figure. 1). The aerospace, automotive, construction, manufacturing, and other industries are just a few that friction welding service providers may serve. They might also provide a range of further services, including help with engineering and design, material sourcing and selection, quality testing, and certification. Providers of friction welding services may be able to accommodate a range of component sizes and shapes and work with a variety of materials, including metals, plastics, and composites. Overall, friction welding services can offer a high-quality and affordable option for attaching parts in a variety of manufacturing applications, and they can be especially helpful in situations where other welding techniques would not be appropriate or efficient.

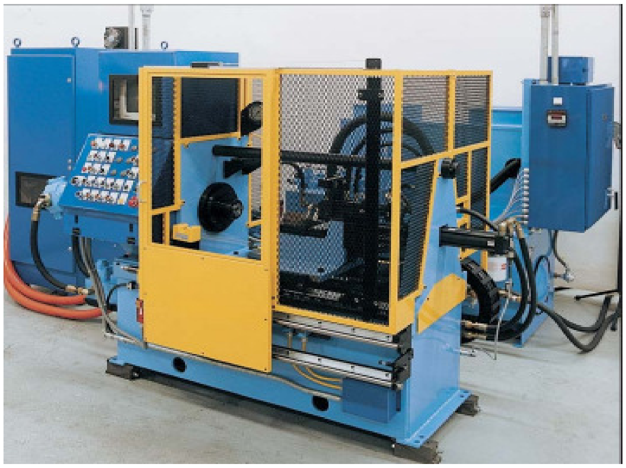


Figure 1: Represting the Model 120B Inertia Friction [Welder with safety guarding installed].

Research & Development and Contract Job Shop for MTI 10 Welding. MTI offers contract welding services to businesses with sporadic or low volume requirements. Our in-house job shop offers both research & development, and production services. For customer needs, a variety of inertia or direct drive friction welders are offered. The expertise, welding capabilities, geographic location, and closeness to heat treat sources of MTI work together to give you the best value for your money.Production runs for material sizes ranging from.250 in. diameter to 6 in. diameter solid, or 43 in.2 tubular steel, are possible on machines with weld forces ranging from 6-ton to 450-ton. Current production lot quantities range from <5 to >300,000 pieces per year. Pre- and post-weld processing is available. The majority of part configurations have access to tooling. Design engineering department with competence in designing parts and tools Experienced metallurgists execute weld development, feasibility analyses, and metallurgical evaluations of weld quality. For essential applications, computer storage of parameter data is provided.

Application of Friction Welding:

The following situations are suitable for friction welding:

1. The manufacturing of tubes and shafts, as well as the mining, automotive, and aviation industries, all require friction welding.
2. Additionally, it is helpful in parts like gears, axle tubes, drivelines, and valves that need friction welding.
3. Additionally, it is utilized to join truck roller bushes and hydraulic piston rods. Drill bits, connecting rods, gear levers, and other similar items can all be soldered using this technique. And lastly, it is frequently used to solder copper and aluminum equipment in the electrical industry.

Advantage:

Friction welding joins a wide variety of materials and is used in many industries. Because it helps to strengthen steel and reduce high heat grain formation, friction welding has many advantages. Additionally, while welding, the metal is not melted. Aerospace, which uses lightweight metals like aluminum, also uses friction welding. One advantage is that the motion between the items being mixed polishes the weld surface, resulting in maximum strength in the joint without adding weight to the workpiece. Friction welding also uses thermoplastic materials. It doesn't subject the parts to much heat or friction. This has demonstrated that employing a machined metal interface, this welding technique may be utilized to join metals to polymers [8]–[10]. Compared to conventional welding techniques, friction welding has the following benefits:

1. Welds of excellent quality and consistency are created by friction welding and have few flaws. This is so that impurities won't be introduced into the process, which is well controlled and doesn't call for filler materials.
2. Friction welding is a quick and effective method that may attach components in a couple of seconds. Throughput can rise and production time can be shortened.
3. Versatile: Using friction welding, a variety of materials can be joined, including dissimilar metals that can be challenging to weld using conventional techniques.
4. Ecologically friendly: Friction welding produces less waste and is more ecologically friendly because it doesn't require any consumables or filler materials.
5. Low heat input: Friction welding produces less heat than conventional welding techniques, which might lessen the chance of the material being fused being warped, distorted, or otherwise damaged.
6. Low maintenance: Because there are no electrodes or gas nozzles to change, friction welding machines require less maintenance than conventional welding equipment. This may lower maintenance expenses and downtime.

Disadvantage:

The restriction on workpiece dimensions is one of friction welding's biggest limitations. Due to the restricted availability of round bars with matching cross sections, work components must be fastened [11], [12].

1. Equipment for friction welding is pricey.
2. Materials that cannot be forged cannot be welded.
3. Friction welding is normally only used to fuse relatively tiny components because larger ones can take more energy to heat to the necessary temperature.
4. Limited Material Compatibility: Friction welding works best with materials that have comparable melting points since materials with significantly different melting points may overheat or fail to soften sufficiently to produce a strong bond.
5. Equipment Cost: Friction welding requires a lot of expensive equipment that may not be suitable for many manufacturing applications.
6. Surface Preparation: For friction welding to be successful, the surfaces of the components being connected must be clean and free of impurities. This can necessitate more planning and money.
7. Operator Skill: To produce the desired weld quality, friction welding calls for operators with a thorough understanding of the procedure and the ability to make modifications as needed.

CONCLUSION

A solid-state welding technique called friction welding uses physical forces to attach components by creating heat through mechanical friction between work pieces that are moving relative to one another. In this Chapter discussed about the friction welding technology that is used to weld the metal. Friction welding has a number of benefits, one of which is the creation of a solid, high-quality bond between the materials without the use of fillers or adhesives. Additionally, it can be used to join materials that aren't identical, which is difficult to do with other welding techniques.

REFERENCES:

[1] W. Li, A. Vairis, M. Preuss, and T. Ma, 'Linear and rotary friction welding review', *International Materials Reviews*. 2016. doi: 10.1080/09506608.2015.1109214.

[2] X. He, F. Gu, and A. Ball, 'A review of numerical analysis of friction stir welding', *Progress in Materials Science*. 2014. doi: 10.1016/j.pmatsci.2014.03.003.

[3] M. Chludzinski *et al.*, 'Full-scale friction welding system for pipeline steels', *J. Mater. Res. Technol.*, 2019, doi: 10.1016/j.jmrt.2018.12.007.

[4] D. G. Mohan and C. S. Wu, 'A Review on Friction Stir Welding of Steels', *Chinese Journal of Mechanical Engineering (English Edition)*. 2021. doi: 10.1186/s10033-021-00655-3.

[5] V. Ajay, N. K. Babu, M. Ashfaq, T. M. Kumar, and K. V. Krishna, 'A Review on Rotary and Linear Friction Welding of Inconel Alloys', *Transactions of the Indian Institute of Metals*. 2021. doi: 10.1007/s12666-021-02345-z.

[6] A. Vairis, G. Papazafeiropoulos, and A. M. Tsainis, 'A comparison between friction stir welding, linear friction welding and rotary friction welding', *Adv. Manuf.*, 2016, doi: 10.1007/s40436-016-0163-4.

[7] D. Kumar Rajak, D. D. Pagar, P. L. Menezes, and A. Eyvazian, 'Friction-based welding processes: friction welding and friction stir welding', *Journal of Adhesion Science and Technology*. 2020. doi: 10.1080/01694243.2020.1780716.

[8] A. U. Rehman, N. K. Babu, M. K. Talari, Y. S. Usmani, and H. Al-Khalefah, 'Microstructure and mechanical properties of dissimilar friction welding ti-6al-4v alloy to nitinol', *Metals (Basel).*, 2021, doi: 10.3390/met11010109.

[9] A. U. Rehman, Y. Usmani, A. M. Al-Samhan, and S. Anwar, 'Rotary friction welding of inconel 718 to inconel 600', *Metals (Basel).*, 2021, doi: 10.3390/met11020244.

[10] P. Jedrasiak, H. R. Shercliff, A. R. McAndrew, and P. A. Colegrove, 'Thermal modelling of linear friction welding', *Mater. Des.*, 2018, doi: 10.1016/j.matdes.2018.06.043.

[11] M. Kimura, K. Ohara, M. Kusaka, K. Kaizu, and K. Hayashida, 'Effects of tensile strength on friction welding condition and weld faying surface properties of friction welded joints between pure copper and austenitic stainless steel', *J. Adv. Join. Process.*, 2020, doi: 10.1016/j.jajp.2020.100028.

[12] M. B. Uday, M. N. A. Fauzi, H. Zuhailawati, and A. B. Ismail, 'Advances in friction welding process: A review', *Science and Technology of Welding and Joining*. 2010. doi: 10.1179/136217110X12785889550064.

CHAPTER 12

WELDING MACHINE AND WELDING POWER SOURCES

Mr. Manjunath Narayan Rao, Assistant Professor
Department of Mechanical Engineering, Presidency University, Bangalore, India
Email Id: - manjunath.n@presidencyuniversity.in

ABSTRACT:

Welding machines, commonly referred to as welders, are tools used to combine two or more pieces of metal by melting the surfaces and allowing the metal to fuse together. In this Chapter discussed about the welding machine and power sources that provides the electrical energy required to create an electric arc or other form of welding process is known as a welding power source. The exact welding procedure being utilized, the material being welded, and the intended welding result all influence the kind of power source that is employed.

KEYWORDS:

Equipment, Machine, Maintenance, Safety, Welding.

INTRODUCTION

An effective tool for joining two pieces of metal together is a welding machine. This device presses the metal parts together while melting and joining them together. It is a necessary tool for every construction-related metalwork task. High temperatures, which are much higher than those needed for cooking or burning, are applied by welding machines to produce strong welds [1], [2].

Automatic and Mechanical Welding:

This section's has a reference to automatic welding. The demand for automatic welding results from a desire for increased output and the removal of human engagement in what appears to be repetitive and regular activity. Additionally, it encourages the use of higher currents and heat that are challenging, if not impossible, to use due to human tolerance levels and safety restrictions. In the fabrication and manufacturing sectors, the terms automation and automation refer to the performance of some tasks or stages by a mechanical, electrical, or hybrid technology. The degree of automation varies since some functions could encompass all operations or just a portion of them.

Such welding procedures are frequently described using the phrases automated and mechanized. Although there are valid arguments against the use of the term AI to suggest that a device is capable of self-learning, which it is not, AI is a future possibility in the field. The term mechanized is used to indicate that the movements of the welding process are simply mechanized and not many of the electronics are controlled by AI. The existing system is essentially a system with computations and kinematic algorithms already coded in. In contrast, the phrase automatic is employed in a variety of ways. it suggests that some form of artificial intelligence AI is used to control the mechanical arms that could assist in moving the welding head torch along the weld line or locating itself to challenging welding positions as the welding advances. In more advanced models, it might manage the current and weld travel speed within a predetermined range of parameter constraints. It may also consist of considerably more intricate controls that are programmed into the system rather than being controlled by operators. To perform welding in the most efficient manner, it may comprise a variety of parameter controls, the manipulation of the welding head, and the work.

The capacity to mount a welding head on a machine with an electronically articulated or mechanical arm is only one aspect of welding automation. Other aspects include planning, organizing, and monitoring the manufacturing process. It entails selecting which of those humanly operated operations to employ and to what extent they need to be automated after carefully evaluating the welding/producing process, processes, production steps, and controls. Because welder judgment is required for the majority of welding tasks, it's critical to base automation decisions on determining which tasks can be automated without relying on welder judgment. The machine in question might use a sophisticated electronic control system, straightforward mechanical movements to mimic manual welding, or a combination of the two.

Mechanized welding, also known as machine welding, and is performed by welding equipment while being closely supervised by a weld operator. The welding process can be carried out with the item stationary and the weld head moving around the weld line to complete the welding, or it can be done with the object stationary and the weld head moving along the weld line. The machine may or may not be able to load and unload the work to the welding station in such a setup. A machine welding system may include one or more of the following features:

1. A machine carriage is the track used to cross a weld line. this movement can be either rail-mounted or tractor-style. The welding head might move both horizontally and vertically on such a carriage. Additionally, girth welds in pipes and other round objects like pressure vessels, tanks, etc. are welded using orbital movement. Precise control of these movements is crucial since position and travel speed are both crucial welding variables. This is closely observed by the welding operator in machine welding.

2. A welding head manipulator essentially functions as a boom-mounted extension of the welding head of the welding equipment. The mast's boom, which is mounted on a swivel, can be moved up or down by the manipulator. For successful welding and high-quality output, the manipulator must move smoothly. The fundamental components of machine welding are as follows:
   - **a)** Travel rate.
   - **b)** Constant filling rate for metal fillers.
   - **c)** Starting and maintaining the welding arc.

When using a machine to weld, the operator must be present since they must see the weld as it is being done. The operator constantly communicates with the welding apparatus to ensure optimum weld head positioning and metal deposition. The research work already done in this particular field has to be discussed here, in this specific section.

DISCUSSION

An instrument used to fuse materials together is a welding machine. Metal components are melted by heat produced by welding machines so that they can be connected. As a result, as it cools, it solidifies and produces a resistant joint. Although the welding equipment normally works best with metals, many materials can be welded. The most common place to find these welding machines today is in industrial settings. Metal components, tools, or materials are produced in these settings [3], [4]. A welding machine is a piece of machinery used to weld together two or more thermoplastic or metal pieces by melting and fusing them together with heat. Electric current is used by welding machines to produce a lot of heat where the metal pieces are to be joined. The metal melts and fuses together as a result of this heat. There are different types of welding machines, including MIG metal inert gas, TIG tungsten inert gas, stick, and flux-cored welding machines. Each type of welding machine has certain benefits and drawbacks of its own and is suitable for various welding applications.

Power sources:

Welding power sources are devices that provide the electrical power needed to generate the heat necessary for welding. There are numerous sorts of welding power sources, each with its own distinct features and advantages. Among the popular kinds of welding power sources are:

1. **Constant Current Cc Power Sources:** These welding power sources produce an electrical current that is constantly the same. They are perfect for welding applications that need precise control over the amount of heat generated, such as in TIG welding.
2. **Constant Voltage Cv Power Sources:** These types of welding power sources provide a constant voltage output. They are perfect for high amperage welding applications, like MIG welding. These welding power sources provide alternating current and are known as AC power sources. They are used in welding applications where the welding material is aluminum or magnesium.
3. **DC Power Sources:** These power sources for welding produce direct current. They are utilized in welding applications when the welding material is steel, stainless steel, or copper. These kinds of welding power sources, known as inverter power sources, transform incoming electricity into a higher frequency output using electronic circuitry. Compared to conventional transformer-based welding power sources, they are more effective and portable. Power sources for welding are a crucial part of any welding operation. The particular welding application and the materials being welded will determine the kind of power supply to employ.

Welding Machine Types:

The primary categories of welding equipment used in the welding industry are as follows:

1. MIG welding apparatus.
2. TIG welding apparatus.
3. Spot welding apparatus.
4. Machine for thyristor MIG welding.
5. Machine for shielded metal arc welding.
6. Machine for flux core arc welding.
7. Equipment for energy beam welding.
8. Nuclear hydrogen welding apparatus.
9. Machine for submerged arc welding.
10. Oxygen-acetylene welding apparatus.
11. Equipment for welding transformers.
12. Equipment for welding rectifiers.
13. Equipment for welding converter.
14. Equipment for welding plastic.

15. Multifunctional welding apparatus.

1. **Mig Welding Apparatus:**
   Machines for metal inert gas welding are typically utilized for large shown in Figure. 1, thick materials. In this, the consumable wire that the welder uses must serve as both the electrode and the filler material. This procedure takes less time and produces goods at a lesser cost than TIG welding.

Figure1: Represting the MIG Welding machine [Ubuy India].

The machine is three-phase, single-phase, and all-in-one capable. These tools make it simple to weld aluminum and stainless steel metals. These welding machines are employed in manufacturing, small companies, and metal production processes.

2. Tig Welding Devices:

Types of Welding Equipment: TIG Welding Machine Because they create precise and clean welds, tungsten inert gas welding equipment are excellent for thin metals and smaller tasks. A tungsten electrode that generates a weld and is non-consumable must be used by the welder. When used on metals like mild steel, stainless steel, or aluminum, these devices generate a strong weld. Welding pipes and pipelines is one of the most crucial uses for TIG welding equipment. However, it is employed in numerous sectors, including sheet metal work, aviation, and aerospace.

3. Sport Welding Apparatus:

Spot welding is a resistance welding technique that involves applying pressure and heat to the weld region with an electric current to join two or more metal sheets together. The advantages of these machines are efficient power use, rapid production, straightforward automation, etc.

4. Machine for Thyristor Mig Welding:

The best accuracy and hard-ground parts are used to build these kinds of welding equipment. The majority of welders favour using this welding machine to mount objects on the proper surface or fix them. These tools work well for welding flux- and solid-core materials. The machine's high level of gripping power and high level of dimensional accuracy, durability, and hardness make it highly sought-after. The minimal amount of spark produced by thyristor MIG welding equipment makes them simple to control.

5. Machine for Shielded Metal Arc Welding:

Shielded metal arc welding equipment typically operate on the basis of the heat generated by an electric arc. Stick welding, which uses an electric current passing through the void between the metal and welding stick filler rod, is another name for this process. Both AC and DC currents can be used to power SMAW machines.

6. Machine for Flux Core Arc Welding:

Typically, thick metals are welded using flux core welding machines. In this equipment, the base metal is fused at the joint region by the heat produced by an electric arc during the welding process. For both indoor and outdoor tasks, FCAW machines are preferable.

There is no requirement to stop and restart because the flux-filled electrode is fed constantly.

7. Energy Beam Welding Devices:

The device applies a fast-moving stream of magnetically concentrated, tightly focused electrons to the materials that need to be connected. Thick metals can be welded to thin metals using an energy beam welding machine. The welder also has the ability to connect various metals. These welding devices have the ability to weld metals at precise metal spots. In the welded sections, there is either little or no thermal distortion. This machine cannot be used at home since the electron beam will be absorbed by the air if the welding is not done in a vacuum.

8. Atomic Hydrogen Welding:

The AHW device generates an arc between two tungsten electrodes and fuels it with hydrogen gas from a hydrogen gas cylinder. The arc divides the hydrogen into atomic form, hence the name atomic hydrogen welding. To use this type of welding machine, you need to be an experienced operator. Due to greater costs, this method is not as frequently used as GMAW and is gradually being replaced. AHW machines can be utilized for thick and thin materials, and they are appropriate for circumstances that call for quick welding.

9. Ranked Submerged Arc Welding Machine:

Submersible Arc Welding Device In these devices, the workpiece to be welded is often brought into contact with an electrode that is continually fed. As a result, there is a flux of powder rather than a gas shield. Machines for submerged arc welding create welds of superior quality than other kinds. The flux can be recycled in this manner, reducing waste. The operator doesn't need a lot of experience to operate this equipment because it is automatic or semi-automatic. This device's primary flaw is that it cannot be moved about. Plumbing and pressure vessel applications frequently use these machines.

10. Machine for Oxy-Acetylene Welding:

Fuel gas and oxygen are both used as heating elements in oxygen acetylene welding machines. The flame is regarded as the primary element created at the torch's tip in this sort of welding machine. The base metal and prospective filler are melted by this heat, creating a continuous weld. Thick materials do not function well with this machine. it performs best with thin materials. With this equipment, a user may weld beads and effectively manage temperature. Due to their portability and affordable price, these welding machines are mostly used throughout the world.

12. Welding Machine for Transformers:

A step-down transformer, it transforms low voltage, high amperage AC welding current from high voltage, low amperage AC input current. Single-phase power can be used to power the transformer welding equipment. The majority of AC power is produced, and every time the polarity shifts, the voltage crosses zero, creating an unstable arc condition. Superior AC electrodes and welders with superior compressive properties have, however, made this issue obsolete.

12. For Transformer-Rectifiers:

This machine's rectifier changes the input AC into DC at the output, allowing for both negative and positive polarity. A single-phase rectifier welder is a particular kind of transformer welder that is used to create a DC output by connecting a rectifier to it.These MIG welding equipment are produced using rectifier technology. For optimal welding performance, they have controls to change the current, voltage, and polarity.

13.Rectifier Welding Machine:

The rectifier welding apparatus may provide high AC frequency and DC welding current when powered by an AC power source. Three-phase AC is used in this case to supply the rectifier units, which produce DC into a single output circuit. The DC current that comes out of a rectifier during welding can either be continuous or varied. It converts AC to DC for output using a transistor, diode, or thyristor. Rectifier welders come in a variety of varieties, but they all function and operate in much the same way [5]–[7].

14. Machine for Welding Plastic:

Plastic is joined together and cracked surfaces are repaired using plastic welding machines. Materials are first connected, then pressurized, while welding plastic materials. Better strength and shorter cycle times are provided by these welding equipment.

15. Welding Machine With Uses:

Other than for welding, several models are also utilized for other tasks. It implies that certain machines might provide a variety of welding procedures. Look for a welding equipment that can perform more than one procedure if you don't want your welding options to be restricted. Some MIG welders are capable of doing FCAW operations. TIG machines can also be used to weld using sticks. However, the operator must either make a setting modification or purchase more accessories.

Advantage:

Welding equipment have a number of benefits, such as:

1. Welding machines can swiftly and effectively unite metal parts, cutting down on the time and labor needed for welding.
2. Welding machines are versatile because they can join a variety of metals, including steel, aluminum, and copper, as well as other materials like plastics and composites
3. Welds made by welding machines are resilient and strong, able to bear tremendous stress and strain.
4. Precise control over the welding process is made possible by welding equipment, which can produce welds of a high caliber with few errors.

5. In contexts with high production volumes, welding machines may be more economical than alternative welding techniques.

Disadvantages:

The use of welding machines has a number of drawbacks. Here are a few of the most typical:

1. Welding equipment can be fairly pricey, particularly high-end units fit for heavy-duty welding tasks.
2. Welding includes the use of high temperatures and possibly dangerous materials, which, if not used appropriately, can present a safety risk.
3. Welding equipment are normally stationary and powered by an external source, which can restrict their flexibility in some circumstances.
4. To keep welding machines in good working order, they need to undergo routine maintenance just like any other piece of equipment.
5. If welding equipment is not correctly maintained, it can produce emissions that are bad for the environment and people's health, including noise, fumes, and gases [8]–[10].

CONCLUSION

A crucial mechanical procedure for attaching metal pieces is welding. Knowing the different types of welding equipment will enable you to select the one that best suits the tasks you intend to carry out. In this Chapter discussed about the welding machine, welding machine is an instrument that used to fuse materials together is a welding machine. Metal components are melted by heat produced by welding machines so that they can be connected. And in this Chapter discussed the various types of welding machine and power sources and advantage or disadvantage of the welding machine.

REFERENCES:

[1] J. Reimann *et al.*, 'Directed energy deposition-arc (Ded-arc) and numerical welding simulation as a hybrid data source for future machine learning applications', *Appl. Sci.*, 2021, doi: 10.3390/app11157075.

[2] N. Jeyaprakash, A. Haile, and M. Arunprasath, 'The Parameters and Equipments Used in TIG Welding: A Review', *Int. J. Eng. Sci.*, 2015.

[3] B. Babes, F. Albalawi, N. Hamouda, S. Kahla, and S. S. M. Ghoneim, 'Fractional-Fuzzy PID Control Approach of Photovoltaic-Wire Feeder System (PV-WFS): Simulation and HIL-Based Experimental Investigation', *IEEE Access*, 2021, doi: 10.1109/ACCESS.2021.3129608.

[4] M. Chiumenti, M. Cervera, N. Dialami, B. Wu, L. Jinwei, and C. Agelet de Saracibar, 'Numerical modeling of the electron beam welding and its experimental validation', *Finite Elem. Anal. Des.*, 2016, doi: 10.1016/j.finel.2016.07.003.

[5] K. Zhou and P. Yao, 'Review of application of the electrical structure in resistance spot welding', *IEEE Access*, 2017, doi: 10.1109/ACCESS.2017.2771310.

[6] J. Huang, J. He, X. Yu, C. Li, and D. Fan, 'The study of mechanical strength for fusion-

brazed butt joint between aluminum alloy and galvanized steel by arc-assisted laser welding', *J. Manuf. Process.*, 2017, doi: 10.1016/j.jmapro.2016.11.014.

[7] A. Simar, J. Lecomte-Beckers, T. Pardoen, and B. De Meester, 'Effect of boundary conditions and heat source distribution on temperature distribution in friction stir welding', *Sci. Technol. Weld. Join.*, 2006, doi: 10.1179/174329306X84409.

[8] A. V. Frolov, 'Pipe welding machine modernization', in *Journal of Physics: Conference Series*, 2021. doi: 10.1088/1742-6596/2096/1/012016.

[9] J. J. Laureto, S. V. Dessiatoun, M. M. Ohadi, and J. M. Pearce, 'Open source laser polymer welding system: Design and characterization of linear low-density polyethylene multilayer welds', *Machines*, 2016, doi: 10.3390/machines4030014.

[10] H. Hu and P. Eberhard, 'Thermomechanically coupled conduction mode laser welding simulations using smoothed particle hydrodynamics', *Comput. Part. Mech.*, 2017, doi: 10.1007/s40571-016-0140-5.

CHAPTER 13

APPLICATION OF THE WELDING METALLURGY

Dr. Chinnakurli S Ramesh, Professor
Department of Mechanical Engineering, Presidency University, Bangalore, India
Email Id: - rameshcs@presidencyuniversity.in

ABSTRACT:

The evolution of the alloys used to make duplex stainless steels has been significantly influenced by welding metallurgy. The early grades typically formed a heat affected zone HAZ that was rich in ferrite due to its high carbon content. These high carbon levels resulted in some austenite reformation but also carbide precipitation and a reduction in Intergranular corrosion IGC resistance. The study of welding's effects on metals' physical, mechanical, and chemical properties is known as welding metallurgy. In this Chapter discussed about the welding metallurgy.

KEYWORDS:

Base Metal, Fusion Zone, Filler Metal, Heat , Welding Metallurgy.

INTRODUCTION

The study of how welding affects a metal's characteristics and behavior is known as welding metallurgy. It entails looking at the physical and chemical alterations that metals go through during welding and how these alterations impact the microstructure, mechanical characteristics, and functionality of welded junctions. The type of welding technique utilized, the make-up of the base metals and filler materials, the welding parameters such as temperature, heat input, cooling rate, and the post-welding heat treatment are all elements that affect the metallurgical properties of a welded connection. To make sure that welded components fulfil the necessary performance requirements and specifications, it's crucial to understand welding metallurgy. Additionally, welding metallurgy is utilized to develop new welding methods, enhance the dependability and quality of welded joints, and optimize welding procedures. The study of solidification and microstructure, phase transitions, residual stresses, and corrosion behavior of welded joints are some of the important fields of welding metallurgy [1]–[3].

Principle of Welding Metallurgy:

This Chapter's main goal is to review the fundamental ideas that underpin how weld microstructure evolves. Understanding the fundamental principles that control the evolution of microstructure during welding is crucial since the cracking susceptibility of welded structures depends on microstructure, environment, and applied stress. The main subject of this Chapter will be fusion welds, however there is also a part dedicated to solid-state welds. The fundamentals of welding metallurgy are not intended to be covered in detail in this article. The reader is directed to textbooks by Kou and Easter ling, Welding Metallurgy and Introduction to the Physical Metallurgy of Welding for a more in-depth discussion of this subject. The microstructure and characteristics of welds are controlled by a variety of metallurgical procedures. Since they are essential to generating satisfactory joints in all fusion welding methods, melting and solidification are significant processes. Segregation and diffusion processes that result in local compositional differences along with solidification have an impact on both weld ability and service performance. Numerous metallurgical processes, including as phase changes, precipitation reactions, recrystallization, grain development, etc., take place in the solid state.

The severity of these reactions may dramatically change the element's microstructure and characteristics including those of the heat-affected zone HAZ and weld metal in relation to the base metal. Several of these reactions, or intricate assemblages of reactions, can cause embrittlement, or welding cracking. This embrittlement may be brought on by liquation, the existence of liquid layers in a solid matrix, or by a decrease in ductility in the solid state. Complex stress patterns can form in and around welds as a result of thermal expansion during heating and contraction during cooling. The microstructure and characteristics of the weldment may be subsequently affected by these stresses, and cracking may be encouraged in areas where the resulting tensile strain is greater than the material's ductility. The combination of the weld heat cycle and the material composition determines the type of weld microstructure for a certain material. The heating and cooling rates involved in welding are typically extremely high 10-1000°C/s, making it difficult to forecast the microstructure using equilibrium thermodynamic concepts. The welding thermal cycle is crucial to the evolution of microstructure and, ultimately, the weld ability of the material because all metallurgical processes that affect the weld microstructure depend on temperature and heating/cooling rates [4]–[6]. The research work already done in this particular field has to be discussed here, in this specific section.

DISCUSSION

A subfield of metallurgical engineering called welding metallurgy investigates the science of welding and how it affects metals. It focuses on the physical and chemical alterations that metals go through during welding and how these alterations affect the microstructure, mechanical characteristics, and functionality of welded junctions. By heating metal to the point of melting and allowing it to solidify, two or more pieces of metal can be joined via the welding process. The metal goes through a variety of physical and chemical changes during welding that may have an impact on the microstructure, residual stresses, and corrosion behavior of the welded junction [7]–[9]. A wide number of subjects are covered by welding metallurgy, such as:

1. **Weld Ability:** A metal's ability to weld is influenced by its chemical make-up, microstructure, and physical characteristics. Understanding how these elements affect the weld ability of various metals and figuring out how to tailor the welding process for particular materials are the main goals of weld ability studies
2. **Phase Changes:** Various phase changes that the metal goes through during welding, such as solidification and the development of distinct crystal structures, can have an impact on the mechanical properties of the welded junction. For the welding process to be optimized and for the welded joint to have the necessary qualities, it is crucial to comprehend these transitions.
3. **Metals' Microstructure:** including grain size, phase distribution, and the existence of flaws like porosity and fissures, can all be impacted by welding. Predicting the mechanical behavior and performance of the welded junction requires an understanding of its microstructure.

4. **Residual Stresses:** Welding can cause residual stresses in the metal, which can impact the welded joint's mechanical characteristics and corrosion and fatigue resistance. To forecast how the welded joint will behave in various scenarios, it is crucial to understand the sources and distribution of residual stresses.
5. **Metals' Corrosion:** behavior can be impacted by welding, including the development of corrosion-resistant phases and the emergence of corrosion sites as a result of flaws. For evaluating the welded joint's long-term performance, it is crucial to comprehend the corrosion behavior of the junction.

Fusion Welding Regions:

The areas where two or more metal components are fused together using a welding procedure are known as fusion welding regions. Three separate zones commonly comprise these regions:

1. The two metal pieces are melted and fused together in this region, which is known as the fusion zone. A strong link between the two parts is made possible by the heat produced during the welding process, which causes the metal to liquefy and flow together.
2. The region around the fusion zone known as the heat-affected zone HAZ is where the metal has been heated but not melted. The metallurgical properties of the metal, such as changes in microstructure, hardness, and tensile strength, are often what define the HAZ.
3. The portion of the metal known as the base metal is unaffected by the welding process. It serves as the weld's base and is often the metal's strongest component.

The qualities of the metal being welded, the welding technique employed, and the welding parameters, such as heat input and welding speed, will all have an impact on the size and shape of the fusion welding areas. For the weld to be solid and dependable, it is crucial to comprehend the several locations and their characteristics.It is possible to see various microstructural regions by looking at a welded joint. Melting is connected with the fusion zone. The heat from the joining procedure has an impact on the HAZ even if it has not melted. The unaffected base metal is located beyond the HAZ. It is possible to further split the fusion zone and HAZ, as discussed in this section.

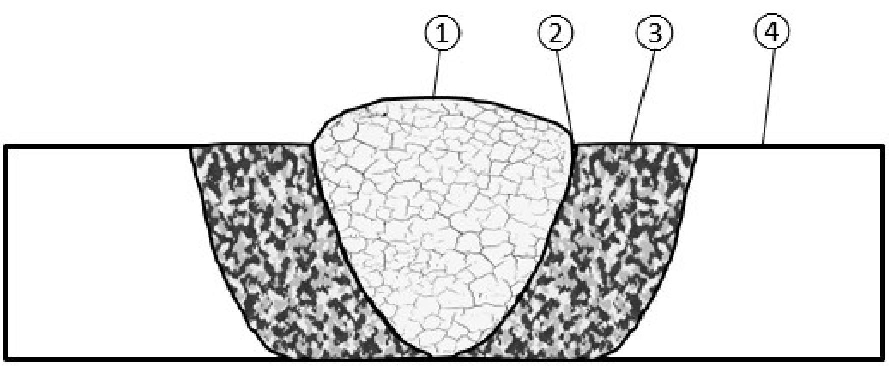


Figure 1: Represting the Fashion welding zone during welding[Research gate].

The term fusion zone refers to the area where melting and solidification take place to create the joint or weld. All metals have general solidification processes in common because they are all crystalline in nature, with many having cubic crystal lattices. The behavior of solidification in many materials is highly composition-dependent. For instance, some steels' ferritic bcc solidification behavior can be changed to austenitic FCC by adding modest amounts of carbon and nitrogen. Steels can suffer significant solidification cracking in the fusion zone from even little sulphar additions. Normally crack-prone aluminum alloys can be welded with a filler material containing more than 6% silicon to prevent cracking. The temperature conditions encountered during welding and post weld heat treatment PWHT are the only factors that affect the microstructure and characteristics of the HAZ. Precipitation hardening or work hardening are common processes used to enhance Figure. 1.

These strengthening effects in the HAZ can be entirely eliminated by welding. When steel goes through a phase transformation, the resulting HAZ can have a microstructure and set of properties that are vastly different from either the base metal or the fusion zone. Since the 1960s, there has been a significant advancement in the understanding of weld areas. Prior to that, it was believed that a fusion weld consisted of just two regionsthe fusion zone and an adjacent HAZas seen in Figure 2 from a 1959 lecture by E.F. Nippes. Other unique zones of a fusion weld were discovered by W.F. Savage and his students at RPI after extensive investigation in the 1960s and 1970s. Illustrates the terminology proposed by Savage et al. In 1976 to describe the zones of fusion weld microstructure. Two sections were thought to make up the fusion zone. The composite region was the area of the fusion zone that included a composite composition of base metal and filler metal. They designated a region known as the unmixed zone UMZ to surround this area along the fusion boundary. The base metal that makes up the UMZ has been melted and then solidified. it does not mix with the filler metal. When various filler metals are utilized, the UMZ in some alloy systems can display microstructures and characteristics that are quite different from those of the composite region.

The HAZ was separated into the true heat-affected zone T-HAZ and the partially melted zone PMZ. The PMZ is present in every fusion weld made in an alloy because the fusion boundary requires a change from 100% liquid to 100% solid. Other methods that caused local melting or liquation in a constrained area surrounding the fusion zone were also discovered. These include the melting of grain boundaries brought on by segregation and the constitutional liquation event, which is the outcome of local melting linked to a constituent particle. A T-HAZ is a zone of the HAZ where all metallurgical reactions take place in the solid state, meaning that no melting or liquefaction takes place there. Although extensive study has been done on a variety of alloy systems to confirm that these zones genuinely exist in different material systems, terminology for characterizing regions of a fusion weld hasn't changed much since 1976. This initial terminology has undergone further elaboration.

For instance, the T-HAZ in steels has been separated into a number of sub regions, including the intercritical HAZ ICHAZ, the fine-grained HAZ FGHAZ, and the coarse-grained HAZ CGHAZ. Only a transition region inside the fusion zone might be added to the terminology in. This would signify a composition transition from the composite zone to the UMZ in heterogeneous welds where the filler metal has a different composition from the base metal. This transition zone TZ can display a microstructure that is noticeably different from the surrounding areas in some alloy systems. For instance, a martensitic structure may emerge in the transition zone of welds between stainless steels and low-alloy steels that does not exist elsewhere in the weld. For a heterogeneous weld provides a revised schematic of the regions of a fusion weld. It resembles the example in Figure 2. But includes a composition TZ that might exist in some systems. The parts that follow will go through the numerous regions that were previously described in great detail and will explain the processes that led to their establishment.

Zone of Fusion:

The area of a fusion weld where full melting and solidification occur when welding is referred to as the fusion zone. The composition and solidification circumstances affect the microstructure in the fusion zone. Large variations in microstructure and characteristics frequently result from even minute compositional variances. In some systems, modifying the speeds of cooling and solidification can also significantly alter the microstructure. When samples are prepared metallographic ally, the fusion zone is typically extremely distinct from the HAZ and base metal in the vicinity. This is a result of compositional fluctuations brought on by the solidification process, both on a macroscopic and microscopic scale.

There are three zones that could theoretically arise in welds where the filler metal has a different composition from the base metal. The largest of them is the composite zone CZ, which is made up of base metal and filler metal that has been equally diluted. Two more zones could occur close to the fusion border. The unmixed zone UMZ is made up of melted and solidified base metal where there has barely been any mixing with the filler metal. A transition zone TZ with a composition gradient from the base metal to the CZ must exist between the UMZ and CZ. Autogenously, homogeneous, and heterogeneous fusion zones are the three categories that have been established. Whether or not a filler metal is employed, as well as the filler metal's composition in relation to the base material, determines the classifications. All three varieties of fusion zones are frequently found.

Autogenously Welds: Autogenously welds are ones in which no filler metal is used and the fusion zone is created by the base metal melting and then solidifying. These are frequent when the technique chosen can easily achieve penetration and section thicknesses are modest. **Autogenously Weld:** Autogenously welding can frequently be used in thin sections at high speeds with minimal joint preparation, such as the use of butt joints. GTAW, EBW, LBW, PAW, and resistance welding are some of the welding methods that are compatible with or can be modified for use with autogenously welding. With the exception of potential losses from evaporation or the pickup of gases from the shielding atmosphere, the fusion zone has basically the same composition as the base metal. Because some materials are difficult to weld, they cannot be connected automatically.

Homogenous Weld: In homogenous welding, a filler metal that closely resembles the composition of the base metal is used. When the properties of the filler and base metal must closely match, this sort of fusion zone is used. Examples of these qualities are corrosion resistance and heat treatment reaction. Two frequent instances include the use of E10016-D2 filler metal on AISI 4130 Cr-Mo steel, which is typically given a full PWHT to ensure uniform strength, and the joining of Type 316L base metal with 316L filler for similar corrosion characteristics.

Metals' Solidification:

Melting and solidification are two fundamental processes in metalworking that allow different elements to be combined to create alloys that can either be cast as-is or thermo mechanically processed into other useful shapes such as bars, plates, and pipes. In order to comprehend the metallurgical character of a fusion weld, one must have a comprehensive understanding of the phenomena that underlie the fusion welding processes [10]–[12]. To solidify, certain conditions must be met. To start, solid species must nucleate, or form, within the liquid phase. The heat of fusion produced by the transition must be eliminated or dispersed when the initial solid develops and the liquid-to-solid transformation is complete. Normally, this happens as a result of conduction through the solid and away from the front of solidification. Since the composition of the liquid and solid in contact at the solidification front changes continuously as the temperature falls within the solidification range, it is also necessary to disperse solute between liquid and solid during the solidification of an alloy. If the solid does not have enough time to reach its equilibrium composition, as is usual in most casting and welding operations, this redistribution will result in local variance in composition in the solidified structure.

Application:

In the building, engineering, and manufacturing sectors, welding metallurgy has a wide range of uses. The following are some of the main applications of welding metallurgy:

1. **Manufacturing:** Welding metallurgy is essential to the production of welded objects such consumer goods, machinery, and automobiles. Manufacturers may optimize their welding operations to create high-quality, dependable products by being aware of the metallurgical qualities of various materials and welding techniques.
2. **Construction:** The joining of structural elements like beams, columns, and plates makes heavy use of welding metallurgy. Construction businesses may guarantee that their constructions are sturdy, long-lasting, and safe to use by creating and putting into practice optimized welding techniques.
3. **Oil and Gas:** The joining of pipes and other components used in exploration, production, and transportation requires the employment of welding metallurgy. Companies can make sure that their pipelines and other components can resist the demanding operating environments of the oil and gas sector by studying the metallurgical qualities of various welding materials and procedures.
4. **Aerospace:** To combine parts used in aeroplanes and spacecraft, welding metallurgy is widely employed in the aerospace industry. Aerospace firms can ensure that their components can endure the harsh conditions of flight while simultaneously minimizing weight and maximizing fuel efficiency by designing and implementing optimized welding techniques.

Advantages:

Because of its many benefits, welding metallurgy is crucial for assuring the effectiveness, safety, and caliber of welded structures. Some of the main benefits are as follows:

1. A welded structure must have the strength and endurance to survive the loads and strains exerted on it, which is why welding metallurgy is so important. Welding experts may develop and optimize welding processes to make sure that the final weld is structurally sound and will function as intended in service by having a thorough understanding of the metallurgical properties of the base metal, the heat-affected zone, and the weld.
2. Welding metallurgy can assist in locating and reducing welded structure flaws such inclusions, porosity, and cracks. Welding experts can create methods that reduce the likelihood of defects and guarantee that welded structures satisfy the appropriate quality standards by knowing the sources of these flaws and how to prevent them.
3. Welding metallurgy can aid in the optimization of welding processes to increase effectiveness and cut costs. Welding experts can choose the best materials and methods for a

particular application by being familiar with the characteristics of various welding materials and processes, which lowers waste and boosts productivity.

4. For the safety of welded structures, welding metallurgy is crucial. Welding experts may create processes that reduce the risk of failures and guarantee that welded structures are secure for use in the applications for which they were designed by studying the qualities of the base metal, the heat-affected zone, and the weld.

Disadvantages:

While welding metallurgy provides many benefits, there are a few potential drawbacks to take into account as well:

1. **Complexity:** The study of welding metallurgy necessitates a thorough comprehension of metallurgical concepts as well as extensive knowledge of welding procedures and techniques. This can make it difficult for welders and engineers who aren't experts in welding metallurgy to design and put the best welding practices into practice.
2. **Cost:** Because welding metallurgy involves specialized tools, materials, and knowledge, the sector can be expensive. This may make it more expensive overall to complete welding projects and make it more challenging for smaller businesses or organizations to use the best welding techniques.
3. **Time-Consuming:**To ensure that welding methods are optimized for a particular application, welding metallurgy involves rigorous planning, testing, and analysis. This may result in welding tasks requiring more time and materials.
4. **Risks to Safety:** Welding metallurgy may expose workers to radiation, fumes, and other potentially harmful substances. To reduce the danger of damage or illness, welders and other workers in welding processes must follow the proper safety procedures.

   Overall, even if the advantages of welding metallurgy can be substantial, it's crucial to take into account these possible drawbacks and take the necessary steps to handle them in welding operations [13], [14].

CONCLUSION

Welding metallurgy is a complicated and significant field that is essential for assuring the effectiveness of the welding procedure as well as the high quality and dependability of welded joints. In this paper discussed about the welding metallurgy and the advantage and disadvantages and application of the welding metallurgy that is used during the welding operation. Welding metallurgy investigates the science of welding and how it affects metals. It focuses on the physical and chemical alterations that metals go through during welding and how these alterations affect the microstructure, mechanical characteristics, and functionality of welded junctions.

REFERENCES:

[1] Welding metallurgy and weldability of stainless steels, *Choice Rev. Online*, 2005, doi: 10.5860/choice.43-2230.

[2] P. Ramakrishnan, Welding Metallurgy, *Indian Weld. J.*, 1972, doi: 10.22486/iwj.v4i3.150243.

[3] P. Ferro and J. O. Nilsson, Welding metallurgy of stainless steels, in *Handbook of Welding: Processes, Control and Simulation*, 2021. doi: 10.22486/iwj.v2i2.150282.

[4] J. C. Lippold, *Welding Metallurgy and Weldability*. 2014. doi: 10.1002/9781118960332.

[5] W. Reitz, A Review of: 'Welding Metallurgy and Weldability of Stainless Steel,' *Mater. Manuf. Process.*, 2006, doi: 10.1080/10426910500476747.

[6] J. Andersson, Welding metallurgy and weldability of superalloys, *Metals*. 2020. doi: 10.3390/met10010143.

[7] S. Kou, *Welding Metallurgy*. 2002. doi: 10.1002/0471434027.

[8] H. Xu, J. Sun, J. Jin, J. Song, and C. Wang, Comparison of structure and properties of mo2feb2-based cermets prepared by welding metallurgy and vacuum sintering, *Materials Basel.*, 2021, doi: 10.3390/ma14010046.

[9] M. Pouranvari, M. Alizadeh-Sh, and S. P. H. Marashi, Welding metallurgy of stainless steels during resistance spot welding part I: Fusion zone, *Sci. Technol. Weld. Join.*, 2015, doi: 10.1179/1362171815Y.0000000015.

[10] M. Alizadeh-Sh, M. Pouranvari, and S. P. H. Marashi, Welding metallurgy of stainless steels during resistance spot welding part II –heat affected zone and mechanical performance, *Sci. Technol. Weld. Join.*, 2015, doi: 10.1179/1362171815Y.0000000010.

[11] W. A. Baeslack, D. W. Becker, and F. H. Froes, Advances in Titanium Alloy Welding Metallurgy, *JOM J. Miner. Met. Mater. Soc.*, 1984, doi: 10.1007/BF03338455.

[12] S. Salimi Beni, M. Atapour, M. R. Salmani, and R. Ashiri, Resistance Spot Welding Metallurgy of Thin Sheets of Zinc-Coated Interstitial-Free Steel, *Metall. Mater. Trans. A Phys. Metall. Mater. Sci.*, 2019, doi: 10.1007/s11661-019-05146-8.

[13] R. Fenn, Welding Metallurgy Of Stainless Steel., *Weld. Met. Fabr.*, 1987.

[14] M. Pouranvari, S. P. H. Marashi, and M. Alizadeh-Sh, Welding metallurgy of dissimilar AISI 430/DQSK steels resistance spot welds, *Weld. J.*, 2015.

CHAPTER 14

INTRODUCTION OF THE OXY-ACETYLENE FLAMES

Mr. Vijaykumar Lingaiah, Assistant Professor
Department of Mechanical Engineering, Presidency University, Bangalore, India
Email Id: - vijaykumarsl@presidencyuniversity.in

ABSTRACT:

Burning a mixture of oxygen and acetylene gases in a torch made specifically for this purpose results in oxygen-acetylene flames. The gases are mixed in the torch in precisely the right amounts, and they are then ignited by a spark or pilot flame. In this Chapter discussed about the Oxy-Acetylene Flames that is used in welding operation. When a mixture of hydrogen and oxygen is burned at an extremely high temperature, roughly 2500 ° C, oxyacetylene is formed. Metals are chopped and joined together using an oxyacetylene flame.

KEYWORDS:

Acetylene, Cylinders, Flames,Oxy-Acetylene, Safety.

INTRODUCTION

Oxy-acetylene flames are a particular kind of flame created when acetylene gas and oxygen are burned together. This procedure generates a high-temperature flame that can be applied in a number of industrial processes, such as brazing, heating, welding, and cutting. An oxy-acetylene flame is produced by combining the two gases in a specified proportion and lighting them in a torch or burner. The torch's design enables the clean combustion of the gases which results in a hot, blue flame that is perfectly controllable. The adaptability of oxy-acetylene flames is one of their key benefits. Different sorts of flames, such as neutral flames, oxidizing flames, and carburizing flames, can be produced by adjusting the flame. Each form of flame has unique qualities and is best suited for a particular use. Oxy-acetylene flames are frequently employed in a variety of fields, including as manufacturing, building, and metallurgy. They are especially helpful in processes requiring a lot of heat, including metal-welding and metal-cutting. They are also utilized in brazing and soldering processes that call for a lower temperature flame. All things considered, oxy-acetylene flames are a crucial tool for a variety of industrial and manufacturing applications. They provide a great level of control and precision, and because of their adaptability, they are an excellent resource for many different sectors. Acetylene gas and oxygen burn together to form oxy-acetylene flames. This procedure generates a high-temperature flame that can be applied in a number of industrial processes, such as brazing, heating, welding, and cutting [1].

An oxy-acetylene flame is produced by combining the two gases in a specified proportion and lighting them in a torch or burner. The torch's design enables the clean combustion of the gases which results in a hot, blue flame that is perfectly controllable. Acetylene gas is created when calcium carbide and water combine chemically, and it is then kept at a high pressure in cylinders. Gas cylinders that have been compressed provide oxygen. The adaptability of oxy-acetylene flames is one of their key benefits. Different sorts of flames, such as neutral flames, oxidizing flames, and carburizing flames, can be produced by adjusting the flame. Each form of flame has unique qualities and is best suited for a particular use. A clean flame with a temperature of about 3,500 degrees Celsius is produced by neutral flames, which are created by a balanced ratio of oxygen and acetylene. Oxidizing flames produce cooler flames that are ideal for cutting and brazing because they include an abundance of oxygen. Carburizing flames provide a hotter flame that is ideal for welding and heating applications because they include an excess of acetylene. Oxy-acetylene flames are frequently employed in a variety of fields, including as manufacturing, building, and metallurgy. They are especially helpful in processes requiring a lot of heat, including metal-welding and metal-cutting. They are also utilized in brazing and soldering processes that call for a lower temperature flame. All things considered, oxy-acetylene flames are a crucial tool for a variety of industrial and manufacturing applications. They provide a great level of control and precision, and because of their adaptability, they are an excellent resource for many different sectors.

Welding with Oxyacetylene:

A fuel gas and oxygen react to form a flame, which is utilized in the welding process known as gas welding to melt and join metals. Due to its high flame temperature, oxyacetylene welding OAW, depicted. Is the most popular gas welding procedure? The weld metal can be cleaned and deoxidized using a flux. On the resulting weld metal, the flux melts, solidifies, and creates a slag skin. Figure 1.8 depicts three distinct flame types used in oxyacetylene welding: neutral, reducing, and oxidizing.

Three Different Flame Types:

1. Neutral Flame:

Natural Flame this is the scenario in which acetylene C2H2 and oxygen O2 are mixed equally and burned at the welding torch's tip. A neutral flame has a longer outer envelope and a shorter interior cone. The primary combustion occurs in the inner cone as a result of the chemical reaction between O2 and C2H2. Two-thirds of the total heat produced is attributed to the heat of this reaction. CO and H2, the byproducts of primary combustion, combine with ambient O2 to generate CO2 and H2O. This is known as secondary combustion, and it produces around one-third of the heat produced overall. The outer envelope is the region where secondary combustion occurs. It is also known as the protective envelope because the CO and H2 in this area scavenge the O2 coming in from the outside air, preventing oxidation of the weld metal. Most metals are heated using a neutral flame.

2. Diminishing Flame:

Diminishing Flame the flame that results from using too much acetylene is referred to as a decreasing flame. Acetylene combustion is not complete. A reducing flame can be identified by a feather of greenish acetylene between the inert cone and the outer envelope Figure 1.8b. Due to the ease with which aluminum oxidizes, a decreasing flame is ideal for welding aluminum alloys. Because too much oxygen can oxidize carbon and generate CO gas porosity in the weld metal, it is also beneficial for welding high-carbon steels also known as carburizing flame in this situation.

3. Oxygenating Flame:

Oxygenating Flame The presence of unconsumed oxygen causes the flame to become oxidizing when too much oxygen is utilized. An oxidizing flame is distinguished by a little white inner cone. When welding brass, this flame is desirable because copper oxide coats the weld pool and keeps zinc from evaporating.

The Flame's Acetylene's Characteristics:

Acetylene, like the majority of fuel gases, is made up of Hydrogen and Carbon. When burned with oxygen, carbon is primarily responsible for the intense heat and extremely high flame temperature 3100°C. If enough oxygen isn't present, the carbon will release black, sooty smuts into the atmosphere. The amount of carbon in acetylene is very high, and if the oxygen is reduced to create a flame with too much carbon, the carbon is drawn into the steel to create a high carbon surface that is utilized for hard surfacing operations.There is no need to apply a flux while welding steel because a neutral oxy-acetylene flame, which burns an equal amount of oxygen and acetylene, is reducing in nature and will convert any iron oxide to iron and absorb the oxygen. Iron oxide is not refractory, it should be emphasized. The research work already done in this particular field has to be discussed here, in this specific section.

DISCUSSION

When acetylene gas and oxygen are burned together, a specific type of flame known as an oxy-acetylene flame is produced. In doing so, a high-temperature flame is produced, which can then be used in a variety of industrial processes like brazing, heating, welding, and cutting. By mixing the two gases in a specific ratio and igniting them in a torch or burner, an oxy-acetylene flame is created. Because of the way the torch is made, the gases may burn cleanly, producing a strong, blue flame that is incredibly easy to manage. One of the main advantages of oxy-acetylene flames is their versatility. By modulating the flame, several flame types, including neutral flames, oxidizing flames, and carburizing flames, can be produced. Each type of flame has distinct characteristics and is most suitable for a particular use. Oxy-acetylene flames are extensively used in a range of industries, including as metallurgy, construction, and manufacturing. They are especially beneficial while doing high-heat operations like metal welding and metal cutting. They are employed in lower temperature brazing and soldering procedures as well. Oxy-acetylene flames are an essential tool for many industrial and manufacturing applications, all things considered. Due to their versatility and high level of control and precision, they are a good resource for a variety of industries [2], [3].

Types of Oxy-Acetylene Flames:

1. Neutral Flame:

Natural Flame this is the scenario in which acetylene $C2H2$ and oxygen $O2$ are mixed equally and burned at the welding torch's tip. A neutral flame has a longer outer envelope and a shorter interior cone. In this gas welding flame, oxygen and acetylene are released at a one-to-one ratio. That is, an equal amount of oxygen and acetylene is released. It absorbs additional oxygen from the air as it provides complete combustion. A neutral flame is fine, clear, and well-defined. It is generally preferred for welding. It produces a luminous cone indicating the completion of the flame. Both ferrous and nonferrous metals, such as mild steel, cast iron, copper, stainless steel, aluminum, etc., can be welded using neutral flames. Before using another flame, welders are expected to adjust to neutral. The inner core of the flame, which is a brilliant cone that is bluish-white, serves as a visual cue. It is renowned for its surroundings, which exhibit a light blue flame envelope.

A balanced flame, often referred to as a neutral flame, is produced by releasing more acetylene. By expanding the oxygen valve, a flame with an inner cone feather extension is produced. The acetylene flame feather, oxygen gas, and neutral flame all vanish at once. The temperature at the tip of the inner core is about 585 degrees Fahrenheit, while the temperature at the end of the outer sheath or envelope is about 2300 degrees Fahrenheit. The primary combustion occurs in the inner cone as a result of the chemical reaction between O2 and C2H2. Two-thirds of the total heat produced is attributed to the heat of this reaction. CO and H2, the byproducts of primary combustion, combine with ambient O2 to generate CO2 and H2O. This is known as secondary combustion, and it produces around one-third of the heat produced overall. The outer envelope is the region where secondary combustion occurs. It is also known as the protective envelope because the CO and H2 in this area scavenge the O2 coming in from the outside air, preventing oxidation of the weld metal. Most metals are heated using a neutral flame.

2. Diminishing Flame:

Diminishing Flame the flame that results from using too much acetylene is referred to as a decreasing flame. Acetylene combustion is not complete. A reducing flame can be identified by a feather of greenish acetylene between the inert cone and the outer envelope Figure.1. Due to the ease with which aluminum oxidizes, a decreasing flame is ideal for welding aluminum alloys. Because too much oxygen can oxidize carbon and generate CO gas porosity in the weld metal, it is also beneficial for welding high-carbon steels also known as carburizing flame in this situation.

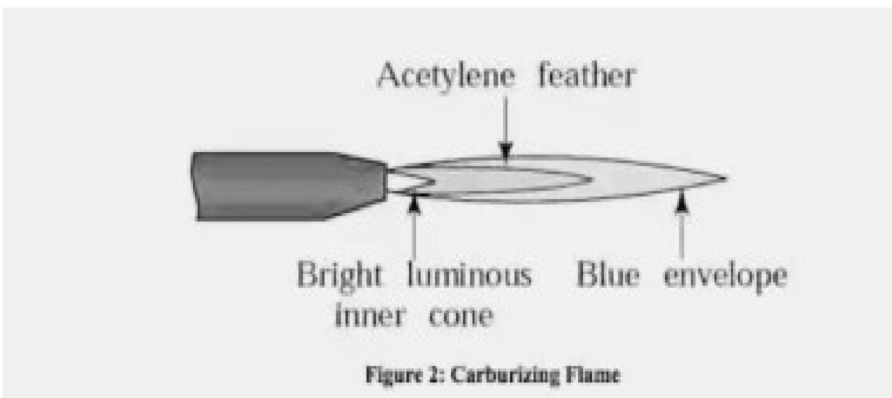


Figure 2: Represting the overview about Carurizing Flame [Imbooz].

Its inner core has a white feather edge extending beyond it, which is also known as an acetylene feather. this acetylene is 2x if it's twice as long as the inner cone, helping to know the amount of acetylene supply. Carburizing is done by adjusting to a neutral flame before increasing the acetylene valve. the inner core will change showing an acetyl flame.Three distinct flame zones identify a carburizing flame A distinct inner core of bluish-white color White immediately cone showing how much extra acetylene is present. An outer flare envelope in light blue. This flare emits a loud, rushing sound when it burns. The temperature at the inner cone tip is roughly 3700 degrees Fahrenheit. When welding with a carburizing flame, carbon absorbs from the flame and causes metals to boil. As it boils, transforms into high carbon steel, becomes brittle, and is susceptible to cracking, this metal loses its transparency.

3. Oxygenating Flame:

Oxygenating Flame The presence of unconsumed oxygen causes the flame to become oxidizing when too much oxygen is utilized. An oxidizing flame is distinguished by a little white inner cone. When welding brass, this flame is desirable because copper oxide coats the weld pool and keeps zinc from evaporating.

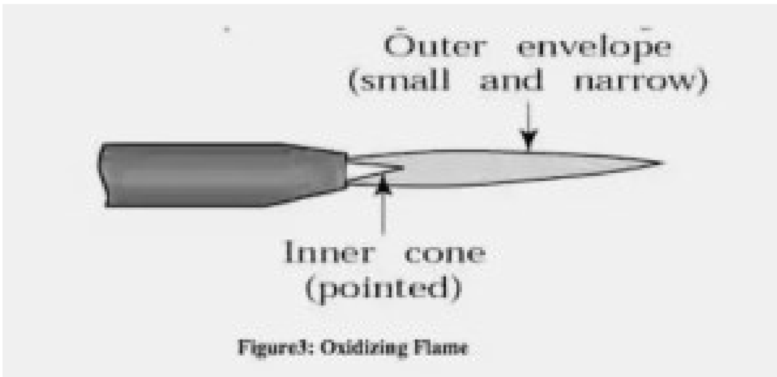


Figure 2: Represting the overview about the Oxidizing Flame [Imbooz].

The third oxyacetylene flame is now visible. It is produced by mixing one volume of acetylene and slightly more than one volume of oxygen. The torch is set to a neutral flame, same as it is done in a carburizing flame (Figure. 2). After that, the oxygen valve will be raised until the inner core is reduced to about one-tenth of its initial length. If the flame is appropriately adjusted, the flame has a tendency to be slightly purple and the inner cone is pointed. Another characteristic of this flame is its audible hissing. The inner core tip of the oxidizing flame has a temperature of roughly 6300 degrees Fahrenheit. Metals including cast iron, manganese steel, zinc, and copper are all welded using this technique. When this flame is applied to steel, the molten metal forms and sparks off, indicating that the steel is receiving too much oxygen. Steel becomes porous, oxidized, and brittle when it is used for welding. for this reason, it is not used [4], [5].

Application of Oxyacetylene Flame:

1. Natural Flame:

The most adaptable oxy-acetylene flame type is the neutral flame, which has a wide range of uses, such as:

- **i.** Neutral flames can be used to weld the majority of metals, including copper alloys, steel, stainless steel, and aluminum. The metals can melt and fuse together under the neutral flame's high temperature, forming a solid connection.
- **ii.** Using a filler metal that melts at a lower temperature than the base metals, two pieces of metal are bonded together via brazing. Because they offer sufficient heat to melt the filler metal and form a solid junction without harming the base metals, neutral flames are perfect for brazing.

iii. Applications like heating metal for bending or shaping use neutral flames frequently. Metal may be swiftly heated to a flexible state due to the flame's high temperature, making it easier to work with.
iv. Although neutral flames aren't frequently employed for this task, they can be used to warm up the metal before switching to an oxidizing flame to carry out the actual cutting.
v. In general, neutral flames are the most adaptable oxy-acetylene flame type and are frequently utilized in a range of welding, brazing, and heating applications.
vi. Compared to acetylene, which creates a cooler flame ideal for cutting and brazing.

2. Oxidizing Flames:

Oxidizing flames have an overabundance of oxygen. Here are a few typical uses for oxidizing flames:

i. Steel and other ferrous metals are frequently cut using oxidizing fires. The metal is oxidized by the excess oxygen in the flame, which causes a chemical process that produces additional heat and aids in melting the metal.
ii. Oxidizing flames may be utilized for brazing and soldering when working with copper and brass alloys. The base metals are kept from oxidizing, which might damage the joint, thanks to the cooler flame temperature.
iii. Oxidizing flames can still be utilized for heating applications, such as annealing or stress relieving metals, even if they are not as hot as neutral or carburizing flames.
iv. Oxidizing flames can be employed in some situations to give metals a hard surface. In order to do this, the metal must first be heated to a specified temperature before being quenched in a cooling media, such as water or oil.

3. Carburizing Flames:

Acetylene is present in excess relative to oxygen in carburizing flames, resulting in a hot, carbon-rich flame. Here are a few typical uses for carburizing flames:

i. Cast iron can be welded using carburizing flames, which require a hotter flame than other metals do. Cast iron is less likely to crack while being welded thanks to the carbon in the flame.
ii. Carburizing flames may be utilized for brazing steel or other ferrous metals in specific circumstances. The molten metal can flow more easily into the joint thanks to the carbon in the flame's assistance in lowering the surface tension of the metal.
iii. Hard facing is the technique of applying a hard, wear-resistant surface on a softer metal. Steel can be hard faced using carburizing flames, which creates a strong surface that is resistant to wear and corrosion.
iv. Carburizing flames can be used to apply heat treatments to metal surfaces, such as annealing or stress relief. The metal's surface hardness and wear resistance may be enhanced by the carbon in the flame.
v. In general, operations requiring a hot, carbon-rich flame, such as welding, brazing, hard facing, and surface treatment, benefit from the use of carburizing flames. Carburizing flames must be utilized carefully since they can release a lot of soot and carbon monoxide, both of which pose risks to people's health and safety.

Advantages of Oxy-Acetylene Flames:

Oxy-acetylene flames have a number of benefits, such as:

1. Oxy-acetylene flames are perfect for welding, brazing, and metal cutting since they can reach temperatures of up to 6,000 degrees Fahrenheit.
2. Oxy-acetylene equipment is portable and may be utilized in far-off places, making it perfect for welding or field maintenance.
3. Oxy-acetylene flames are suitable for a variety of welding, brazing, and cutting applications because they can be altered to produce several types of flames, such as neutral, oxidizing, or carburizing.
4. Oxy-acetylene flames are capable of being carefully controlled to produce a flame and temperature that are constant, which is necessary for high-quality brazing and welding.
5. Oxy-acetylene equipment is reasonably priced and simple to maintain, making it an economical choice for small-scale welding or repair projects.

Disadvantages of Oxy-Acetylene Flames:

Oxy-acetylene flames provide a number of benefits, but they also have certain drawbacks, such as:

1. When utilized improperly, oxygen-acetylene flames can produce high temperatures and be dangerous. The risk of fire, explosion, and burns is included here.
2. Although oxy-acetylene flames are adaptable, some metals, like aluminum and stainless steel, cannot be welded or cut with them.
3. Oxy-acetylene flames consume a lot of acetylene, which can be expensive if used regularly.
4. To avoid mishaps or injuries, the large gas cylinders used in oxy-acetylene equipment must be handled and stored properly.
5. Carbon dioxide is produced when acetylene is burned, and this gas adds to air pollution and greenhouse gas emissions.

CONCLUSION

Oxyacetylene welding, often known as gas welding, is a procedure that depends on the combustion of oxygen and acetylene. When combined in the proper proportions inside a hand-held torch or blowpipe, a reasonably hot flame with a temperature of about 3,200 degrees is created. The oxyacetylene flame is utilized for welding because it produces a great quantity of heat and a very high temperature flame. The process of welding using oxyacetylene is also known as oxy-fuel welding, oxy welding, or gas welding.

REFERENCES:

[1] Z. G. Wang *et al.*, 'Formation mechanism of a wrinkled and textured Al2O3-ZrO2 nanoeutectic rapidly solidified from oxy-acetylene flame remelting', *J. Am. Ceram. Soc.*, 2019, doi: 10.1111/jace.16003.

[2] V. D. Zegarra Torres, M. A. Vaz, and J. C. R. Cyrino, 'Estimation of distributed heat flux parameters in localized heating processes', *Int. J. Therm. Sci.*, 2021, doi: 10.1016/j.ijthermalsci.2020.106808.

[3] R. Kapil, B. R. Mehta, V. D. Vankar, C. Roy, and A. Pradhan, 'Growth of diamond thin films in a cyclic growth-etch oxy-acetylene flame process', *Thin Solid Films*, 1998, doi: 10.1016/S0040-6090(97)00960-7.

[4] J. Thamilarasan, N. Karunagaran, and P. Nanthakumar, 'Optimization of oxy-acetylene flame hardening parameters to analysis the surface structure of low carbon steel', in *Materials Today: Proceedings*, 2020. doi: 10.1016/j.matpr.2021.02.680.

[5] M. Malhotra, S. C. Agarwal, and S. Kumar, 'Deposition of diamond films on metal substrates', *Bull. Mater. Sci.*, 1996, doi: 10.1007/BF02744817.

CHAPTER 15

WELDING OF LOW CARBON STEEL AND MEDIUM CARBON STEEL

Mr. Manjunath Narayan Rao, Assistant Professor
Department of Mechanical Engineering, Presidency University, Bangalore, India
Email Id: - manjunath.n@presidencyuniversity.in

ABSTRACT:

When carbon is the only alloying element, the steel is referred to as plain carbon steel. The quantity of carbon in the steel determines how ductile, strong, and hard it is. The less ductile the steel is, the higher the carbon concentration. According to the amount of carbon they contain, carbon steels are categorized. The terms low, medium, and high carbon steels are used to describe them. In this Chapter discussed about the welding of low carbon steel and medium carbon steel that is used to join the metallic pieces together.

KEYWORDS:

Carbon, Cracking, Steel, Strength, Welding.

INTRODUCTION

The method of attaching two or more pieces of steel together by heating them to their melting points and fusing them together is known as welding for low carbon steel and medium carbon steel. Due to its affordability, strength, and ease of welding, carbon steel is a frequently used material. To achieve a solid and long-lasting joint, welding low carbon steel and medium carbon steel involves careful consideration of a number of aspects, including the type of welding technique, the kind of filler metal used, and the welding parameters employed. A strong and structurally sound joint that can resist the intended usage and environment of the welded structure is the aim of welding low carbon steel and medium carbon steel. To produce a high-quality weld with little distortion and few faults, proper preparation, welding procedures, and post-weld treatments are crucial [1], [2].

Low carbon steels are defined as having a total carbon content of less than 0.30 percent. During fabrication and throughout their working lives, these steels can tolerate harsh treatment. Without significantly weakening, it can be heated to a greater temperature up to a red or even white hot color before being quenched with cool water. By any welding techniques. The choice of the welding approach and process results in low cost and excellent welding performance. The elements that must be taken into account in order to accomplish those are:

1. Thickness.
2. Joint design.
3. Production Position needed.

There are fewer choices to be taken when welding low carbon steel compared to high alloy, which leads to a larger difference in cost and weld performance. All carbon steels are easily arc wieldable, albeit they might not be appropriate for high-speed production welding if the carbon percentage is too low. Because they generate internal porosity in the weld metal, steels with carbon contents less than 0.13% and 0.40% manganese cannot be used for high speed production welding. Steels with reduced carbon content have stronger ductility and impact strength but lower tensile strength and hardiness. Low carbon steels can be welded without the need for any particular safety measures because of their outstanding weld ability. Since these steels cannot be heat treated to produce remarkable mechanical qualities, heating them to melt or weld them will not cause any damage to their fundamental properties.

Each and every weld joint needs to be well ground and machined, free of rust, moisture, dirt, paint, etc.

Low Carbon Steel:

Low carbon steel is a subcategory of carbon steel with a relatively low carbon content, usually less than 0.30 percent by weight. Compared to high carbon steel, which contains more than 0.60% carbon, it is softer and more ductile as a result. The most popular type of steel used in manufacturing, construction, and other uses is low carbon steel, sometimes known as mild steel. It is a popular choice for a variety of items and constructions, including buildings, bridges, cars, and machinery, due to its affordability, ease of fabrication, and good weld ability. However, because it contains less carbon than high carbon steel, it is weaker and softer and may not be appropriate for applications requiring great tensile strength or wear resistance [3], [4].

Medium Carbon Steel:

A type of carbon steel known as medium carbon steel has a carbon content that ranges from 0.30% to 0.60% by weight. As a result, it is more brittle, tougher, and less ductile than low carbon steel. It is also more challenging to weld and process. In applications where more strength and hardiness are required than in low carbon steel, such as cutting tools, machinery parts, and automobile parts, medium carbon steel is frequently utilized. Additionally, it can be heat-treated to make it stronger and more resilient. However, because medium carbon steel has a higher carbon content, it is also more likely to break when it is being welded, necessitating greater caution and attention to guarantee a strong, long-lasting weld. The research work already done in this particular field has to be discussed here, in this specific section.

DISCUSSION

The method of attaching two or more pieces of steel together by heating them to their melting points and fusing them together is known as welding for low carbon steel and medium carbon steel. Due to its affordability, strength, and ease of welding, carbon steel is a frequently used material. To achieve a solid and long-lasting joint, welding low carbon steel and medium carbon steel involves careful consideration of a number of aspects, including the type of welding technique, the kind of filler metal used, and the welding parameters employed. A strong and structurally sound joint that can resist the intended usage and environment of the welded structure is the aim of welding low carbon steel and medium carbon steel. To produce a high-quality weld with little distortion and few faults, proper preparation, welding procedures, and post-weld treatments are crucial [5]–[7].

Welding of Low Carbon Steel:

When two or more pieces of low carbon steel are joined together through welding, they are heated to their melting temperatures and fused together. Due to its low price, high strength, and excellent weld ability, low carbon steel is a frequently used material in welding. To ensure a solid and long-lasting bond, low carbon steel welding calls for careful consideration of a number of parameters. Shielded metal arc welding SMAW, gas tungsten arc welding GTAW, and gas metal arc welding GMAW are a few typical welding techniques used for low carbon steel. The selection of a method will depend on the particular project needs and the welding circumstances.

Each process has benefits and drawbacks of its own. The kind of filler metal used is crucial, in addition to choosing the right welding procedure. In order to ensure a strong, uniform weld and match the composition of the base metal, low carbon steel filler metals are often utilized. Pre-weld preparation, such as cleaning and surface preparation, and post-weld treatments, such as stress release and heat treatment, are additional elements that might affect the weld's quality. It's crucial to take into account the possibility of distortion as well as other welding-related flaws like cracking, porosity, and insufficient fusion. In order to reduce these hazards and create a high-quality weld with few errors, suitable welding techniques, such as managing heat input and keeping the correct electrode position, can be used. Overall, careful preparation and execution are needed when welding low carbon steel to achieve a strong, long-lasting weld that satisfies the demands of the intended use.

How to WELD LOW CARBON STEEL:

It can be formed into a variety of joints and parts. Hardened structures, cracks, and pores are difficult to build during the welding process as shown in Figure. 1, and it is also difficult to create hardened structures. The greatest welding material is this one. Good welding joints can be achieved via gas welding, manual arc welding, automatic submerged arc welding, and gas shielded welding. Avoid heating for an extended period of time while using gas welding. otherwise, the grain size of the heat-affected zone is likely to increase. When the ambient temperature is low and the joint stiffness is high, the workpiece should be warmed to between 100 and 150 °C to prevent cracks.

Figure 1:Represting the Low carbon steel welding [epower metals].

Welding of Medium Carbon Steel:

Due to its higher carbon content, which makes it more prone to cracking and other welding flaws, welding medium carbon steel might be more difficult than welding low carbon steel. However, a solid and long-lasting weld is still possible with the right methods and techniques.

Shielded metal arc welding SMAW, gas tungsten arc welding GTAW, and gas metal arc welding GMAW are a few typical welding techniques used for medium carbon steel. The particular project requirements and the welding environment will determine the welding procedure to be used. To guarantee a strong weld, pre-weld preparation such as cleaning and surface preparation is also crucial. Managing the heat input to prevent cracking and other faults is one of the main difficulties in welding medium carbon steel.

Preheating the material can also assist lessen the danger of cracking? Low hydrogen filler metals are frequently utilized to lower the risk of cracking. To avoid cracking and guarantee a robust weld, it may also be necessary to use low heat input, moderate cooling rates, and post-weld heat treatments. Controlling the weld bead's size and form, maintaining proper electrode positioning, and ensuring proper shielding gas flow rates and gas coverage are additional elements that might affect the weld's quality. To find any flaws and make sure the weld satisfies the standards of the intended application, the weld must also undergo proper inspection and testing. Overall, careful preparation and execution are needed when welding medium carbon steel to produce a strong, long-lasting weld that satisfies the needs of the intended application while reducing the likelihood of flaws and cracking.

How to Weld Medium Carbon Steel:

To create a solid, long-lasting weld, welding medium carbon steel involves careful planning, execution, and post-weld treatment. For welding medium carbon steel, follow these general procedures as shown in Figure. 2.

Figure 2: Representing the general procedures ofMedium carbon steel [iStock].

1. Preparation of the material for welding is the first step in welding medium carbon steel. This entails thoroughly washing the surface to get rid of any impurities and making sure the edges that will be welded are clean and ready.
2. The welding process will be chosen based on the project's individual requirements and the welding environment. Shielded metal arc welding SMAW, gas tungsten arc welding GTAW, and gas metal arc welding GMAW are
3. When welding medium carbon steel, the filler metal type is particularly crucial. Low hydrogen filler metals are frequently employed to lessen the chance of cracking, and the filler metal should have a chemical makeup as similar as feasible to the base metal.

4. Preheating the material before welding might assist lower the danger of cracking. The thickness and makeup of the material should be taken into consideration when determining the preheat temperature.
5. To prevent overheating the material and cracking, the welding procedure should be carefully managed. Controlling heat input, keeping the correct electrode position, and making sure that the shielding gas flows properly are all included in this.
6. To relieve stress and provide a solid, long-lasting weld, the material may need to be heated after welding. Other post-weld heat treatment procedures, slow cooling rates, and controlled cooling might also be used.
7. After welding medium carbon steel, the weld must be examined and tested to make sure it satisfies the demands of the intended application. This could entail radiographic testing, dye penetrant testing, ocular inspection, or other non-destructive testing techniques. Overall, careful planning and execution are necessary when welding medium carbon steel to provide a solid, long-lasting weld that satisfies the demands of the intended use while reducing the likelihood of flaws and cracks.

Application of Welding of Low Carbon Steel:

Low carbon steel can be welded in a variety of different industries. Here are a few typical examples:

1. Low carbon steel is frequently utilized in construction projects, and structural elements like beams, columns, and plates are frequently joined via welding.
2. Low carbon steel is widely utilized in the production of numerous automotive parts, including the chassis, body panels, and exhaust systems. Frequently, these components are joined via welding.
3. Low carbon steel is used to make a variety of machines and pieces of equipment, and welding is frequently utilized to assemble the parts.
4. In the oil and gas sector, water treatment facilities and other industrial uses, low carbon steel is frequently utilized.
5. Low carbon steel welding is widely utilized in shipbuilding to combine different structural components and hulls.
6. Low carbon steel is utilized in the aircraft sector to create a variety of parts, including frames, brackets, and landing gear. Frequently, these components are joined via welding.
7. The production of several components, including rails, carriages, and locomotives, uses low carbon steel welding extensively.

   In conclusion, low carbon steel welding is employed in a number of applications across numerous industries because it is simple to weld, inexpensive, and has good mechanical qualities.

Application of Welding of Medium Carbon Steel:

Medium carbon steel can be welded in a variety of different sectors. Here are a few typical examples:

1. Medium carbon steel is widely utilized in the production of numerous automotive parts, including gears, axles, and crankshafts. Frequently, these components are joined via welding.

2. Bridges, buildings, and other constructions requiring exceptional strength and toughness are built with medium carbon steel. The joining of structural elements including plates, beams, and columns frequently involves welding.
3. Manufacturing of numerous pieces of machinery and equipment, such as shafts, crankshafts, and machine parts requiring great strength and hardness, uses medium carbon steel. Frequently, these components are joined via welding.
4. The fabrication of numerous components, including tracks, wheels, and other structural components, uses medium carbon steel welding extensively.
5. Medium carbon steel is used to create a variety of cutting tools with high wear resistance and hardness requirements, such as knives, chisels, and saw blades. These tools are frequently repaired or modified using welding.
6. Medium carbon steel is used to manufacture a variety of parts, including drilling equipment and pipelines, which call for great strength and hardness. Frequently, these components are joined via welding.
7. Ploughs, harrows, and cultivators are only a few examples of the different agricultural tools and equipment made from medium carbon steel. The structural elements of these instruments are frequently joined via welding.

Advantages of Welding of Low Carbon Steel:

Low carbon steel can be welded and has a number of benefits, such as:

1. Low carbon steel is among the simplest materials to weld. It can be joined using a number of welding processes, such as resistance, arc, and gas welding.
2. Low carbon steel is an incredibly adaptable material that may be utilized in a variety of applications. In addition to other industries, it is utilized in manufacturing, construction, and the automobile sector.
3. Low carbon steel is a cost-effective material for many applications since it is an economical material.
4. Good weld ability: Low carbon steel may be welded successfully without the risk of deformation or cracking.
5. Low carbon steel may be easily mounded and shaped without breaking or cracking since it is ductile.
6. Low carbon steel is strong enough to be used in many applications, while not being as robust as high carbon steel.
7. Good machinability: Low carbon steel is a great material for applications that call for precise machining since it is simple to work with.

Disadvantages of Welding of Low Carbon Steel:

There are some drawbacks to welding low carbon steel, including Low carbon steel is more vulnerable to cracking during welding because of its lower carbon content and diminished hardenability. This might happen if the cooling rate is too sluggish or the residual stress in the weld is very high. This problem can be reduced by regulating the cooling rate and preheating [8], [9]. Compared to other types of steel, low carbon steel has lesser strength, which could be a drawback for some applications. Additionally, the weld's heat affected zone HAZ may be less sturdy than the base metal.

Advantages of Welding of Medium Carbon Steel:

The benefits of welding medium carbon steel include the following:

1. **Great Strength:** Due to its great strength and toughness, medium carbon steel is suited for a variety of applications. Its strength and endurance can be further increased through welding.
2. **Versatility:** Welding is a flexible solution for a variety of applications since it enables the joining of different types and thicknesses of medium carbon steel. Welding is a financially advantageous way to join medium carbon steel. It eliminates the need for complicated fabrication techniques and permits the use of less expensive materials.
3. **Improved Corrosion Resistance:** By creating a consistent, continuous weld that completely eliminates the chance of corrosion between the joints, welding can increase the corrosion resistance of medium carbon steel.
4. **Precision:** Welding can offer a regulated, accurate joining procedure that ensures a robust, high-quality weld with no deformation.
5. **Enhanced Aesthetics:** By creating neat, appealing welds that are flush with the base material, welding can enhance the aesthetics of medium carbon steel.

Disadvantages of Welding of Medium Carbon Steel:

Welding of medium carbon steel has a number of drawbacks, including Due to its increased carbon content, medium carbon steel is more vulnerable to cracking during welding. Through adequate preheating, welding technique, and post-weld heat treatment, the danger of cracking can be reduced. Due to its increased carbon content compared to other forms of steel, welding medium carbon steel might be more difficult. To produce a weld of excellent quality, more knowledge and expertise are needed. Medium carbon steel is susceptible to deformation during welding, particularly when joining thicker pieces. This can result in warping, twisting, and other problems that can lower the weld's overall quality. If the necessary preheat and post-weld heat treatment procedures are not followed, welding can make medium carbon steel more brittle. Brittle welds increase the risk of cracking and other failures, which reduces the weld's strength and longevity [10], [11].

CONCLUSION

Due to its lower carbon content, low carbon steel is easier to weld and less likely to crack or deform when being welded. It is also more economical and has exceptional ductility, which makes it perfect for all types of welding applications. On the other hand, medium carbon steel is more adaptable and has higher strength and hardness while also enabling the connection of various steel types and thicknesses. However, because to its increased carbon content, which raises the possibility of cracking and brittleness, welding medium carbon steel can be more difficult. In a variety of factors, including the intended application, the qualities needed, the welding procedure, and the welder's skill level, influence the choice of the type of steel to be welded. By applying the right welding procedures, preheat, and post-weld heat treatment, low carbon steel and medium carbon steel can both be successfully welded.

REFERENCES:

[1] C. Borchers *et al.*, 'Microstructure and mechanical properties of medium-carbon steel bonded on low-carbon steel by explosive welding', *Mater. Des.*, 2016, doi: 10.1016/j.matdes.2015.09.164.

[2] B. Guney, 'Microstructure analysis of welding fume of low and medium carbon steels', *Rev. Metal.*, 2021, doi: 10.3989/REVMETALM.187.

[3] R. Kuroiwa *et al.*, 'Microstructure control of medium carbon steel joints by low-temperature linear friction welding', *Sci. Technol. Weld. Join.*, 2020, doi: 10.1080/13621718.2019.1600771.

[4] M. A. Bodude and I. Momohjimoh, 'Studies on Effects of Welding Parameters on the Mechanical Properties of Welded Low-Carbon Steel', *J. Miner. Mater. Charact. Eng.*, 2015, doi: 10.4236/jmmce.2015.33017.

[5] Z. Lin, C. Goulas, W. Ya, and M. J. M. Hermans, 'Microstructure and mechanical properties of medium carbon steel deposits obtained via wire and arc additive manufacturing using metal-cored wire', *Metals (Basel).*, 2019, doi: 10.3390/met9060673.

[6] G. I. Khidhir and S. A. Baban, 'Efficiency of dissimilar friction welded 1045 medium carbon steel and 316L austenitic stainless steel joints', *J. Mater. Res. Technol.*, 2019, doi: 10.1016/j.jmrt.2019.01.010.

[7] C. Cheng, K. Kadoi, H. Fujii, K. Ushioda, and H. Inoue, 'Improved strength and ductility balance of medium-carbon steel with chromium and titanium fabricated by friction stir welding process', *Mater. Sci. Eng. A*, 2021, doi: 10.1016/j.msea.2020.140689.

[8] D. Deng, 'FEM prediction of welding residual stress and distortion in carbon steel considering phase transformation effects', *Mater. Des.*, 2009, doi: 10.1016/j.matdes.2008.04.052.

[9] H. Zulhafril, J. Jasman, and K. J. Tespoer, 'The Effect of Cooling Media on Tensile Strength of Medium Carbon Steel in Post Welding Process Using Electric Welding (SMAW) with E7018 Electrodes', *Teknomekanik*, 2020, doi: 10.24036/teknomekanik.v3i2.6472.

[10] C. Cheng, K. Kadoi, S. Tokita, H. Fujii, K. Ushioda, and H. Inoue, 'Effects of carbon and chromium on microstructure evolution and mechanical properties of friction stir weldment in medium-carbon steel', *Mater. Sci. Eng. A*, 2019, doi: 10.1016/j.msea.2019.138060.

[11] P. Podany, C. Reardon, M. Koukolikova, R. Prochazka, and A. Franc, 'Microstructure, mechanical properties and welding of low carbon, medium manganese TWIP/TRIP steel', *Metals (Basel).*, 2018, doi: 10.3390/met8040263.

CHAPTER 16

INTRODUCTION ABOUT CUTTING AND WELDING ECONOMICS

Mr. Sanjeet Kumar, Assistant Professor
Department of Mechanical Engineering, Jaipur National University, Jaipur, India
Email Id:sanjeet.kumar@jnujaipur.ac.in

ABSTRACT:

The study of the expenses and advantages related to the welding process is known as welding economics. It entails examining the expenses of welding-related tools, supplies, labour, and other costs, as well as the advantages welding can provide, such as greater performance, increased durability, and lower maintenance costs. In this Chapter discussed about the welding economics and cutting.Optimizing the effectiveness and affordability of cutting and welding processes in manufacturing is the goal of cutting and welding economics.Many industries, including manufacturing, construction, and the automotive, rely heavily on cutting and welding. The future scope of cutting and welding economics is considerable as the demand for these industries continues to increase.

KEYWORDS:

Arc Cutting, Cost ,Estimate, Fuel ,Gas, Welding.

INTRODUCTION

The study of the costs and advantages of the various cutting and welding procedures used in the manufacturing and construction industries is referred to as cutting and welding economics. In order to unite and separate metals, cutting and welding are vital procedures. They are used in a variety of industries, including manufacturing, construction, aerospace, and transportation. A cost analysis of various cutting and welding methods, such as oxy-fuel, plasma, laser, and water jet cutting, as well as arc, resistance, and laser welding, is required for cutting and welding economics. The cost of the necessary tools, labour, and energy, as well as the effectiveness and caliber of the welding process, all have an effect on the price of cutting and welding.The welding industry is developing its vision and strategic goals for the 21st century based on the challenges and possibilities it will experience beyond 2020. Businesses based on welding require technology advancements that enable quick and flexible manufacturing. Modifications to investment choices are among the strategies to boost the welding economy. Manufacturers will be able to integrate techniques into manufacturing processes and profit from cost-saving advantages by utilizing information technologies. Productivity gains will also result from increased energy efficiency and environmental compliance in the welding sector [1]–[3].

The study of the expenses and advantages connected with the welding process is referred to as welding economics. Using pressure or filler material, two or more pieces of metal or thermoplastic are heated during the welding process and fused together. Many different businesses, including manufacturing, transportation, and construction, use welding. Welding's costs and advantages can be examined from an economic point of view. The price of supplies, tools, and labour are all included in the cost of welding. The capacity to produce sturdy, long-lasting joints that can resist the stresses and strains of regular use is one of welding's advantages. Economic factors also play a role in the production of high-quality welds. Failures brought on by poor welding may need expensive repairs or even accidents. As a result, it's crucial to spend money on top-notch welding equipment and to work with qualified welders who can create strong, dependable welds. Environmental effects of welding are another crucial economic factor. Because welding can emit dangerous fumes and gases, it's crucial to practice proper safety measures and buy machinery that can reduce emissions.

i. **Cost and Productivity:** By optimizing the welding procedure and the final product, achieve more productive and cost-effective welding operations.
ii. **Technologies and Processes:** Enhance the use of welding-related technologies in manufacturing operations, implement virtual welding design qualification, successfully integrate welding into the entire factory, transition to an architecture of machining or automation in welding technology, and exchange solutions with other welding industries.
iii. **Quality Standards:** Create products with the highest possible quality welds and manufacturing procedures rather than relying on individuals. Predict manufacturing goods' structure and lifespan with accuracy. Dispense with the causes of faults. Utilize the adaptability of welding codes and standards.
iv. **Material Performance:** Use the most cutting-edge and cost-effective material for each application, while simultaneously developing welding technology.
v. **Education and Training:** Encourage more educated individuals to attend the programme. More welding professionals should be certified. Energy, the environment, safety, and health: reducing the amount of energy used during pre- and post-heating processes, making welded manufacturing more environmentally conscious while also providing workers with a safe and healthy working environment.
vi. **Cost-Reduction Measures:** Implement thorough weld cost reduction, advance increasing process automation utilization, implement welding integration, and incorporate weld information into total manufacturing planning.The research work already done in this particular field has to be discussed here, in this specific section.

DISCUSSION

The capacity of a corporation to keep costs within the boundaries set by competitive selling prices is typically used to determine the success of a business. When the elements determining those costs are known and the proper estimation techniques are employed, the costs connected with welding and related operations may be easily estimated for any work. If the estimate is to be used effectively for price fixing, bidding, or comparing welded construction to an alternative procedure, welding costs must be precisely determined. A product's cost components are those that have to do with its materials, labour, and overhead. Only welding materials such filler metals, gases, and fluxes are taken into account in this Chapter, and only the labour particularly related to welding is discussed. As a result, information on layout, forming, fitting, and other metalworking costs as well as base metal costs are not included. Since the quantity of overhead and the manner of allocating overhead expenses vary from industry to industry, overhead costs are not covered in length in this Chapter. Factual data and adaptable advice are provided to make it easier to build welding cost criteria for individual businesses. The methods for calculating cycle time in the manufacture of elements using automated arc welding and resistance spot welding are covered in detail due to the significance of cost estimation for automated systems.

We provide a detailed description of a cost model created to calculate the manufacturing costs specifically for resistance spot welding. Due to the processes' similarities, many of the methods used to calculate welding cost estimates can also be used to calculate brazing, soldering, and thermal spraying cost estimates. The sections Economics of Brazing and Soldering and Economics of Thermal Spraying include information relevant to these procedures [4]–[6].

The Estimated Cost:

A cost estimate is a projection of potential costs associated with the production of goods or components, as well as the introduction of new procedures or operations. A typical cost estimate contains information on administrative, handling, warehousing, and storage charges in addition to manufacturing costs. An accurate cost estimate can provide information that can be used to inform the following management choices. Determine whether a proposed product can be manufactured and sold at a profit by taking into account current prices and anticipated competition. Establish the selling price of a product for quotation purposes.

1. Determine whether parts and assemblies should be manufactured in-house or purchased from a vendor.
2. Determine whether parts and assemblies should be manufactured in-house or purchased from a vendor.
3. Determine the amount of investment required for the acquisition of the tools and equipment needed to produce.
4. 5.Deciding on the best and most affordable technique, procedure, and components for the product's production.
5. Creating a foundation for a cost-cutting programme by showcasing savings that have been realized, could be realized, or both through the use of value-analysis tools.
6. Predicting the effects of production volume changes on future profits as a result of the introduction of automation, mechanization, or other improvements suitable for mass production. 7. Predetermining standards of production performance that can be used at the start of production to control operating costs.
7. If a new product is being produced, the first official process planning should be included in the cost estimate's specifics. The following choices may subsequently be made using the information from this process planning:
8. Setting the overall schedule or timetable for achieving company goals. Specifying the equipment, machines, and facilities required for the production of a proposed product in the quantities required and within the allotted timeframes.
   1. Establishing personnel requirements to meet future work plans.
   2. Predicting material needs over the course of a contract.

Welding Economic Studies:

When creating a cost estimate or setting a product's selling price, the corporation must take into account all potential costs. General and administrative costs are frequently determined by the accounting department, whereas management typically determines the anticipated level of profit. The processes for costing elements or brazements, if the product to be manufactured include either, must be compatible with the enterprise's standard accounting methods. The only costs that matter most to the cost estimator are those related to manufacturing.Direct materials, direct labour, expendable equipment, and factory overhead sometimes known as burden are the four components of manufacturing expenses. Direct materials are the parts of the product that are included in the final item. When considering the number of units and materials used to produce one product, they are easily linked to the product. Included in direct materials are those whose cost per unit can be precisely determined [7]–[9].

Cost Estimates for Welding:

The essential components found in other industrial processes and activities are included in welding cost estimates. But in welding, these components are subject to a wide range of variations, some of which are specific to the welding process and others of which can be trade secrets. Individuals with knowledge and experience in the fields of engineering, metallurgy, manufacturing, and quality control are needed to define these variables.Lists the variables typically taken into account when determining arc welding expenses.

Data processing and computerization are crucial instruments for calculating expenses. Although compiling and analyzing data for welding cost estimates can be an expensive and time-consuming task, it is now possible to quickly and easily examine numerous welding variables with computers and the right application software. For the management of welding practices and welder performance qualifications, production welding, and quality control, for instance, database systems have been developed.The welding procedure specification WPS gives crucial information required to determine the weld's cost.So, since the welding procedure specification specifies the welding variables to be employed in the manufacturing process and offers a foundation for repeatability and consistency in production, it can serve as the beginning point for a welding cost estimate. Many businesses have A cost estimate's foundational components are the quantity of consumable materials needed and the number of tasks required to finish manufacture of the item. An accurate list of the materials needed and a summary of the procedures necessary to produce each component can be used to estimate the number of labour hours. Standard production procedures are created by several fabricators so that the labour allowances can be calculated based solely on the material needs.

Materials list. The estimator needs a list of every weld in the assembly, including its kind, size, and length, as well as a list of all the materials needed to make the welds, in order to create a welding cost estimate.Less judgment is needed on the part of the estimator when creating a bill of materials and converting the material requirements into a labour estimate for businesses that manufacture a small variety of identical items using a few conventional manufacturing techniques. However, the estimator needs to be aware of the specialized shop methods for bespoke fabricators that create a wide range of items. The estimator must predict whether the efficiencies typically attained in shop procedures will be realized for each product manufactured.Depending on how simple or difficult the work is, the estimator must determine various numbers if it is predicted that standard efficiency won't be possible.

Despite being for steel, the information in the tables can be used to estimate the weight of any deposited metal. The following equation can be used to perform calculations: where W = Weight of the deposition in question, in pounds per square foot kg/m. = Density of the deposition, in pounds per square inch g/mm3. and DV = Volume of the deposition, in inches per square foot mm3/mm from through.All arc welding expenses, except from those associated with autogenously processes, must be determined using the weight of the deposited weld metal. The amount of filler metal, flux, gas, and labour needed to fabricate each weldment depends on the welding technique and welding procedure. The weight of the deposited metal can be used to calculate each of these values.

Thermal Cutting Economics:

Due to the processes' many similarities, the methods used to estimate welding costs can also be used to estimate thermal cutting costs. With the exception of filler metal consumption, plasma arc cutting and welding, as well as ox fuel welding, share most of the same characteristics.

Estimation of Fees:

Workpiece made of sheet and plate metal are frequently shaped using ox fuel gas OFC and plasma arc cutting PAC.16 Steels made of carbon and low alloy are often the only materials that can be cut with oxygen fuel gas. High-alloy steels must have certain process adjustments in order to be cut. Any metal can be sliced with a plasma arc. Carbon steel, aluminum, and stainless steel are the most common metals used in plasma arc cutting applications. For plate beveling, form cutting, and piercing, both procedures are applicable.Both the plasma arc and ox fuel gas cutting operations can be carried out manually or with the aid of mobile machine tools. However, ox fuel gas cutting torches are often smaller and lighter than plasma arc cutting torches, and the plasma arc cutting technique necessitates a unique power supply. Therefore, ox fuel gas cutting is frequently favored in both manual and portable machine cutting applications when either ox fuel gas cutting or plasma arc cutting is appropriate.

Similar in design are the shape-cutting devices used for plasma arc and ox fuel gas cutting. In general, plasma arc form cutting machines are faster than comparable ox fuel gas cutting machines at cutting.When the right tools are used, plasma arc cutting can be faster than ox fuel gas cutting when cutting carbon steel plate that is less than 3 in. 75 mm thick. Plasma arc cutting speeds can be up to five times faster than those for ox fuel gas cutting for thicknesses smaller than 1 in. 25 mm. The decision between plasma arc cutting and ox fuel gas cutting when the base metal is beyond 1-1/2 in. 38 mm thick depends on additional parameters such cost of the equipment, load factor, and whether or not it will be used to cut nonferrous metals and thinner steel plates.Compared to plasma arc cutting equipment, the capital costs for ox fuel gas cutting equipment are comparatively low. The power source is the component of plasma arc cutting equipment with the highest cost. To cut thick plate, large, high-voltage power sources are necessary.

Plasma arc cutting stations are typically reserved for plates with a thickness of less than 1 in. 25 mm, and ox fuel gas cutting is utilized on thicker plates since the speed advantage of plasma arc cutting over ox fuel gas cutting declines with increasing plate thickness.The best plasma arc cutting machines have several torch configurations and either numerical or optical control. Plasma arc cutting is more cost-effective than ox fuel gas cutting.

Large fabrication plants, service centers, shipyards, and other facilities that need a lot of cut material often use plasma arc cutting in high-volume stations.Machines for high-capacity plasma arc cutting frequently have water tables. Although it further raises the initial capital cost, the use of water tables enhances cut quality and decreases smoke and glare associated with plasma arc cutting in ambient air [10]–[12].

Managing Costs:

Estimates can serve more than just the obvious purposes of facilitating bids or requests for quotes. They can also act as the first stage in the cost-controlling planning process. An overview or explanation of the key factors influencing costs must be taken into consideration when creating a cost estimate. A general comprehension of the welding or cutting procedure, method, or sequence of operations is required to address these variables. The more specific techniques, methods, and sequences needed to construct the task after a successful bid are developed from this basis.

Follow-up is needed throughout the job to implement the plan created during the estimating phase. All efforts to keep expenses within the range of the expectations established during the estimating stage could fail without this follow-up. An auditing, monitoring, and reporting system is the most effective type of follow-up. To verify that welders and welding operators are following the processes and methods as intended, such a system entails monitoring by supervisors and lead staff. In order to prevent noncompliance with the plan, manufacturing engineering or quality assurance experts also audit all plans created for the expected job. This allows for the comparison of a job's quality and cost results to the expectations formed during the estimate and the maintenance of successful cost control.Industrial operations like cutting and welding are frequently utilized in production, building, and maintenance work. In terms of economics, cutting and welding both have significant advantages that can help enterprises and sectors.

Benefits of Cutting:

i. **Material optimization:** Cutting enables precise and accurate material optimization, minimizing waste and raising material utilization efficiency, both of which can result in financial savings for organizations.
ii. **Flexibility:** Since cutting may be done on a variety of materials, it is possible to design and manufacture products with greater freedom, which helps reduce costs.
iii. **Time savings:** Cutting with contemporary equipment and methods can speed up production and turnaround times.

Improved product quality and uniformity can decrease the need for rework and increase customer satisfaction. This can be achieved by precise cutting.

Benefits of welding

i. **Savings:** Using welding to combine materials can save money by eliminating the need for pricy fasteners and other connectors.
ii. **Strength and Durability:** Welded joints are frequently stronger and more long-lasting than other types of joints, leading to products that last longer and require less upkeep.Flexibility in product design and development is possible thanks to welding's ability to unite a variety of materials.
iii. **Efficiency Gain:** Welding has the potential to be more rapid than other joining techniques, which boosts productivity and lowers labour costs [13], [14].

Advantages of Welding Economics:

Welding is a cost-effective and efficient joining procedure in various industries thanks to its many economic benefits. The following are some of the main economic benefits of welding:

1. Welding can be used to connect two or more materials, which can eliminate the need for expensive fasteners or connectors and hence lower material costs. This can save a lot of money on material costs, especially for big projects.
2. Compared to other joining techniques, welding can be a comparatively quick and efficient operation. Additionally, skilled welders can be trained very rapidly, which can aid in lowering labour costs in general.
3. Welding can be carried out swiftly and effectively, which can result in higher output and quicker project completion dates. This can assist companies in completing projects on time and for less money overall.

CONCLUSION

The information in this Chapter is meant to act as a general guide. Every task estimate has components that differ from the information provided here and may consequently need to be changed or extrapolated. Because a substantial amount of research is devoted to this stage of the estimate, specific information on the cost of welding, brazing, soldering, or cutting is typically well developed. These details outline how long it takes for different procedures to generate welds during the arc-on time. Arc-on time, however, only makes up a small fraction of the time a welder or operator spends creating welds. The remaining time is nonarc time, but it is still included in the total cycle time and, in many situations, can make up the majority of the time needed to produce welds.

REFERENCES:

[1] S. K. Ghosh, Manufacturing Engineering And Technology, *J. Mater. Process. Technol.*, 1991, Doi: 10.1016/0924-01369190107-P.

[2] A. Y. Adesina, Z. M. Gasem, And F. A. Al-Badour, Characterization And Evaluation Of Alcrn Coated Fsw Tool: A Preliminary Study, *J. Manuf. Process.*, 2017, Doi: 10.1016/J.Jmapro.2016.12.019.

[3] C. Brecher, D. Özdemir, And M. Brockmann, Introduction To Integrative Production Technology, *Prod. Eng.*, 2017, Doi: 10.1007/S11740-017-0730-Y.

[4] Proceedings Of The 3rd International Conference On Lasers In Manufacturing. 1986.

[5] Manufacturing Engineering Handbook, *Choice Rev. Online*, 2005, Doi: 10.5860/Choice.42-2831.

[6] B. S. Dhillon, Corrective Maintenance, In *Engineering Maintenance*, 2019. Doi: 10.1201/9781420031843-5.

[7] K. Suitsu And T. Yasuda, Stack Cutting In Ship Building, *J. Japan Weld. Soc.*, 1960, Doi: 10.2207/Qjjws1943.29.615.

[8] Proceedings - 16th International Symposium On Industrial Robots. 8th International Conference On Industrial Robot Technology. . 1986.

[9] S. T. Riches And J. D. Russell, Laser Welding Technology For Off-Road Vehicle Manufacture, 1998. Doi: 10.4271/981520.

[10] Proceedings - 16th International Symposium On Industrial Robots. 8th International Conference On Industrial Robot Technology. 1986.

[11] Advanced Manufacturing Systems, Proceedings Of The Ams ’86 Exposition And Conference. 1986.

[12] Advanced Manufacturing Systems, Proceedings Of The Ams ’86 Exposition And Conference. . 1986.

[13] S. Franklin, *Redefining Maintenance-Delivering Reliability*. 2008.

[14] M. Popescu, M. Vartolomei, And G. Mocuta, Economic Aspects Of Welding Process, 2009.

CHAPTER 17

ADVANCED GAS WELDING TECHNOLOGY AND ITS SIGNIFICANCE

Mr. Dipendra Kumar, Associate Professor
Department of Mechanical Engineering, Jaipur National University, Jaipur, India
Email Id:dipendra1987@jnujaipur.ac.in

ABSTRACT:

Gas welding can be used to fuse nonferrous metals without iron and ferrous metals, and it doesn't need electricity to do it. Oxy-acetylene welding, which mixes oxygen and a fuel gas often acetylene, is mostly used to attach thin metal pieces. To provide a graduate the edge they need to get a welding career, it combines in-depth technical knowledge, welding expertise, and exposure to cutting-edge technology. The fundamental abilities needed by businesses, such as production, product invention, and inspection processes are covered in this Chapter.

KEYWORDS:

Carbon Steel, Filler Metal, Gas, Metal Pieces, Peen Hammer.

INTRODUCTION

The joining of two or more pieces of metal with gas welding involves the use of a flame created by the combustion of a fuel gas, such as acetylene, and oxygen. The edges of the metal pieces are melted with this flame, and as they cool, they fuse together [1], [2]. The following steps are commonly included in the gas welding process. Setting up the equipment entails attaching the welding torch's oxygen and fuel gas tanks and setting the gas flow and pressure. To achieve a solid, spotless bond, the edges of the metal parts that will be welded are usually cleaned and ready. The edges may need to be filed or ground, and any rust, oil, or other impurities may also need to be eliminated. The flame is ignited using a spark lighter or another ignition source, and it is then shaped and heated to the required level. The flame is focused on the metal pieces, heating them until they start to melt.

Filler metal is injected to the joint when the metal starts to melt to aid in the joining of the pieces. Usually, a wire or rod is introduced into the joint to serve as the filler metal. To make a strong, continuous weld, the filler metal and torch are moved back and forth along the joint, melting the metal and adding filler as necessary. After the welding is finished, the junction is given time to slowly cool. This aids in preventing cracking and other weld problems. The kind of fuel gas utilized, the size and temperature of the flame, as well as the welder's expertise and experience, can all have an impact on the quality of a gas weld. Gas welding, however, can be a very efficient and dependable way to join metal pieces if done correctly with the right tools and technique [3]. Oxy-fuel welding, often known as oxy welding or gas welding, is a method of fusing metals by using the heat produced by a gas flame. When the fuel gas frequently used for welding, acetylene, is combined with the right amount of oxygen, a very high flame, ranging from 3150 to 3300. Gas welding can be used to fuse nonferrous metals without iron and ferrous metals, and it doesn't need electricity to do it. Oxy-acetylene welding, which mixes oxygen and a fuel gas often acetylene, is mostly used to attach thin metal pieces. To provide a graduate the edge they need to get a welding career, it combines in-depth technical knowledge, welding expertise, and exposure to cutting-edge technology. The fundamental abilities needed by business, such as production, product invention, and inspection processes. The following are the essential tools for doing gas welding:

1. An oxygen gas cylinder in a black tint with a brass valve with right-hand threads.
2. An acetylene gas cylinder with a valve that has left-hand threads and is maroon or red in color.
3. an oxygen pressure controller.
4. An regulator for acetylene pressure.
5. Black oxygen gas hose.
6. Red/maroon acetylene gas hose.
7. A gas lighter, blowpipe with a pair of nozzles and a welding flame.
8. Carts for carrying cylinders of oxygen and acetylene.
9. A set of spanners and keys.
10. Fluxes and filler rods.
11. Welder safety gear, such as an asbestos apron, gloves, and safety glasses.

We shall study gas welding's principles, methods, tools, varieties, applications, benefits, and drawbacks. In the liquid state welding method known as gas welding, fuel gases are burned to produce heat. The contact surfaces of welding plates that are held together to form a joint are also melted using this heat. The fuel gas used in this process is primarily oxy-acetylene gas. You can carry out this technique with or without the aid of filler material. If filler material is employed, it is manually fed into the weld region [4]. Most industrial procedures that call for welded joints use gas welding. The definition of welding is the use of heat to unite two metals, whether they are similar or dissimilar. The warmth offered The key instrument in oxyacetylene welding is the flame. The sole purpose of the welding apparatus is to keep the flame alive and under control. To function at its best, the flame must have the appropriate size, shape, and condition. By varying the acetylene and oxygen ratios, one can produce three different types of flames as shown in Figure 1.

By utilizing intense heat to melt the components together and then allowing them to cool, which results in fusion, welding is a fabrication method that unites materials, typically metals or thermoplastics. Welding is separate from lower-temperature processes that don't melt the base metal parent metal, such as brazing and soldering. The base metal is normally melted first, followed by the addition of filler material to create a pool of molten metal the weld pool, which cools to form a joint that, depending on the welded design butt, full penetration, fillet, etc., may be stronger than the base metal. To create a weld, pressure can either be applied alone, in combination with heat, or both. A type of shield is also necessary during welding to safeguard the filler. Welding can be done with a variety of energy sources, such as gas flames chemical, electric arcs electrical, lasers, electron beams, friction, and ultrasound. Welding can be done in a variety of settings, including the open air, underwater, and in space, despite the fact that it is frequently an industrial activity. Welding is a risky activity, thus safety measures must be taken to prevent burns, electric shocks, visual impairment, inhalation of toxic fumes, and exposure to strong ultraviolet radiation [5].

Application:

1. To combine thin metal plates, it is employed.
2. Both ferrous and non-ferrous metals can be joined with it.
3. Most sheet metal fabrication uses gas welding.
4. In the automotive and aviation industries, it is widely used.

Hou et al. [6] proposed a gas welding technology. The bulk of welding robots now used in manufacturing engineering applications fall into the teach-and-playback category. teaching welding trajectories prior to welding is time-consuming and ineffective. The currently available welding seam tracking techniques likewise rely on historical trajectory data. The current research topic in welding manufacturing is Intelligent Welding Manufacturing IWM. Intelligent Robot Welding Technology IRWT is the foundational technology of IWM. The implementation of IRWT required a system based on sensing technologies. This study examines a teaching-free welding technique for robotic gas metal arc welding GMAW based on a laser visual sensing system LVSS. A LVSS was first created. To increase the calibration effectiveness, a quick uniform calibration approach for LVSS is suggested. then, utilising a prior knowledge-based image processing technique [7], [8].

Shukla et al [9] developed an IoT Based system for gas welding technology. With the urbanisation and industrialisation of the world's growing population, demand for oil and gas is rising. Globally, the production of enormous oil sources is falling, necessitating the quest for additional conventional and unconventional fossil reserves. The quest for fossil fuel is shifting to deep-water and ultra-deep water offshore resources due to the rapid depletion of large onshore and shallow-water offshore oil fields. Naturally, new reserves are situated in harsh, hostile, and difficult-to-access environments. Due to the numerous serious health, safety, and environmental HSE issues associated with oil exploration, development, and production from such challenging offshore fields, there is an increasing need for sophisticated technological advancements to meet this demand.

With the urbanisation and industrialisation of the world's growing population, demand for oil and gas is rising. Globally, the production of enormous oil sources is falling, necessitating the quest for additional conventional and unconventional fossil reserves. The quest for fossil fuel is shifting to deep-water and ultra-deep water offshore resources due to the rapid depletion of large onshore and shallow-water offshore oil fields. Naturally, new reserves are situated in harsh, hostile, and difficult-to-access environments. Due to the numerous serious health, safety, and environmental HSE issues associated with oil exploration, development, and production from such challenging offshore fields, there is an increasing need for sophisticated technological advancements to meet this demand [10]–[12].

DISCUSSION

Compared to arc welding, the gas welding technique is far less complicated. All of the equipment is carefully linked throughout this operation. Through pressure regulators, the gas and oxygen cylinders were joined to the welding torch. Now, gas and oxygen are given to the torch at the right pressure so that they can combine properly. A striker ignites the flame. Make sure the torch's tip is pointing down. At this time, the welding torch's valves are used to control the flame. Depending on the welding situation, the flame is set at natural flame, carburizing flame, or oxidizing flame. The welding torch was now moving along the line where the junction was to be made. This will permanently link them by melting the interface component. The key instrument in oxyacetylene welding is the flame. The sole purpose of the welding apparatus is to keep the flame alive and under control. To function at its best, the flame must have the appropriate size, shape, and condition. By varying the acetylene and oxygen ratios, one can produce three different types of flames: A file is a piece of high-grade steel that has been hardened and has rows of teeth that are angled inward. It is used to remove extra material to smooth or fit metal parts. Typically, high carbon steel or tungsten steel is used to forge files, and then the teeth are cut, the steel is hardened, and the steel is tempered.

The gas-welding procedure uses an intense high-temperature burst that is produced by the ingestion of gas or a gas mixture Ogundimu, 2017. The workpieces to be joined are subsequently compressed using this engaged blast in conjunction with an outside filler material for legal welding. The most well-known type of gas welding is oxyacetylene gas welding. When welding with oxyacetylene gas, an oxygen and acetylene mixture burns and ignites at a temperature of about 3500°C. According to Shiri, Nazarzadeh, Sharifitabar, and Afarani 2012, when the engaged fire comes into contact with the workpieces, it softens the surface, creating a liquid pool and allowing welding to proceed. This method of welding can also be used for brazing, bronze welding, metal moulding, and cutting.

Type of Gas Welding Flame :

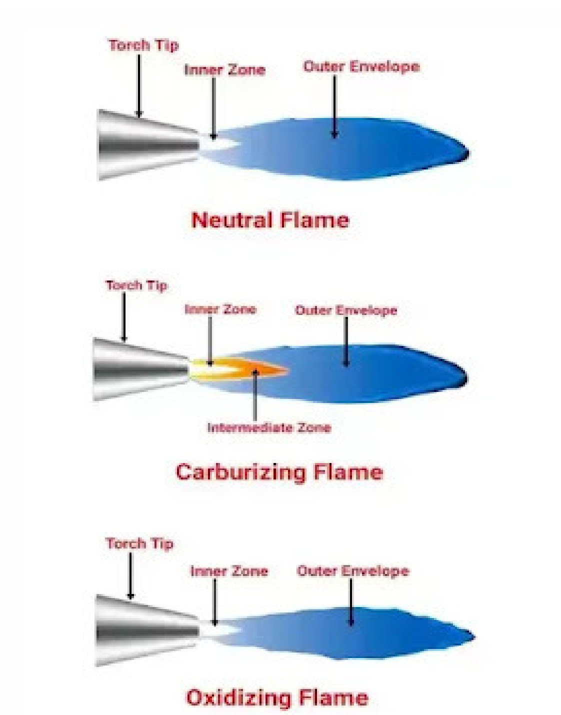


Figure 1: Represting the type of gas welding flame [Mechanical].

Tools And Accessories Used In Welding Shop:

a) Flat file

A file is a piece of high-grade steel that has been hardened and has rows of teeth that are angled inward. It is used to remove extra material to smooth or fit metal parts. Typically, high carbon steel or tungsten steel is used to forge files, and then the teeth are cut, the steel is hardened, and the steel is tempered.

b) Hack saw

The success of your project depends on the hacksaw blade you use. If you select the incorrect blade, you can have trouble cutting through the intended material. Similar to this, a blade that is the incorrect size will not fit on a hacksaw. The length of the hacksaw should be your first priority. The length of these instruments varies from 6 to 12 inches. The blade you choose should match the saw's length. The kind of material you're working with is the next thing to think about. Blades made of carbon steel are excellent for general-purpose use on hard plastic or soft metals like copper or lead, but bimetal blades are recommended when working with hard metals like stainless **steel.**

c) Try Square

Try squares are mostly used to mark lines on work pieces, check the squareness of neighboring surfaces or edges, and flatness of filed surfaces. It consists of a steel blade and stock that are fixed securely at a 90-degree angle to one another**.**

d) Steel Rule

A rounded, ball-shaped peen on one end of the head distinguishes the ball peen hammer from other varieties of hammers. In metalworking, this kind of hammer is frequently used to shape and form metal as well as to drive and set tiny nails or pins. You can also strike metal or other objects with the flat side of the hammerhead. Other types of hammers include sledgehammers, which have a large, heavy head and are used for heavy-duty tasks like breaking concrete or driving stakes, claw hammers, which have a curved claw on the opposite end of the head from the peen, and mallets, which have a softer head and are used for tasks that require a soft touch.

e) Ball Peen Hammer

A hammer is a hand tool made of tool steel, largely used for striking on metals. A hammer is named by its peen. The ball-shaped peen hammer is known as the ball peen hammer. The peen and face are hardenedA rounded, ball-shaped peen on one end of the head distinguishes the ball peen hammer from other varieties of hammers. In metalworking, this kind of hammer is frequently used to shape and form metal as well as to drive and set tiny nails or pins. You can also strike metal or other objects with the flat side of the hammerhead. Other types of hammers include sledgehammers, which have a large, heavy head and are used for heavy-duty tasks like breaking concrete or driving stakes, claw hammers, which have a curved claw on the opposite end of the head from the peen, and mallets, which have a softer head and are used for tasks that require a soft touch. The gas welding technique does not directly involve the use of punches. A gas flame is used to heat metal to its melting point, and after that, a filler metal is used to glue the heated metal pieces together. This procedure is less focused on using punches and more on heating, melting, and connecting metal components.

Punches may, however, be utilized in gas welding-related metalworking or manufacturing procedures. For instance, metal pieces that need to be welded together may be marked with punches to ensure exact alignment and location throughout the welding process. Punches can also be used to make tiny depressions or indentations in metal components [13].

f) Punches

The gas welding technique does not directly involve the use of punches. A gas flame is used to heat metal to its melting point, and after that, a filler metal is used to glue the heated metal pieces together. This procedure is less focused on using punches and more on heating, melting, and connecting metal components. Punches may, however, be utilized in gas welding-related metalworking or manufacturing procedures. For instance, metal pieces that need to be welded together may be marked with punches to ensure exact alignment and location throughout the welding process. Punches can also be used to make tiny depressions or indentations in metal components, which can aid in.

g) Chipping Hammer

The chipping hammer has served the welding industry well for many years as the basic tool for the removal of slag from Shielded Metal Arc Welding and Flux Core Arc Welding. Fabricators, currently employ other methods in production facilities to speed up the removal of slag from welds. The best slag is one that peels off by itself and only needs a light effort to remove the balance of it. Getting the correct filler metal, shielding gas, if used, and flux combination will help in this regard. Besides the chipping hammer, air chisel, and air hammer, many other pneumatically powered tools are used. The needle scalar is also widely used for removing slag that is stuck to the weld and doesn't readily come right off. The needle scalar leaves fewer tool marks than an air chisel or air hammer. In larger production facilities, especially the steel building manufacturers, the use of a tool called the Wheelabrator is another more extensive piece of powered equipment for cleaning up base material after welding. Sandblasting and shot blasting are other alternatives for post-weld cleanup in large-scale operations when hand-working the components is cost prohibitive or not practical.

h) Electrode Holder

The insulated handle that clamps onto the electrode is known as an electrode holder. To regulate the arc when welding, the welder uses this tool. Excellent current transfer between the electrode and the holder is one benefit. Using two holes at 45° and 90° to weld in various positions

i) Tongs

When welding, a type of tool called tongs can be used to handle hot metal. They are made to prevent the welder from touching the hot surface directly while grasping and manipulating metal objects. For safety reasons, this is crucial since it can help avoid burns or other accidents. Tongs typically have two arms joined by a pivot or hinge and are constructed of metal. The metal object may be moved around by the welder since the arms are made to grab it firmly. Some tongs may have specialized tips or ends that are made for carrying out particular tasks, like grasping spherical objects or squeezing into small spaces. It's crucial to get the right tongs for welding. are used to handle the hot metal welding job for positioning or while cleaning.

j) Wire Brush

Yes, a wire brush can be held in place using tongs. Wire brushes are frequently used in welding to clean the metal's surface and remove slag from the welds. The wire brush usually has a wooden handle or grip with bristles or steel wires placed on it. The welder typically scrubs the metal's surface back and forth when using a wire brush for cleaning. This helps clear the surface of any dirt, rust, or other material that may be there. The welder will often use the wire brush to gently scrape away any extra material that has accumulated on the weld's surface when removing slag from the joint.

k) Earth Clamp

The earth clamp's function is to give the electrical current utilized in welding a secure and dependable path of return. When the welding machine is in use, electricity is produced. This electricity travels from the welding machine through the electrode, into the work piece, and then returns through the earth clamp to the ground terminal of the welding machine. The electrical circuit would be incomplete without a correctly attached earth clamp, which could result in issues like welding flaws or even electrical shock. The welder will normally choose a spot on the work piece or welding table where the clamp may be safely fastened before using an earth clamp. The connection is then made strong and stable by tightening the clamp against the metal surface [14].

Advantages and Disadvantages:

Advantages

1. It is simple to use and does not need a highly skilled operator.
2. In comparison to other welding methods like MIG and TIG, equipment costs are modest.
3. It may be applied on-site.
4. More portable than other types of welding, the equipment.
5. Additionally, it can be used to cut gas.

Disadvantages

1. It offers a rough surface finish. After welding, this technique needs a finishing step.
2. Large heat impacted zones during gas welding might influence the mechanical properties of the parent material.
3. High temperature naked flames present a greater safety risk.
4. It only works with thin, soft sheets.
5. No shielding area which causes more welding defects.

Application:

1. A multitude of industries employ gas welding. Here are a few of the most typical.
2. Repair work: One of the most often used gas welding applications is for repairs.
3. Fabrication of sheet metal: Gas welding is a simple method for joining thin to medium-gauge sheet metals.
4. Aviation industry Welding with oxygen-acetylene is frequently used to connect different aircraft elements.

5. Used in the automotive sector to weld frame and chassis components.
6. Joining High carbon steel: High carbon steel may be melted very effectively with gas welding.

As we've seen, one of the most significant and popular weld techniques is gas welding. Gas welding is one of the most often used weld techniques due to a combination of its comparatively low cost, simplicity of usage, and portability.

Safety Precautions in Gas Welding

While working in a welding shop, the following safety precautions must be taken into consideration:

1. Gas cylinders should always be handled carefully.
2. Prior to opening a cylinder valve, the regulator's adjustment screw must be completely loosened.
3. Never light a torch with matchsticks.
4. Never use grease or oil to lubricate the regulator valve as this could result in an explosion.
5. Wear eye protection whenever working.
6. The shop must have adequate ventilation.
7. Acetylene cylinders should be kept upright when being stored.
8. Avoid opening acetylene cylinders close to flames or sparks.
9. Never use pliers to remove torch tips.
10. The cylinder must not leak.
11. Consistently cover the valves with safety caps.
12. Bear in mind where the fire extinguishers are.

CONCLUSION

Nonferrous metals devoid of iron and ferrous metals can be fused using gas welding, which doesn't require electricity. Most typically, thin metal parts are joined by oxygen-acetylene welding, which combines oxygen and a fuel gas generally acetylene. It brings together in-depth technical knowledge, welding expertise, and exposure to cutting-edge technology to provide a graduate the edge they need to land a welding career. This Chapter covers the core skills required by businesses, such as production, product invention, and inspection procedures.

REFERENCES:

[1] J. Devaraj, A. Ziout, and J. E. A. Qudeiri, 'Dissimilar non-ferrous metal welding: An insight on experimental and numerical analysis', *Metals*. 2021. doi: 10.3390/met11091486.

[2] Z. Fei *et al.*, 'Effect of heat input on weld formation and tensile properties in keyhole mode TIG welding process', *Metals (Basel)*., 2019, doi: 10.3390/met9121327.

[3] J. D. Tucker, T. K. Nolan, A. J. Martin, and G. A. Young, 'Effect of travel speed and beam focus on porosity in alloy 690 laser welds', *JOM*, 2012, doi: 10.1007/s11837-012-0481-3.

[4] R. G. N. Silva, A. de S. P. Pereira, J. M. S. de Sousa, M. Pereira, and R. H. G. e Silva, 'Tribological comparison of Inconel 625 coatings deposited via laser metal deposition and tungsten inert gas welding process', *J. Laser Appl.*, 2020, doi: 10.2351/7.0000090.

[5] Y. Guo, H. Pan, L. Ren, and G. Quan, 'An investigation on plasma-MIG hybrid welding of 5083 aluminum alloy', *Int. J. Adv. Manuf. Technol.*, 2018, doi: 10.1007/s00170-018-2206-4.

[6] Z. Hou, Y. Xu, R. Xiao, and S. Chen, 'A teaching-free welding method based on laser visual sensing system in robotic GMAW', *Int. J. Adv. Manuf. Technol.*, 2020, doi: 10.1007/s00170-020-05774-0.

[7] S. Yan, H. Chen, Z. Zhu, and G. Gou, 'Hybrid laser-metal inert gas welding of Al-Mg-Si alloy joints: Microstructure and mechanical properties', *Mater. Des.*, 2014, doi: 10.1016/j.matdes.2014.04.062.

[8] M. Gierth, P. Henckell, Y. Ali, J. Scholl, and J. P. Bergmann, 'Wire Arc Additive Manufacturing (WAAM) of aluminum alloy AlMg5Mn with energy-reduced Gas Metal Arc Welding (GMAW)', *Materials (Basel).*, 2020, doi: 10.3390/ma13122671.

[9] A. Shukla and H. Karki, 'Application of robotics in offshore oil and gas industry-A review Part II', *Rob. Auton. Syst.*, 2016, doi: 10.1016/j.robot.2015.09.013.

[10] B. Han, H. Wang, H. Huang, T. Liu, G. Wu, and J. Wang, 'Micro-fabricated packed metal gas preconcentrator for enhanced monitoring of ultralow concentration of isoprene', *J. Chromatogr. A*, 2018, doi: 10.1016/j.chroma.2018.08.058.

[11] J. Norrish, *Advanced Welding Processes*. 2006. doi: 10.1533/9781845691707.

[12] A. K. Bhaduri, 'Development and Deployment of Welding Technologies for the Indian Sodium-Cooled Fast Reactor and Advanced Ultra-supercritical Thermal Power Programmes', *Trans. Indian Inst. Met.*, 2021, doi: 10.1007/s12666-021-02260-3.

[13] K. A. Bello, M. A. Maleque, and A. A. Adebisi, 'Processing of Ceramic Composite Coating via TIG Torch Welding Technique', in *Encyclopedia of Renewable and Sustainable Materials*, 2020. doi: 10.1016/b978-0-12-803581-8.10807-0.

[14] B. Irving, 'Trying to make some sense out of shielding gases', *Weld. J. (Miami, Fla)*, 1994.

CHAPTER 18

INTRODUCTION TO ADVANCE LASER BEAM MACHINING

Mr. Ashok Singh Gour, Assistant Professor
Department of Mechanical Engineering, Jaipur National University, Jaipur, India
Email Id:asgour@jnujaipur.ac.in

ABSTRACT:
One of the most popular thermal energy-based, non-contact types of advanced machining methods that may be utilised on practically any material is laser beam machining LBM. A laser beam is directed towards the undesirable component of the parent material, melting and vaporising it. This technique uses a variety of parts, including a laser source, optics, a control system, a cooling system, and a delivery system.

KEYWORDS:

Atom, Beam, Cutting, Leaser, Welding.

INTRODUCTION

The laser is a potent light source with unique features not present in common light sources like tungsten lamps, mercury lamps, etc. The special characteristic of a laser is the extremely low divergence of its light waves as they travel across very long distances. A traditional light source emits light as a tangle of distinct waves that cancel one another randomly and can only travel extremely short distances. A circumstance where numerous pebbles are simultaneously tossed into a pool serves as an analogy. Each pebble creates its own wave. Because the pebbles are tossed at random, the waves they produce cancel each other out, causing them to travel only a very short distance. In contrast, if pebbles are dropped into a pool one at a time, at the same location, and at regular intervals of time, the waves that are created strengthen one another and go farther. In this instance, it is claimed that the waves move coherently. The light waves in a laser are perfectly in phase with one another and have a set phase relationship as a result [1]–[3].

The laser term, which stands for Light Amplification by Stimulated Emission of Radiation, has been used in more fascinating applications than any other scientific discovery of the 20th century. An American physicist named Charles Hard Townes and two Soviet scientists named Alexander Mikhailovich Prokhorov and Nikolai Gennediyevich Basov, who shared the prestigious Nobel Prize in 1964, were the first to explain the fundamentals of laser technology. The first person to experimentally demonstrate a laser by flashing light through a ruby crystal was TH Maiman of the Hughes Research Laboratory in California in 1960. These light beams are likewise characterised by great monochromaticity and directionality. As a result, during the course of a laser beam, the light waves have the same colour wavelength in addition to being in the same phase. Ordinary light has a fairly quick spread in its beam. The laser beam, on the other hand, is tightly focused and barely spreads. The spread of laser light has been discovered to be just approximately 3 kilometres broad even after travelling to the surface of the moon. Assuming that regular light was able to reach the moon, its beam would have fanned out considerably, resulting in a diameter of light on the moon.

The laser's ability to concentrate its energy to extraordinarily high intensities, with the intensity essentially maintaining constant across extended distances due to low divergence, is another notable characteristic. The intensity of a laser beam climbs to a few hundred billion watts per square centimetre when it is focussed by a lens to a spot with a diameter of 1/1000 of a centimetre. This focused energy is so strong that sparks can readily be produced by the air it ionises. Even the hardest materials, like diamond, can be melted in a split second when the beam from a powerful laser is focused. Due of its distinct qualities, the laser is a crucial tool in many applications. The first major use of laser was in the lunar range experiment of the Apollo II Mission in 1969, when pulses from a ruby laser were delivered from the earth to an array of retro reflectors erected on the moon's surface. The reflected beams were picked up by appropriate detectors, and the distance between the moon and the earth was determined with a 15 cm accuracy by calculating the time it took the pulses to travel from the earth to the moon and back.

Since the initial laser demonstration in 1960, new laser applications in a variety of fields are reported virtually every day. Applications for lasers In the areas of industry, medicine, military operations, research, and so forth. Additionally, laser has already made significant advances in engineering, data storage, holography, photography, surgery, and other fields. The main significant laser applications are discussed in the Chapters on Laser Applications, even if it is not possible to demonstrate all of the laser uses documented thus far in this tiny book. A groundbreaking and quickly developing field, laser beam technology has a wide range of uses in many different fields, including industry, medical, communication, entertainment, and scientific research [4]–[6]. Laser beam technology makes use of intensely focused, coherent, and monochromatic light beams created by photons' stimulated emission. Laser beams, in contrast to traditional light sources, may be concentrated to a very small point, offering excellent precision and accuracy. Due to its distinct characteristics, such as their high intensity, directionality, and rapid pulsing, laser beams are an appealing technology for a variety of uses.

When Albert Einstein first put forth the idea of stimulated emission in the early 20th century, laser technology had its beginnings. Nevertheless, Theodore Maiman did not create the first useful laser until the 1960s. Since then, the development of new laser types, enhanced optics, and sophisticated control systems has sped up the development of laser technology. Today, the manufacturing sector uses laser beam technology for a variety of purposes, including cutting, welding, drilling, marking, engraving, and surface treatment. Laser beams are employed in medicine for cancer treatment, surgery, and imaging diagnostics. While laser-based entertainment systems are utilised for light shows and special effects, laser communication systems are used to transmit high-speed data across large distances. Laser beams are employed in scientific research for spectroscopy, microscopy, and holography as well as for examining the properties of materials. Furthermore, laser beams are employed in remote sensing techniques like LIDAR Light Detection and Ranging, which employs laser beams to measure distances and produce three-dimensional maps of the environment. In conclusion, the development of laser beam technology has significantly improved many different sectors and changed how we live and work. Future potential and innovation are being fueled by the creation of new laser technologies and applications.

History of Laser Technology:

1960s

The first CO2 laser was created in 1964 and only produced one milliwatt of power. CO2 lasers with a power output of more than 1,000 watts were practical by 1967. In May 1967, Peter Houldcroft of TWI The Welding Institute in Cambridge, England, used an oxygen-assisted CO2 laser beam to cut through a sheet of steel that was 1 mm thick, marking the beginning of commercial laser materials processing.1970s The earliest Laser Machining applications were made possible by ongoing improvements to CO2 lasers as well as the creation of new kinds of lasers. In 1975, Laser-Work AG created the first 2-axis laser system. The initial applications were driven by the car and aviation industries, who were learning how useful lasers were for metal cutting and welding. 1980s A new era of Laser Materials Processing began with the development of small, affordable lasers like the Carbon Dioxide Slab Laser. Applications now include processing organic materials like plastic, rubber, and foam in addition to cutting and welding metal.

Dubey et al [1]conducted a study in which they characterized and tested the a Laser beam machining LBM is one of the most widely used a non-contact, advanced machining method that uses heat energy and may be used on practically any material. The laser beam is concentrated to melt and vaporise the undesired component from the parent component. It works well for cutting geometrically challenging profiles and drilling tiny holes in sheet metal. The most well-known types of lasers for machining in industries are CO2 and Nd:YAG lasers. By examining the various aspects that influence the quality features, researchers have recently investigated a number of strategies to enhance the LBM process performance. According to practical and theoretical investigations, selecting the right laser parameters, material parameters, and operating parameters can significantly increase process performance. In this essay, the research on LBM of various materials and shapes that has been done up to this point is reviewed. It details the theoretical and experimental LBM research done to boost process efficiency. For the purpose of determining the ideal laser beam cutting condition, a number of modelling and optimisation strategies have been critically reviewed. The final section of this essay covers LBM advancements and identifies a research trend for the future. Elsevier Ltd. is a 2007 registered trademark [7], [8].

Xie et al [2] evidence for While improvements in laser technology now enable the processing of almost any material, additional precision and efficiency optimisation is highly desirable, particularly through the creation of real-time detection and feedback systems. Here, we use visual observations of the workpiece being processed by the laser to demonstrate the use of neural networks for system monitoring. We demonstrate quantification of unwanted laser beam alterations, such as translation and rotation, as well as real-time closed-loop feedback capable of promptly stopping laser processing after cutting through a copper layer that is around 450 nm thick. We demonstrate that our method can identify beam position translations that are smaller than the observation camera's pixel size. We also demonstrate a data augmentation technique that may be applied to dramatically lower. Unintentional beam rotations and translations are discovered simultaneously, proving that it is possible to identify numerous laser machining characteristics at once. Neural networks are the best option since they can be trained directly from experimental data and don't need to be aware of the physical characteristics of laser machining. Gao et al. [3]stated that a Laser beam machining LBMDevice miniaturization is an emerging advanced technology in the 21st century. The manufacturing of micro- and nano-scale components is necessary for the miniaturisation of devices in several sectors. These components' characteristics range from sub-micron to a few hundred microns, and they have a high tolerance to a wide variety of engineering materials. These industries mostly focus on optics, electronics, biology, medicine, communications, and avionics. This study examined the most recent developments in micro- and nano-machining techniques, such as focused ion beam, laser, and micro-electrical discharge machining. Additionally, the four machining techniques were contrasted in terms of surface polish, minimum feature size, maximum aspect ratio, and materials used to manufacture the workpiece.

DISCUSSION

A laser is a device that uses optical amplification to produce a coherent light beam. Gas lasers, fibre lasers, solid state lasers, dye lasers, diode lasers, and excimer lasers are just a few of the several types of lasers. These various laser types all have the same fundamental parts [9].

Types of Leaser Beam Technology:

There are numerous varieties of laser beam technology, each with special characteristics and uses. The following are a few of the most popular kinds of laser beam technology.These lasers produce the laser beam through a solid crystal or glass medium. They are frequently employed in material processing operations like drilling, welding, and cutting.These lasers produce the laser beam by using a gas medium, such as carbon dioxide, helium-neon, or argon. They are employed in processes including laser surgery, academic research, and laser-based production.These lasers produce the laser beam using a semiconductor substance, such as gallium arsenide or indium phosphide. They are frequently utilised in communication systems like laser diodes and fibre optic networks.The laser medium in these devices is a liquid dye. They are employed in scientific research techniques like fluorescence microscopy and spectroscopy.These lasers produce a high-energy laser beam using a combination of noble gases and halogens. They are frequently employed in commercial and medical settings, including those involving eye surgery and the production of microelectronics.The laser medium in these devices is a fibre optic cable. They are frequently employed in communication systems as well as in processes for processing materials including welding, cutting, and drilling.The laser medium in these devices is carbon dioxide gas. They are frequently employed in gynaecology and dermatology as well as materials processing, such as metal cutting and welding.

How is Laser Technology Used?

Many of the things we use on a daily basis use lasers as essential parts. Laser technology is used in consumer items like Blu-Ray and DVD players to read data from discs. Lasers are used in bar code scanners to process data. Numerous surgical treatments, like LASIK eye surgery, also involve lasers. Lasers are used in manufacturing to cut, engrave, drill, and mark a variety of materials.

A) Laser Action & Quantum Theory :

Quantum theory's well-established principles serve as the foundation for laser action. The greatest modern physicist, Albert Einstein, stated that an excited atom or molecule will emit photons packets of light with the same wavelength as the impinging electromagnetic wave when stimulated by an electromagnetic wave i.e., light. By designing and creating the first maseracronym for microwave amplification by stimulated emission of radiationCharles Townes was the first to use this stimulated emission mechanism as an amplifier. A 1.25 cm wavelength in ammonia vapour led to the creation of the first maser. Townes and Arthur Leonard Schawlow invented the idea of employing a laser amplifier and an optical mirror cavity to create the maser at optical wavelengths.

B) Principle of Laser Action:

The quantum theory asserts that each atom can only have energies in specific discrete states or energy levels. The atoms are typically in their ground state, which has the lowest energy. The atoms in a substance can be energised to move to one of the higher levels when light from a strong source, such as a flash lamp or a mercury arc, strikes it. Absorption is the name of this procedure. The atom emits a photon as it returns to its initial ground state after a very little time on the order of 10-8 second in that level. This action is referred to be spontaneous or an emission. The two processes, called spontaneous emission and absorption, occur in a standard light source, If an outside photon with the exact energy needed for spontaneous emission strikes an atom while it is still in its excited state, the energy of the outside photon is increased by the energy released by the excited atom. Additionally, both photons are released from the same excited state in the same phase. The operation of lasers depends on this procedure, known as stimulated emission. The laser is therefore comparable to a spring that has been cranked up and cocked, as the atom is stimulated or encouraged to release its photon earlier than it would have done typically under spontaneous emission. To unlock it, a key is required,

More and more atoms are forced to release photons when favourable conditions are created for the stimulated emission, starting a chain reaction and releasing a tremendous amount of energy. This leads to a rapid buildup of energy that emits light of a specific wavelength monochromatic light, moving coherently in a specific, fixed direction (Figure.1). Amplification by stimulated emission is the name given to this phenomenon. The population of a level is the total number of atoms present there at any particular time. The population of the lower level or ground state is often higher than that of the upper level when the material is not activated externally. Population inversion is the process that occurs when the regular occupancy is reversed, with more people living on the upper level than the lower level. For a laser action, this scenario is necessary. The met stable state, or upper energy level, must have a long life time for any stimulated emission to occur, meaning that the atoms must pause there for a longer period of time than they do at the lower energy level, Consequently, the exciting pumping mechanism for laser action.

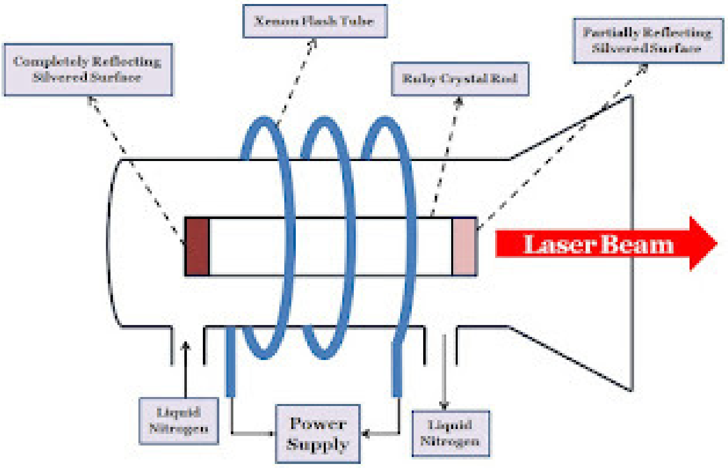


Figure 1: Representing the Level of Leaser System [Physics Vidhyapits].

The basis for the operation of lasers is a procedure known as stimulated emission, which Albert Einstein initially outlined in 1917. A photon of a specific frequency interacts with an excited atom or molecule to trigger a process known as stimulated emission, which results in the release of a second photon that has the same frequency, direction, and phase as the first photon. The original photon gets amplified as a result of this. Pumping energy into a medium, such as a gas, solid, or semiconductor, and causing a significant number of atoms or molecules to get excited, produces a population inversion in a laser. A second photon with the same frequencyas shown in figure 1, direction, and phase as the first is released when a photon of the right frequency interacts with an excited atom or molecule. This process is known as stimulated emission. Following this, the second photon interacts with additional excited atoms or molecules, causing additional stimulated emission and an avalanche effect. This causes a series of events to happen, and the end consequence is the emission of a coherent, monochromatic, highly directional beam of light.

The characteristics of the laser medium and the laser cavity determine the attributes of the laser, such as wavelength, pulse duration, and power. With each trip through the laser medium, the laser beam is amplified because the laser cavity is an optical resonator made up of two mirrors, one of which is slightly reflecting. While the type of mirror coating and the calibre of the laser medium affect the laser's pulse duration and strength, the distance between the mirrors dictates the laser's wavelength and beam quality. Overall, the basis of laser action is the stimulation of emission, which amplifies light and produces a coherent, monochromatic beam of light with distinct properties.

Advantages and Disadvantages:

Depending on the application and environment, laser beam technology has a number of benefits and drawbacks. The following are some of the most notable benefits and drawbacks of laser beam technology [10], [11].

Advantages:

1. Laser beams may be concentrated to a very small point, resulting in great precision and accuracy in manufacturing operations such as drilling, welding, and cutting.
2. Because laser beams don't need to come into direct touch with the workpiece, there is less chance of contamination or damage, and processing can proceed at a fast rate.
3. A variety of materials, including metals, polymers, ceramics, and composites, can be worked with by laser beams.
4. Laser beams can be very effective, using little power and generating little waste.
5. High-speed processing with laser beams enables quicker production at more affordable prices.

Disadvantages:

1. If not utilised appropriately, laser beams can constitute a safety risk by potentially damaging the eyes, burning the skin, or igniting a fire.
2. The cost of laser beam technology can be high because it calls for specialised tools, facilities, and skilled workers.
3. Limited depth of penetration: Lasers may not be able to penetrate deeply into all materials, which limits their applicability in some situations.
4. Surface deterioration: Some materials may experience surface deterioration from laser beams, such as cracking or discolouration, which may change the material's characteristics.
5. The use of laser beam technology may result in the production of hazardous waste, such as contaminated materials or toxic fumes, which must be properly disposed of.

Application of Leaser Beam Technology:

There are many applications for laser technology including the following:

1. Laser Range Finding.
2. Information Processing DVDs and Blu-Ray.
3. Bar Code Readers.
4. Laser Surgery.
5. Holographic Imaging.
6. Laser Spectroscopy.
7. Laser Material Processing.
8. Cutting.
9. Engraving.
10. Drilling.
11. Marking.
12. Surface Modification.

CONCLUSION

Laser is an abbreviation for Light Amplification by Stimulated Emission of Radiation. Resonant effects are critical for laser functioning. A laser produces a coherent electromagnetic field, which means that all of the waves in the beam have the same frequency and phase. Because of its coherence, the laser may provide a focused and intense output. A laser may create a coherent beam of electromagnetic energy with amazing features and uses by stimulating the emission of photons from an active medium, such as a crystal or gas, and reflecting them back and forth between mirrors to increase the intensity.

REFERENCES:

[1] A. K. Dubey and V. Yadava, 'Laser beam machining-A review', *International Journal of Machine Tools and Manufacture*. 2008. doi: 10.1016/j.ijmachtools.2007.10.017.

[2] Y. Xie *et al.*, 'Deep learning for the monitoring and process control of femtosecond laser machining', *JPhys Photonics*, 2019, doi: 10.1088/2515-7647/ab281a.

[3] S. Gao and H. Huang, 'Recent advances in micro- and nano-machining technologies', *Frontiers of Mechanical Engineering*. 2017. doi: 10.1007/s11465-017-0410-9.

[4] P. Parandoush and A. Hossain, 'A review of modeling and simulation of laser beam machining', *International Journal of Machine Tools and Manufacture*. 2014. doi: 10.1016/j.ijmachtools.2014.05.008.

[5] P. Patel, P. Gohil, and S. Rajpurohit, 'Laser Machining of Polymer Matrix Composites : Scope , Limitation and Application', *Int. J. Eng. Trends Technol.*, 2013.

[6] S. Umredkar and V. Bhoyar, 'Advance Manufacturing Processes Review Part V: Laser Beam Machining (LBM)', *Int. Res. J. Eng. Technol.*, 2019.

[7] G. Chang and Z. Wei, 'Ultrafast Fiber Lasers: An Expanding Versatile Toolbox', *iScience*. 2020. doi: 10.1016/j.isci.2020.101101.

[8] Q. McCulloch, J. G. Gigax, and P. Hosemann, 'Femtosecond Laser Ablation for Mesoscale Specimen Evaluation', *JOM*, 2020, doi: 10.1007/s11837-020-04045-3.

[9] J. Dutta Majumdar and I. Manna, 'Laser processing of materials', *Sadhana - Acad. Proc. Eng. Sci.*, 2003, doi: 10.1007/BF02706446.

[10] M. K. Bhuyan *et al.*, 'High aspect ratio nanochannel machining using single shot femtosecond Bessel beams', *Appl. Phys. Lett.*, 2010, doi: 10.1063/1.3479419.

[11] W. Wei, Z. Di, D. M. Allen, and H. J. A. Almond, 'Non-traditional machining techniques for fabricating metal aerospace filters', *Chinese J. Aeronaut.*, 2008, doi: 10.1016/S1000-9361(08)60057-6.

CHAPTER 19

RUBY LASER BEAM USED IN WELDING INDUSTRY

Mr. Ranveer Singh, Associate Professor
Department of Mechanical Engineering, Jaipur National University, Jaipur, India
Email Id:ranveer@jnujaipur.ac.in

ABSTRACT:
The goal of a Ruby laser is to induce emission to produce a focused beam of red light at a certain wavelength 694.3 nanometers. Ruby lasers are frequently employed in scientific and medical applications, such as in spectroscopy, holography, and dermatology. The term Ruby refers to the material used as the laser's active medium, which is a synthetic ruby crystal that is optically pumped using flash lamps to generate the laser light. A Ruby laser's main goal is to offer a dependable and potent source of coherent light at a particular wavelength for a variety of applications, including industrial processes like cutting and welding metals and military ones like range finding and targeting.

KEYWORDS:

Crystal, Energy Level, Flash Pump, Laser Light, Stimulated Emission.

INTRODUCTION

A solid-state laser known as a ruby laser uses a synthetic ruby crystal as its gain medium. The first time it was used, on May 16, 1960, at Hughes Research Laboratories, it was the first kind of laser ever created. It was operated by Theodore H. Ted Maiman. Aluminium oxide with a tiny quantity 0.05% of chromium, which gives the ruby mineral corundum its distinctive pink or red color by absorbing green and blue light, makes up the ruby mineral. Ruby laser is a When utilized as a pulsed laser, the ruby laser emits red light at a wavelength of 694.3 nm. The excited atoms in the ruby rod continue to be stimulated after receiving a pumping flash from the flash tube, which normally lasts for around a millisecond [1]–[3].The first laser in historyalso referred to as the ruby laserwas created by Theodore Maiman in 1960. Aluminum oxide, in which part of the aluminium atoms have been swapped out for chromium atoms, makes up ruby crystal. The ruby's vivid red hue is derived from chromium.

A cylinder-shaped ruby crystal is created in a ruby laser. On one end, a mirror that entirely reflects light is set up, and on the other, a mirror that partially reflects light. A white light flash that starts the laser action is produced by a high-intensity bulb spiraled around the ruby cylinder.The green and blue wavelengths in the flash raise the energy level of the electrons in the chromium atoms. The electrons release their distinctive ruby-red glow as they return to their regular form. Once the light pulse reaches a high power and exhausts the crystal's energy, it generates what we normally refer to as laser light. Some of this light is reflected back and forth by the mirrors inside the ruby crystal, inspiring other excited chromium atoms to make more red light.

Despite the development of numerous other types of lasers since Maiman's creation, the ruby laser is still employed, primarily as a light source for medical and aesthetic procedures, as well as for high-speed photography and pulsed holography.One of the first lasers to be created, the Ruby laser is named after the artificial ruby crystal that serves as the laser's active ingredient. Theodore Maiman first suggested the idea for a ruby laser in 1959, and later that year he was able to build and successfully demonstrate the first functional Ruby laser.A technique known as stimulated emission is used by the Ruby laser to create a highly focused beam of light. A flash bulb surrounds a ruby crystal that is located inside the laser. The flash lamp emits a brilliant flash of light when it is turned on, which the ruby crystal absorbs. The electrons in the ruby crystal become energized and shift to a higher energy level as a result of this energy absorption.The electrons release energy in the form of photons light particles as they return to their initial energy level. This mechanism, which is also known as spontaneous emission, causes photons to randomly scatter in all directions. These photons can cause an excited electron to produce a second photon in the same direction as the first one if one of them occurs to pass by another excited electron. This procedure, known as stimulated emission, results in a series of photons that all move in the same direction and at the same time to produce a focused beam of laser light.

The Ruby laser emits light with a wavelength of 694.3 nanometers, which falls inside the visible spectrum's red region. The transfer of electrons in the ruby crystal between two energy levels results in this particular wavelength.Numerous industries use the Ruby laser, including spectroscopy, holography, dermatology, and the military for range finding and targeting. It is a useful instrument in many scientific and industrial domains due to its capacity to produce a highly concentrated beam of light at a particular wavelength. However, other kinds of lasers, such the Nd:YAG laser, which can generate higher power levels and operate at a variety of wavelengths, have largely supplanted it.The well-known laser range experiment, carried out with a corner reflector that the Apollo astronauts had put on the Moon, employed a pulsed ruby laser. Using a three stage solid state laser, this calculated the distance to the Moon with an accuracy of roughly 15 cm.In order to generate a population inversion, a ruby laser typically consists of a ruby rod that must be blasted with extremely high energy, typically from a flashtube. The rod is frequently sandwiched between two mirrors to create an optical cavity that oscillates the fluorescence light from the ruby, stimulating emission [4]–[6].T.H. Maiman demonstrated the first laser emission utilising ruby crystal in 1960.Aluminium oxide Al_2O_3 is known as sapphire when a little amount 0.05% of Cr^{3+} replaces Al^{3+}. The chromium ions give the ruby its pink colour and are what cause it to emit light.

A cylindrical ruby rod with a diameter of about 0.8 cm and a length of around 15 cm serves as the active component. The ends are flatter than a tenth. To avoid complete internal reflection, the rod's cylindrical surface is grounded. Population inversion is produced via the optical pumping technique. It has a ruby rod at the axis and is shaped like a helical xenon discharge tube. A circulating water arrangement is employed to provide cooling since only a small portion of the pump's energy is used to excite the atoms. the remainder produces heat. By placing a completely reflective plate on the left and a partly reflective plate on the right, a resonant cavity is created. Depending on the optical source of the pumping mechanism, the ruby laser is commercially available as both a pulsed and continuous wave CW laser. The two primary pump bands in a ruby laser, $4F_1$ and $4F_2$, are centred at wavelengths of 0.42 m violet and 0.55 m green, respectively. The energy levels in a ruby laser are those of Cr^{3+}. The width of each pump band is 1000.

There are two sublevels of the metastable levels. $4F_1$ with an E=29 cm^{-1} separation.Other flash lights range in brightness from 0.42 to 0.56 m, but a xenon flash lamp emits a flash light of 5600

m. Pump bands E1 and E2 exist, together with a metastable band M and the ground level G. Pump bands have a life length of 10-9 seconds, whereas metastable bands have a life period of 10-3 seconds. The xenon flash light contains the ruby rod. Ruby rod and flash light alignment with cylindrical reflector's focal line. The atoms are raised to pump bands by the energy from the flash lamp, and these bands then decay non-radiatively to the metastable band. As the metastable state becomes heavily populated and the metastable band's atoms decay to ground level, releasing radiation with wavelengths of 6943 and 6929, the population inversion is realised extremely quickly. About 14 centimetres separate the lines. The three-level laser system known as the ruby laser. It is important to note that photons going in any other direction would get lost after a few reflections. Photons travelling along the cavity's axis are reflected back and forth and pass through the amplifying medium several times. A pulse from a ruby laser that is commercially accessible has an output power of around 100 joules and lasts for about 10-7 seconds.

DISCUSSION

The first laser to be found was the ruby laser, which emits laser energy in pulsed form 1 nm = 10-9 m.A ruby rod xenon flash tube, an appropriate cavity to reflect the light from the flash tube to the ruby rod, and a high voltage power source make up this device. The laser setup of Maiman.In the course of his research, Maiman discovered that a concentration of 0.05 percent, or five chromium atoms for every 10,000 aluminium atoms, is the perfect composition for the ruby crystal. The employed ruby rod was 4 cm long, 1/2 cm in diameter, and the ends were highly flattened and parallelized. In order to reflect all the light rays hitting it, one end was silvered to create a mirror that was nearly entirely reflecting. The laser beam was emitted via the opposite end of the rod, which was slightly silvered. Both the helical xenon flash lamp and the ruby rod were kept within a cylindrical chamber that was lined with reflecting material. The cylindrical cavity directed the xenon flash tube's light onto the ruby rod, where it excited the chromium atoms that produced the laser activity [7]–[9].

Due to the fact that only three energy levels are involved in the process of stimulated emission, the ruby laser is a three-level system Fig. 3.2. A xenon flash lamp's strong light is used to excite the atoms in the ruby crystal in order to depopulate the ground state for population inversion. As a result, absorption is used to excite atoms from their ground state level 1 to an upper state level 3. Atoms are moved from energy level 3 to energy level 2 non-radiatively non-radiative transfer. Since the atoms remain at energy level 2 for a longer period of time, this level is referred to as the met stable level. A powerful laser light is produced at 6943A when the atoms finally promoted emission back to the ground state from the met stable level. A pulse of the laser beam of a millisecond or less in length exits the laser. It is exceedingly challenging to get the system to operate in continuous waves. To produce the laser action, just 1% to 2% of the input is needed. The remainder is squandered since it is converted to heat. Power up to 500 MW has been obtained in Q-switched mode. Since this laser takes a large amount of input energy to produce laser activity, it is currently only employed in a small number of applications, such as holography and high-speed photography.

Rare Earth Ion Lasers :

The active components of several lasers have been found to be rare earth ions doped in the appropriate crystal lattices or glasses. These lasers are built on a technology that uses four different energy levels to create stimulated emission. Between the met stable level and a lower energy level that is just above the ground state, the laser action occurs Fig. 3.3. This favourable circumstance makes population inversion possible with ease. Neodymium that has been triply ionised has been shown to be the most significant of the 14 rare earth elements employed. There are a lot of optical pumping-compatible absorption bands. In the near infrared area at 1.06 micrometre wavelength, strong laser emission is generated with continuous powers of over 1000 Wand and pulsed powers of several MW 1 MW = 10 W. The ND:YAG Neodymium Yttrium Aluminum-Garnet and Nd:Glass Neodymium in Glass lasers are the most well-known neodymium lasers.

Nd: YAG Lasers:

A mixed oxide system including Y3Al5OI2 is used to create YAG. The Czochralski process involves dipping a spinning seed into a crucible of molten material and pulling it out at a consistent pace to develop the crystal in a specially built furnace. Due to the high melting point of YAG 1910–1970°C, an iridium crucible is employed. Neodymium should be present in YAK at a maximum of 1%. The laser rods can only be made as large as 1 cm in diameter due to problems with YAG crystal formation. These crystals can be operated at high repetition rates in the order of several pulses per second because to the YAG host's benefit of having a relatively high thermal conductivity to disperse the heat created. A continuous laser output of roughly 1 kW power might be achieved using an excitation source that runs continuously, such as a tungsten lamp or krypton arc lamp. Due to these outstanding qualities, Nd:YAG laser is widely utilised in both industrial applications such as drilling holes in solid objects, welding metals and alloys, etc., and medical applications such as treating cancer and performing eye surgery.Nd:glass is a crucial component in high energy laser systems. It is available in huge, uniform pieces and offers a great deal of versatility in terms of size and shape. Glass is a mixture of oxides, with silicon dioxide, phosphorus pentoxide, and boron oxide making up the majority of its composition.

Due to the occurrence of multiple metal oxides, which change the structure in different ways, it is possible to acquire a wide range of qualities. When the necessary laser glass is created, these elements and the laser activators are combined and heated to melt in a furnace. The main drawback of glass is that it results in lines that are uniformly widened and broader than those seen in crystals. As a greater Inversion is needed for the same benefit, the threshold is raised as a result. The limited heat conductivity of glass is another drawback. Because of this, it can't be used for CW operations or applications requiring high repetition rates. For CW operations, Nd:YAG is often favoured over Nd:glass. Fluorescence and absorption lines are becoming broader, which is advantageous for usage in Q-switch and amplifier applications. Military and industrial applications employ glass lasers, which are often operated in pulsed mode. Laser fusion uses glass lasers with amplifier chains because they can generate extremely high energy. The GSGG:Cr3:Nd3+ laser is another kind of neodymium laser. It utilises a garnet crystal co-doped with chromium and neodymium ions and composed of gadolinium, scandium, and gallium. Because chromium possesses strong absorption bands in the visible range, the pumping efficiency is boosted. Additionally, because chromium and neodymium transfer energy efficiently, CW laser action is much easier to accomplish than in Nd:YAG or Nd:Cr:YAG lasers.

Process of Ruby Laser:

A fundamental concept of laser operation, stimulated emission is the mechanism through which the Ruby laser functions. The ruby crystal serves as the laser's active medium, while other components include a flash lamp to inject energy into the crystal, a resonator to amplify and direct the laser light, and mirrors to concentrate and reflect it. The stages the laser takes to work are as follows:

1. When the flash lamp is switched on, a brilliant white flash is produced, which the ruby crystal absorbs. A population inversion is produced when the crystal's electrons are elevated to a higher energy level by the energy that is absorbed.
2. When the electrons in the ruby crystal return to their initial energy level, they spontaneously emit photons, which are particles of light. This phenomenon, known as spontaneous emission, causes photons to emit in arbitrary phases and orientations.
3. If an excited electron in a ruby crystal comes in contact with one of the photons produced by spontaneous emission, it may be stimulated to emit a second photon in the same phase and direction as the first. The number of photons in the laser beam increases exponentially throughout this procedure, which is known as stimulated emission, since they are stimulated by other excited electrons in the crystal.
4. Stimulated emission occurs within an optical resonator, which is made up of two mirrors that are placed in a precise alignment to create a cavity. The beam is amplified as the photons bounce back and forth between the mirrors, passing through the ruby crystal each time.
5. A highly collimated, coherent, and monochromatic laser beam is created when the amplified photons ultimately break free via one of the mirrors.

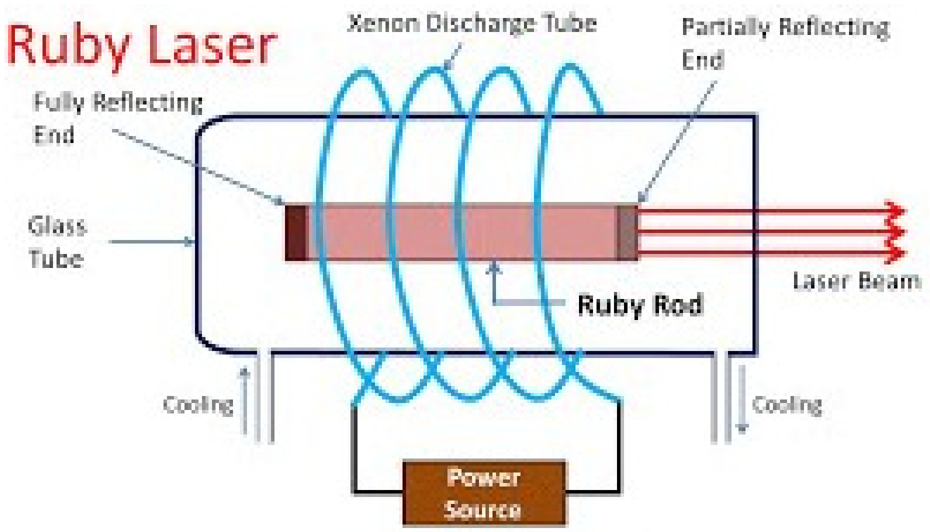


Figure 1: Represting the Process of Ruby Laser [Engineering Physics by Sanjive].

The Ruby laser emits a red laser beam in the visible spectrum with a wavelength of 694.3 nanometers as shown in Figure. 1. Depending on the laser's design, the flash lamp pumping mechanism may generate laser light in either continuous waves or brief bursts. The Ruby laser's high power output has made it helpful for scientific and medical applications including holography, spectroscopy, and dermatology, as well as for cutting, welding, and drilling metals.

Type of Ruby Laser :

Flashlamp-pumped and diode-pumped Ruby lasers are the two most common varieties. Both variants employ various techniques to inject energy into the ruby crystal while still operating according to the same basic principles of laser operation.

1. Ruby lasers that employ a xenon flash lamp to inject energy into the ruby crystal are known as flashlamp-pumped Ruby lasers. The flash lamp emits a brief burst of intense light that is absorbed by the ruby crystal when it is activated. The absorbed energy causes a population inversion and the emission of laser light by pushing the electrons in the crystal to a higher energy level. High peak power levels may be produced using flashlamp-pumped Ruby lasers, which can also function in continuous wave and pulsed modes. They are extensively employed in a variety of scientific and industrial processes, including spectroscopy, holography, metal cutting, and welding.
2. Ruby lasers that employ a semiconductor diode laser as the pump source rather than a flash lamp are known as diode-pumped Ruby lasers. The diode laser is set to a certain wavelength that is absorbed by the ruby crystal, infusing it with energy and starting the laser light's emission. Ruby lasers that are diode-pumped are more efficient and portable than flashlamp-pumped lasers, and they can function in both pulsed and continuous wave modes. They are used in several processes, including micromachining, marking, and engraving.There are also Q-switched Ruby lasers, which employ a Q-switch to generate brief bursts of laser light with high peak powers, in addition to these two primary categories. Q-switching is a method that includes placing a substance into the laser cavity to operate as a shutter that quickly opens and shuts, enabling energy to build up within the cavity before being released in a brief, strong burst of laser light. The material may be a crystal or a dye. Numerous applications, including lidar, photolithography, and rangefinding, use Q-switched Ruby lasers.

Range finding was one of the early uses of the ruby laser. Military rangefinders started using ruby lasers with spinning prism q-switches in 1964. however, a decade later, more effective Nd:YAG rangefinders were introduced. Research was the principal use for ruby lasers. The ruby laser is well suited to excite laser dyes radiating in the near infrared and was the first laser used to optically pump tunable dye lasers.Due of their poor efficiency and low repetition rates, ruby lasers are seldom employed in industry. Because diamond's large absorption band the GR1 band in the red and ruby's powerful beam roughly coincide, drilling holes through diamond is one of the primary industrial applications. With the development of improved lasing media, the usage of ruby lasers has decreased. Numerous applications that need for quick bursts of red light still employ them. Holographers use ruby lasers to create holographic portraits up to one metre square in size. The red 694 nm laser light is preferable over the 532 nm green light of frequency-doubled Nd:YAG, which often needs numerous pulses for big holograms, due to its high pulsed power and excellent coherence length.In order to examine for flaws in the lining, many non-destructive testing facilities employ ruby lasers to make holograms of huge items like aeroplane tyres. In this application, alexandrite and Nd:YAG lasers are taking the place of the once-commonly employed ruby lasers for hair removal and tattooing [10]–[12].

CONCLUSION

In conclusion, the Ruby laser is a significant kind of laser that functions in accordance with stimulated emission principles. A flash lamp or a diode laser is used as the pump source, a ruby crystal serves as the active medium, and mirrors are used to magnify and direct the laser light. In the red region of the visible spectrum, the Ruby laser emits a highly collimated, coherent, and monochromatic laser beam.Flashlamp-pumped and diode-pumped Ruby lasers are the two primary varieties, while Q-switched Ruby lasers are used to create brief, intense laser light pulses. The best kind of laser depends on the needs of the particular application in question. Each type has benefits and limits of its own. Overall, the Ruby laser is a substantial and adaptable device that has had a considerable impact on a wide range of industries and applications.

REFERENCES:

[1] Y. Kimura, Y. Yamada, F. Kurumada, Y. Sato, T. Kanazawa, And Y. Hashimoto, Laser Applications In Endodontics, *J. Japanese Soc. Laser Dent.*, 2021, Doi: 10.5984/Jjpnsoclaserdent.31.31.

[2] F. P. Schäfer, W. Schmidt, And J. Volze, Organic Dye Solution Laser, *Appl. Phys. Lett.*, 1966, Doi: 10.1063/1.1754762.

[3] Q. Peng *Et Al.*, Lasers In Medicine, *Reports Prog. Phys.*, 2008, Doi: 10.1088/0034-4885/71/5/056701.

[4] H. A. B. B.-G. Fojtik.A, Laser Ablation Of Films And Suspended Particles Formation Of Cluster And Colloidal Solutions., *Phys. Chem.*, 1993.

[5] L. C. Ming And W. A. Bassett, Laser Heating In The Diamond Anvil Press Up To 2000°C Sustained And 3000°C Pulsed At Pressures Up To 260 Kilobars, *Rev. Sci. Instrum.*, 1974, Doi: 10.1063/1.1686822.

[6] J. F. Friichtenicht, Laser-Generated Pulsed Atomic Beams, *Rev. Sci. Instrum.*, 1974, Doi: 10.1063/1.1686447.

[7] M. L. Leuenberger, M. W. Mulas, T. R. Hata, M. P. Goldman, R. E. Fitzpatrick, And J. M. Grevelink, Comparison Of The Q-Switched Alexandrite, Nd:Yag, And Ruby Lasers In Treating Blue-Black Tattoos, *Dermatologic Surg.*, 1999, Doi: 10.1046/J.1524-4725.1999.08122.X.

[8] M. C. Grossman, C. Dierickx, W. Farinelli, T. Flotte, And R. R. Anderson, Damage To Hair Follicles By Normal-Mode Ruby Laser Pulses, *J. Am. Acad. Dermatol.*, 1996, Doi: 10.1016/S0190-96229690111-5.

[9] M. Bass, P. A. Franken, And J. F. Ward, Optical Rectification, *Phys. Rev.*, 1965, Doi: 10.1103/Physrev.138.A534.

[10] Nd: Yag Laser, In *Laser Hair Removal, Second Edition*, 2008. Doi: 10.29309/Tpmj/18.4743.

[11] R. J. Abraham And A. S. Lankupalli, Laser Management Of Introral Soft Tissue Lesions – A Review Of Literature, *Iosr J. Dent. Med. Sci.*, 2014, Doi: 10.9790/0853-131105964.

[12] J. F. Ward And G. H. C. New, Optical Third Harmonic Generation In Gases By A Focused Laser Beam, *Phys. Rev.*, 1969, Doi: 10.1103/Physrev.185.57.

CHAPTER 20

APPLICATION OF X-RAY LASERS USED IN INDUSTRY

Mr. Robin Khandelwal, Assistant Professor
Department of Mechanical Engineering, Jaipur National University, Jaipur, India
Email Id:robinkh16@jnujaipur.ac.in

ABSTRACT:

An X-ray laser is a laser that uses the technique of amplification by stimulated emission to generate coherent, high-intensity X-ray beams. X-ray lasers have very narrow beams with very small wavelengths and enormous energy inputs. They might be used in plasma physics, materials science, and imaging. Although X-ray lasers are sophisticated technologies that need substantial resources and knowledge to operate, they are anticipated to play an expanding role in a number of industries.

KEYWORDS:

Free Electron, Gas, Gain Medium, Laser, Laser Beam.

INTRODUCTION

Generating stuff out of nothing, filming a chemical reaction at the atomic scale in a few femtoseconds 1 fs = 10-15 sec, or deciphering the intricate molecular makeup of a single protein or virus. These are a few of the interesting and intriguing experiments that an X-ray free-electron laser radiation source will enable. Since the first free-electron laser was constructed at Stanford in the 1970s by John Madey and his colleagues, the technology has undergone extensive development. It is a potent and difficult fusion of laser and particle accelerator physics and technology. Free-electron lasers have just lately been able to operate at infrared or close to ultraviolet wavelengths. X-ray free-electron lasers are now feasible due to a combination of theoretical, experimental, and technical advancements. By enabling atomic resolution photographs on the ultrafast timeframe associated with the inherent atomic movements of atoms in matter, they have the potential to revolutionize the way we investigate matter at the atomic and molecular level [1], [2].

From the use of sunshine until the development of the laser, photons have been the main instrument for the study of matter throughout history. X-rays have given us the ability to view the invisible throughout the last century, and their influence on materials and the study of life is widely known and cannot be understated. During the last three decades, the development of synchrotron radiation sources in particular has sparked a true scientific revolution. Numerous facilities specifically designed for synchrotron radiation research have been built as a result of the significance of this field of study. The most cutting-edge facilities available today, known as third generation facilities, are based on undulators, and thousands of scientists use such sources worldwide. Despite how helpful they are, some amenities have drawbacks. The Xray pulse has a minimum pulse duration of roughly 50 picoseconds, and there are a finite amount of photons that can be focused on a tiny sample.

To explore the dynamics of atomic and molecular processes, the new experiments need X-ray pulses with a huge number of photons focused on a sample as tiny as a molecule and compressed into a duration of a few femtoseconds. Significant advancements have been achieved in X-ray laser technology since the first soft X-ray laser demonstration in 1985. At wavelengths as brief as 3.5 nm, laser activity has been seen. A collisional excitation of an active medium and a high power laser operating in the visible region as a pump source have been used to create the most successful X-ray laser to date. The main areas of emphasis for current research are the increase of X-ray laser beam brightness and coherence, as well as the improvement of gain efficiency. X-ray lasers offer a wide range of uses, and further advancements in this area are to be expected. One may argue that we are now moving from the discovery phase of X-ray lasers towards the age of optimisation and applications. The proceedings of many X-ray laser conferences and the technical articles cited therein include comprehensive information on the developments in this sector during the last several years.

Physical Background:

Up to this point, X-ray lasers have only been used as basic amplifiers of spontaneous emission in a hot plasma column of a few centimetres in length and a diameter of around 100 pm. A thin foil, fibre, or solid target is typically irradiated with a strong laser beam that has been focussed into a line to create the plasma column. In a book by Elton, the relevant X-ray laser physics is covered in great depth. There are two main methods for activating an X-ray laser active medium. Neon-like or nickel-like ions are excited in the collision excitation scheme from the ground states 2p for neon-like and 3d for nickel-like ions, respectively to the laser higher levels 3p or 4d. The population of the laser's lower levels 3s or 4p, which are radiatively 945 946 H. Fiedorowicz connected to the ground state, is inverted between 3p-3s or 4d-4p as a result of resonance emission. In the recombination system, the heated plasma must include strongly ionised bare nuclei or helium-like ions in order for the X-ray laser to work.

The population of excited states of lithium- or hydrogen-like ions is produced by quick recombination, which is caused by rapid cooling during the hydrodynamic expansion of the plasma. Given the population inversion between the first and higher excited states, resonance emission depopulates the first excited state. For the collision excitation strategy and the recombination scheme, the typical plasma temperatures to achieve population inversion of highly charged ions are several hundred eV and few tens of eV, respectively. The power density of the laser light that creates the plasmas must be more than 1013 W cm-2 in the case of the collision scheme and 1012 W cm-2 in the case of the recombination scheme in order to heat plasmas to these temperatures. Therefore, in order to generate subnanosecond laser pulses with energies ranging from several hundred joules to several kilojoules, a large laser facility is needed. The width of the line focus of the laser beam powering the X-ray laser is about equal to the spatial coherence of X-ray lasers as measured using a uniformly redundant array of slits.

The exceptional brightness of the line emission is a feature of X-ray lasers. Estimated brightness for the yttrium laser was 4.6 x 1017 W/cm2 sr nm, which is comparable to the brightness of a 3-GeV black body at this wavelength. At the apex of the pulse, the output intensity was estimated to reach 4.0 x 10 11 W/cm2. It has been noted that the X-ray laser beam exhibits polarisation in a germanium plasma that resembles neon.:In summary, typical X-ray laser characteristics available today are listed below.

Table 1: Table summarized the X-ray laser characteristics.

laser wavelengths	3.5-60 nm
output power	0.1-10 MW
output energy	μJmJ
divergence	1-10 mrad
longitudinal coherence	100 pm

In-depth studies at several facilities around the globe have shown that both pumping techniques can produce X-ray lasing at wavelengths between 3.5 and 60 nm. It has previously been possible to produce X-ray laser beams with MW power and mJ energy in subnanosecond pulses. The Lawrence Livermore National Laboratory LLNL in Livermore, California, has so far produced the strongest X-ray laser in neon-like yttrium ions at 15.5 nm using the Nova laser (Table.1).

It has a radiation output pulse width of 200 ps, an integrated energy of 7 mJ, and a power of 32 MW. The gain zone where the yttrium X-ray laser beam originates has a diameter of around 120 pm, and its divergence is 10 mrad. X-ray lasers' line widths get smaller during amplification because the gain is greater towards the line centre. The line width for the neon-like selenium laser at 20.6 nm is 1.0-1.2x 10-3 nm. According to line width calculations, the longitudinal coherence length for the selenium laser is around 300 pm.

DISCUSSION

The majority of normal X-rays don't need people to be ready. However, patients must adhere to specific directions from the doctor before participating in special tests like contrast radiography or barium enemas. Before the assessment, patients could be instructed to adjust their diet. Patients may also be requested to leave jewellery and other metal items that can obstruct the X-ray pictures at home. On the day of the visit, patients may be requested to refrain from applying deodorants, body powders, or lotions [3]–[5].

Depending on the diagnostic X-ray technique, patients will follow a distinct protocol. They may be instructed to don a gown or smock.Patients will encounter X-ray specialists at the appointment who have been properly trained to assist with the procedure:

1. A physician with expertise in imaging the human body is known as a radiologist.
2. To use the tools and produce X-ray pictures, a radiologic technician has received training.
3. Throughout the process, a radiologic nurse looks after the patient's care, gives medicine, and checks vital signs.

A comparison between the main properties of an advanced synchrotron radiation source and an X-ray free-electron laser is shown in Table. 2. Table. 1 lists some typical features of the undulator radiation produced by free-electron laser light sources and third generation ring-based light sources. The peak power is measured in W, the emittance is measured in nm rad, the pulse width is measured in ps, the average and peak brightness are measured.

Table 2: Table summarized an advanced synchrotron radiation source and an X-ray free-electron laser.

	3rd Gen.	SASE-FREE-ELECTRON LASER	Short pulse SASE-FREE-ELECTRON LASER
Wavelength range, nm	1-0.1		
Emittance, nm rad	2	0.03	0.03
Pulse length, ps	15-30	0.06	0.01
Average brightness	10^{20}	10^{22}	10^{21}
Peak brightness	10^{23}	10^{33}	10^{33}
Peak power, W	10^{3}	10^{10}	10^{10}

X-Ray Laser Applications:

The extraordinarily high brightness of X-ray lasers is used in current applications. Imaging of biological items and imaging of quick processes in laser fusion plasmas are two examples of these applications. An approach created for synchrotron sources is a logical extension of X-ray imaging of biological microstructures using X-ray lasers. Short pulse 1 ns X-ray laser microscopy allows for high resolution imaging of biological specimens in their natural setting without the impacts of motion blur and radiation-induced damage. Additionally, zone plates and multilayer mirrors used in X-ray image microscopy work well with the narrow spectral breadth of the X-ray laser. Using a contact microscopy approach and the hydrogen-like carbon recombination laser at 18.2 nm, the first picture of a living cell was captured with an X-ray laser with submicron = 0.1 pm resolution . At the LLNL, direct X-ray pictures of living cells were captured using a 4.48 nm nickel-like tantalum X-ray laser produced by the Nova laser.

Using a spherical tungsten-carbide/carbon multilayer coated X-ray mirror, the X-ray laser beam was collected and focussed onto a specimen in this first X-ray laser microscope working inside the water window between the K-absorption margins of carbon and oxygen. The background X-ray continuum is removed by the mirror's narrow band pass. The object to be photographed is deposited onto a silicon nitride window that is 100 nm thick and positioned at the spherical mirror's focal point. An X-ray zone plate lens is used to image the lighted specimen onto a microchannel plate detector. The microscope's alleged resolution was 55 nm. Since the majority of biological microstructures of interest are three-dimensional in nature, it is obvious that three-dimensional imaging needs to be created in order to improve X-ray microscopy's capabilities. It has been explored how to employ X-ray lasers to produce high-resolution three-dimensional images using a number of methods. Both X-ray tomography and X-ray holography were among them . As density diagnostics for laser-produced plasma investigations, X-ray laser beams are currently in use. These research made use of X-ray radiography as well as X-ray interferometry.

A neon-like yttrium X-ray laser at 15.5 nm is used in the first X-ray interferometer created at the LLNL. The system comprises of an imaging multilayer mirror, two multilayer beam splitters, and a MachZehnder interferometer with two flat multilayer mirrors. The 15.5 nm laser wavelength may be reflected by the multilayer optics components at a near normal incidence with a reflectivity of roughly 60%. Using a back-illuminated charge coupled device CCD detector, the X-ray picture was recorded. High-density laser-produced plasmas were studied using the X-ray interferometer. Along with these two methods of use, X-ray lasers have a wide range of prospective uses in atomic and molecular physics, surface physics and chemistry, material science, and modern technology that are anticipated to enhance the research potential of synchrotron radiation. The proceedings of the 1992 X-ray lasers application workshop in San Francisco and other review publications include an extensive discussion of this topic.

New Trends in X-Ray Laser Research:

Existing X-ray lasers were developed in tandem with massive laser facilities, which were constructed primarily for laser fusion research. The potential for creating a short wavelength, highly efficient, affordable, and compact X-ray laser will determine the scope of future scientific uses for these devices. An effort is being made to get such a laser. There are currently two active research projects. One significant effort is on increasing the effectiveness and brightness of the current collisional excitation lasers by pumping the gain medium using pulse-shaping, pre-pulse. or multi-pulse techniques and by employing a curved slab target. The curved target makes up for the X-ray laser beam's refraction on the high density gradients while the multi-pulse pumping makes it easier to produce adequate density gradients of the plasma in a gain medium. The features of the current X-ray lasers are greatly improved by these procedures.

These techniques are anticipated to enable the creation of a compact collisionally stimulated X-ray laser. Additionally, an injector/amplifier double target setup and travelling wave excitation were used to increase brightness and coherence. Other methods focus on enhancing the X-ray recombination laser through the use of a capillary target to confine the plasma column, a specially designed target surrounded by metal blades to increase radiation cooling, or high-intensity short-pulse driving lasers to excite the gain medium. Recent developments in subpicosecond laser technology have made small-scale lasers with concentrated power densities surpassing 1018 – 1020 W cm-2 available. With these lasers, it seems that two suggested X-ray laser schemesbased either on inner-shell photoionization ISPI by laser-produced X-rays or on direct optical-field ionisation OFI by laser radiationare both feasible.

Although soft X-ray amplification by OFI has been shown, the gain is limited by the confocal geometry-related ionization-induced refraction of the X-ray laser beam . The plasma channel technique to channel an X-ray laser beam using a wave guide during amplification is likely to be used to tackle this issue. The ISPI system offers the capability of X-ray lasing in a very short-wavelength region 1.5 nm, but it necessitates a greater driving laser intensity. In order to create a collisional excitation X-ray laser at 41.8 nm with xenon ions that resemble palladium, a high-power femtosecond laser has also been used. Along with these initiatives, we suggest using a gas puff target rather than a solid target to produce an X-ray laser active medium. The gas puff target made possible by the pulsed injection of gas into the laser focus should enhance the properties of X-ray lasers by providing the opportunity to create a gain medium with a flat density profile and suitable maximum density. The ability to operate at a high repetition rate and the lack of debris released from the laser-irradiated target are additional benefits of the gas puff target. The gas puff target was used to record the first observations of X-ray lasing using neon-like argon at 46.9 nm and nickel-like xenon ions at 10.0 nm. The resonant self-photopumping of neon-like ions has also been achieved in a novel X-ray laser excitation technique [6]–[8].

When compared to teasers that operate in the visible and infrared spectrum, x-ray lasers provide a significant challenge to current technology. The transmission and reflection characteristics of materials are particularly poor in the x-ray range, or below a few nanometers 10-9m wavelengths, and as a consequence, the cavity design is subject to strict restrictions. There are restrictions on the Medium's ability to provide enough laser activity. A fairly rapid electrical circuit supplying a weakly ionised discharge may be utilised as a lasing medium for a visible laser since the characteristic energies are on the order of electron volts with an excitation time of 10-9 s. Contrarily, in the x-ray region, energies of the order of keV and time scales of the order of 10-15 s necessitate the use of highly stripped ions or inner shell electronic transitions in certain materials as the medium, pumped by a source with a pumping time considerably shorter than a pecosecond 10-12 s. To produce the stimulated emission from the medium, particularly large energy densities are necessary.For these reasons, the x-ray lasers excite the medium using a secondary laser or a particle beam. By creating an inversion in the laser-heated plasma, a multi-joule visible laser may either directly pump the gain medium or indirectly pump a different x-ray laser medium with the help of the x-rays from the laser plasma. Thus, selenium has shown x-ray laser activity at around 21 nm. In some recent studies at the Lawrence Livermore National Laboratory in the United States, small metal targets lit by extremely brief laser pulses have generated laser emissions over a distance of 15.5 NM. X-ray laser efficiency is now being worked on, and novel x-ray laser systems that might be used in military applications are also being developed.

One can wonder whether we are ready to properly use the unique radiation qualities of an XFEL for scientific inquiry at a time when we have just begun to use the most sophisticated features of third generation light sources. One may argue that an XFEL constitutes a revolutionary step into uncharted terrain in the development of x-ray sources. The destructive force of such a death ray with a peak saturation power of roughly 10 GW was in fact a major issue when the properties of x-ray radiation generated by an XFEL were initially explored. Such a beam will surely kill anything in its path, including the sample itself and x-ray optics. In the past, we have utilised x-rays to gently probe matter in order to examine it in its natural equilibrium condition while avoiding any modifications to the substance being probed, especially any radiation damage, brought on by the x-ray beam itself. A notable example is structural molecular biology, where considerable care is taken not to have the x-ray beam disturb the delicate condition of organic matter while taking measurements. There are luckily other methods to employ XFEL radiation as a gentle probe, even while part of the enthusiasm around XFELs certainly pertains to examining the interaction of the strong x-ray beam with a sample and producing new types of matter. One of the main aspects of XFEL radiation's use for study is its flexibility, which will be covered first.

Adaptive XFEL radiation use: manipulating and exploring matter The changeable focussing and tweaking of the x-ray energy underpins the adaptability of XFEL radiation utilisation. By using these techniques, it is possible to drastically alter the power density of the incident x-rays. Additionally, the atomic number of the elements in the material has a significant impact on how the beam interacts with the sample. The unfocused XFEL beam size at the undulator's output is about 100x100mm 2, or the size of a little needle see Fig. 1. The beam has only extended to a size of 200x200mm 2 at a typical testing site around 200m from the undulator outlet. Modern methods can concentrate this beam to a size of around 0.1 x 0.1 mm 2 with a power loss of up to a factor of 10. The smallest structures that may currently be lithographically manufactured on an electrical chip are about the size of a virus see Figure 1. Therefore, by adopting variable focusing, the x-ray beam's flux density may be adjusted by a startling factor of roughly one million.

Risk During Operation :

Radiation exposure occurs even though diagnostic X-ray treatments are often safe and extremely effective. The advantages of early diagnosis and treatment, however, far outweigh the hazards.

Contrast media, which is used in certain diagnostic X-rays, might cause an allergic response in some persons. An allergic response may cause these symptoms:

1. Hives.
2. Itchiness.
3. Nausea.
4. Shortness of breath.
5. Weakness.

Process of X-Ray Laser:

Amplification by stimulated emission, a technique used by X-ray lasers to create coherent, high-intensity X-ray beams. This method is similar to how conventional lasers work, however it works in the electromagnetic spectrum's extreme ultraviolet and X-ray regions. The process of X-ray laser generation involves several steps:

1. High-energy electron production is important for X-ray lasers to provide the population inversion required for amplification via stimulated emission. Free-electron lasers or plasma sources may be used to generate these electrons.
2. After the high-energy electrons are produced, they are employed to produce a population inversion in the X-ray laser's active medium. A gas, solid, or plasma may serve as the active medium.
3. To produce a significant population inversion, high-energy electrons are pushed into the active medium. The electrons in the active medium are often excited during this procedure using an external energy source, such a laser or a particle accelerator.
4. After the population inversion has been established, the X-ray laser uses this process to produce coherent, high-intensity X-ray beams. When an excited electron in the active medium interacts with a photon of a certain wavelength, the excited electron emits a second photon with the same wavelength and direction. This process is known as stimulated emission.
5. As it passes through the active medium, the X-ray radiation generated by stimulated emission is amplified. The significant population inversion produced in the active medium is what causes the amplification.
6. Mirrors or other optical components are used to extract the amplified X-ray energy from the active material and shape it into a beam.

The resulting X-ray laser beams have a very small bandwidth and a very short duration, measured in femtoseconds or attoseconds. Due of this, they are perfect for a number of uses, including as imaging and microscopy, materials research, and plasma physics. However, X-ray lasers are sophisticated technology that need a lot of money and knowledge to run. They are still quite new, and research is being done to increase their effectiveness, dependability, and adaptability [9], [10].

CONCLUSION

The X-ray laser complements synchrotrons and is currently the brightest laboratory source of soft X-rays. It also provides special opportunities for applications in a number of scientific and technological fields. Before X-ray lasers are widely used, however, a lot of issues need to be resolved. First and foremost, X-ray generating efficiency has to be significantly improved. Strong efforts are being increased in this regard, and the creation of small, inexpensive desktop X-ray lasers seems to be within reach in the near future. X-ray interferometry of laser plasmas and X-ray microscopy of biological microstructures are two applications of X-ray laser technology, despite its recent development. There have been discussions and proposals on further X-ray laser uses in research and technology.

REFERENCES:

[1] N. Nudelis and P. Mayr, 'A novel classification method for pores in laser powder bed fusion', *Metals (Basel).*, 2021, doi: 10.3390/met11121912.

[2] K. H. Nam, 'Sample delivery media for serial crystallography', *International Journal of Molecular Sciences*. 2019. doi: 10.3390/ijms20051094.

[3] M. Zubko, J. Loskot, P. Świec, K. Prusik, and Z. Janikowski, 'Analysis of stainless steel waste products generated during laser cutting in nitrogen atmosphere', *Metals (Basel).*, 2020, doi: 10.3390/met10121572.

[4] T. Shobu *et al.*, 'Internal strain distribution of laser lap joints in steel under loading studied by high-energy synchrotron radiation X-rays', *Quantum Beam Sci.*, 2021, doi: 10.3390/qubs5020017.

[5] E. Atzeni, S. Genna, E. Menna, G. Rubino, A. Salmi, and F. Trovalusci, 'Surface finishing of additive manufactured ti-6al-4v alloy: A comparison between abrasive fluidized bed and laser finishing', *Materials (Basel).*, 2021, doi: 10.3390/ma14185366.

[6] M. Yakout, M. A. Elbestawi, and S. C. Veldhuis, 'Density and mechanical properties in selective laser melting of Invar 36 and stainless steel 316L', *J. Mater. Process. Technol.*, 2019, doi: 10.1016/j.jmatprotec.2018.11.006.

[7] C. Taute, H. Möller, A. Du Plessis, M. Tshibalanganda, and M. Leary, 'Characterization of additively manufactured AlSi10Mg cubes with different porosities', *J. South. African Inst. Min. Metall.*, 2021, doi: 10.17159/2411-9717/1331/2021.

[8] W. Huang, H. Wang, T. Rinker, and W. Tan, 'Investigation of metal mixing in laser keyhole welding of dissimilar metals', *Mater. Des.*, 2020, doi: 10.1016/j.matdes.2020.109056.

[9] B. Aminforoughi, S. Degener, J. Richter, A. Liehr, and T. Niendorf, 'A Novel Approach to Robustly Determine Residual Stress in Additively Manufactured Microstructures Using Synchrotron Radiation', *Adv. Eng. Mater.*, 2021, doi: 10.1002/adem.202100184.

[10] T. Durejko and M. Łazińska, 'Characterization of cobalt-based stellite 6 alloy coating fabricated by laser-engineered net shaping (LENS)', *Materials (Basel).*, 2021, doi: 10.3390/ma14237442.

CHAPTER 21

INTRODUCTION PF THE UNDERWATER LASER TECHNOLOGY

Mr. Sanjeet Kumar, Assistant Professor
Department of Mechanical Engineering, Jaipur National University, Jaipur, India
Email Id:sanjeet.kumar@jnujaipur.ac.in

ABSTRACT:
We discuss recent developments in the realm of visible light communications, such as the 2.5 Gbit/s OOK data transfer across water and the direct modulation of blue laser devices at data rates exceeding 10 Gbit/s. In the context of applications with a large solar backdrop, we also go through the benefits of using single mode laser devices and matched filtering at the receiver. Two different direct-detection receiver types, a PIN detector and a less common silicon Photomultiplier technology, will each have their system performance demonstrated.

KEYWORDS:

Acoustic, Defence, Laser Beam, Laser Technology, Security System.

INTRODUCTION

The development and use of laser systems that can function efficiently in underwater conditions constitute the complicated topic of underwater laser technology. Communication, sensing, photography, material processing, and defence and security systems are just a few of the possible uses for underwater lasers.Beams produced by underwater lasers are created in a manner similar to that of conventional lasers. A coherent light beam is produced by a laser source, such as a solid-state or semiconductor laser, and directed to the underwater environment via an optical fibre or a set of lenses. For sensing or imaging applications, the beam may be modulated with information or sculpted into a particular pattern. However, because of the characteristics of water, using a laser underwater poses a number of difficulties. The laser beam's range and strength are decreased by water's absorption and scattering of light. The range and precision of communication and sensing systems may be constrained as a result. Additionally, water may have mechanical and thermal impacts that reduce the stability and effectiveness of the laser system.Underwater laser systems may make use of specialised optical parts and coatings to enhance the transmission and focus of the laser beam in order to get over these difficulties. For instance, materials that lessen the effects of water absorption and scattering may be used to optical fibres. Additionally, lenses and mirrors may be created with unique shapes and coatings to enhance the laser beam's focusing and reflection. temperature and lessen the impacts of thermal stress brought on by the water. A flow of cold water, for instance, may be used in water-cooled systems to maintain the laser's temperature and avoid overheating.

Underwater laser technology may use sophisticated signal processing methods and algorithms to filter out noise and enhance the detection and decoding of signals in order to increase the precision and range of communication and sensing devices. To enhance the data rate and lessen the impacts of signal distortion, for instance, sophisticated modulation methods like orthogonal frequency-division multiplexing OFDM may be utilised.The subject of underwater laser technology is quickly developing and shows potential for a variety of uses. Underwater laser systems are now being researched to increase their effectiveness, dependability, and adaptability as well as to create new use cases and applications. The capacity to transfer data between vehicles and equipment underwater is a technology with a broad variety of applications, including underwater sensor networks UWSNs, remotely operated vehicles ROVs, and autonomous underwater vehicles AUVs. The undersea environment makes up 70% of our globe. Underwater free-space optical FSO communication, or an underwater optical connection using water as the propagation medium, is a desirable choice for underwater optical communications systems UOCS. There is a resurgence of interest in the development of UOCS that use visible light for communication VLC as a result of recent advancements in high bandwidth GaNbased sources operating inside the low loss transmission window of water at visible wavelengths [1]–[3].

Data rates of up to 4 Gbit/s have been shown for laser-based VLC using direct NRZ-OOK and it is conceivable to achieve 9 Gbit/s by utilising more complicated modulation methods like OFDM [3]. We use direct modulation methods using a 450 nm InGaN laser diode and a receiver with an optical -3 dB bandwidth of 1.4 GHz to experimentally show large data rates over a free space connection for NRZ-OOK 4.7 Gbit/s and 64-QAM OFDM 11.9 Gbit/s. Additionally described are a 2.5 Gbit/s OOK data transfer system and an underwater optical tracking system. For a single mode laser matching a Fraunhofer line, the performance enhancement brought about by solar background rejection in an oceanic situation is studied for various receiver setups.There are many strategies described for using laser characteristics to increase visibility when scattering restricts range. Underwater applications are being tested using simple pulsed viewing devices. Alternative benefits that scanning technologies provide make them better in various situations. Lasers might be employed for communications up to 0.75 km when real-time data presentation with a big visual bandwidth is required. With good vision in the deep ocean, laser navigational aids may provide ranges of up to 1 km. There are several surveying options as well.

In labs, Doppler methods are used to quantify things like particle velocity, turbulence, current, and similar things. These methods will soon be applied to ocean measurements. Holography might make it possible to conduct behavioural, speed, distribution, and species identification investigations while the study vessel is moving and without sample contamination.As a practical way to meet the escalating needs of underwater high-data-rate transmission, underwater optical wireless communication UOWC has garnered significant attention from academics and business. UOWC systems feature more bandwidth, reduced latency, and superior security when compared to their traditional, extensively used acoustic communication equivalents. These outstanding intrinsic qualities make it a viable complement or replacement for a variety of underwater applications, including photography, real-time video transmission, and high-throughput sensor networks for the study of natural marine resources. As part of an integrated air-space-ground-sea communication network, future 6G coverage is also planned to be extended to distant places, water surface, undersea, and satellite scenarios. Due to its extensive frequency spectrum bandwidth resources, it is also recognised as one of the important promising technologies in the 6G underwater high-capacity wireless communication scenarios.

Future underwater wireless sensor communication networks UWSN and the Internet of Underwater Things IoUT are projected to heavily rely on hybrid acoustic/optical communication schemes that make use of both technologies. The fundamental design of a typical UWSN is shown in Figure 1, which consists of sensor nodes, solar-powered communication buoys, autonomous underwater vehicles AUV, and remotely operated underwater vehicles ROV. With bottom fixed or anchored sensors, the optical base station OBS may collect ocean monitoring data and communicate with ROVs, AUVs, or divers through optical/acoustic linkages. The transmitted data is then sent to submarines, communication buoys, ships, or other equipment by ROVs or AUVs. Information interchange between ships and the onshore data stations is carried out above sea level via radio frequency RF or free space optical FSO communication lines. Despite all the benefits listed above, UOWC connections have substantial channel impairments as a result of the absorption and scattering effects of seawater's intrinsic optical characteristics IOP. The process by which water molecules and other small objects absorb photons and transform them into thermal or chemical potential energy is known as the absorption effect. Spatial and temporal dispersion are two time-varying multipath effects that are brought on by the scattering process, which also modifies photon propagation directions. Additionally, repeated scattering results in energy loss because fewer photons arrive to the receiver plane as a result of energy loss, particularly in environments with poor water quality.

DISCUSSION

Since World War II, audio communication has been developed for an underwater network. Using the More and more underwater acoustic network initiatives have been carried out in response to marine resource extraction. For instance, several other colleges, like the University of Princeton, Massachusetts Institute of Technology, and the Georgia Institute of Technology, have already created various underwater acoustic sensor networks. However, path loss, noise, multi-path, Doppler dispersion, and high variable propagation delay all affect the underwater acoustic signal. The acoustic connection is also impacted by the direction of underwater acoustic communication, which implies that various propagation directions have varied propagation characteristics, particularly in terms of time dispersion, multi-path spread, and delay variance. As a result, the underwater acoustic channel is a temporally and spatially changeable system, and as a result, the bandwidth is constrained and greatly influenced by range and frequency [4], [5].

In order to address these difficulties, several research projects for underwater channel characterization and performance analysis have been conducted. Analytical, experimental measurement, and numerical modelling methodologies have been the fundamental foundation of earlier efforts in this area. The basic radiative transfer equation RTE, which describes the light field flowing through the scattering medium, was solved by many researchers using the analytical technique. However, in order to make the derivation process and findings simpler, this technique makes a lot of assumptions and approximations, making it very challenging to derive precise analytical answers.

Due to its simplicity, Beer-Lambert's rule was used by the authors in to describe line-of-sight LOS underwater optical wireless channels. However, this method cannot convey temporal dispersion but simply spatial route attenuation. The following list of unfavourable aspects that affect acoustic communications outlines some of the difficulties that the underwater channel for underwater sensor networks presents.

1. The underwater acoustic channel has a signal transmission speed of 1.5 103 m/s, which is five orders of magnitude slower than radio 3 108 m/s. The system's throughput is severely reduced by the significant propagation delay, which also contributes to the instability of the underwater control network system.
2. Because of absorption, the underwater acoustic band is quite small, and most acoustic communication systems work below 30 KHz. As a consequence, short-range systems

working over few tens of metres may reach hundreds of kbps, whereas underwater acoustic channels operating over several kilo metres have a bandwidth of roughly several tens of kbps.

3. The underwater acoustic channel has a high bit error rate that is on the range of 10-2- 10-5 due to path loss, multi-path fading, Doppler dispersion, and noise from ambient and human sources.
4. Because receivers require more energy to decode complex signals to make up for channel deficiencies, underwater audio communication uses more energy than terrestrial radio communication does. Due to the aforementioned issues, the underwater acoustic sensor network only now offers the July 2015, Volume 2, Issue 7 JETIR ISSN-2349-5162 JETIR1507032 Journal of Emerging Technologies and Innovative Research JETIR www.jetir.org 3164 restricted communication for varied applications may implement information exchange between several sensor nodes without providing any high-quality services. The aforementioned issues also make the underwater acoustic sensor network's efficiency extremely poor and the protocol stack's complexity very high.

Underwater Laser Sensor Network:

A novel strategy for underwater sensor networks, which is now the most active field of study, is as follows in order to solve the drawbacks in the underwater acoustic sensor network**:** The majority of lasers are unable to pass through water because they are absorbed by it, however blue-green lasers, whose wave length is between 470 and 570 nm, have the least energy loss in the water and fade at a rate of 0.155 to 0.5 dB/m. The window effect refers to the fact that the blue-green laser may propagate in the water across distances of several hundred metres to kilometres. Some undersea communication methods have been created based on the blue-green laser's window effect. When using these communication devices, the sender should aim the collimated blue-green laser towards the submarine when attempting to communicate with it.

1. Unspecific Communication Protocol and System:

Transceiver units, a user interface, and a communication channel make up a generalised full-duplex communication system as shown in Figure. 1. A transceiver is made up of a transmitter and a receiver. A baseband signal modulates a high frequency carrier in a radio frequency RF communication system to embed the information for transmission, and a carrier signal is demodulated to extract the embedded information at the receiving end. Similar to radio waves, light is a component of the electromagnetic spectrum EM and acts as a carrier for embedded information. However, unlike RF carrier waves, THz signals cannot currently be processed by optical receivers, so light cannot be modulated. Intensity modulation is the most prevalent modulation strategy used in Laser communication for free space and underwater communication. Light may be modulated in numerous ways, including phase modulation using an interferometer, Pulse position modulation PPM, intensity modulation, etc.

Sometimes a sinusoidal carrier with information packed in it is used to modulate the laser's intensity directly. At the detector, the information-laden carrier may be created again and subjected to further demodulation or processing using standard RF techniques. However, a base band signal that has undergone digitalization may be utilised straightaway to modulate a laser without being superimposed on a sinusoidal carrier. This is known as an OOK on off key signal.Digital communication also heavily depends on the kind of communication asynchronous vs. synchronous. The majority of cable communication uses synchronous communication like

RS 422/485 since it is quicker and needs synchronisation clock pulses to synchronise the transmitter and receiver. Asynchronous communication moves a little more slowly than synchronous communication, but it reduces the complicated synchronisation issues between the transmitter and receiver, making it appropriate for both wireless and cable communication.

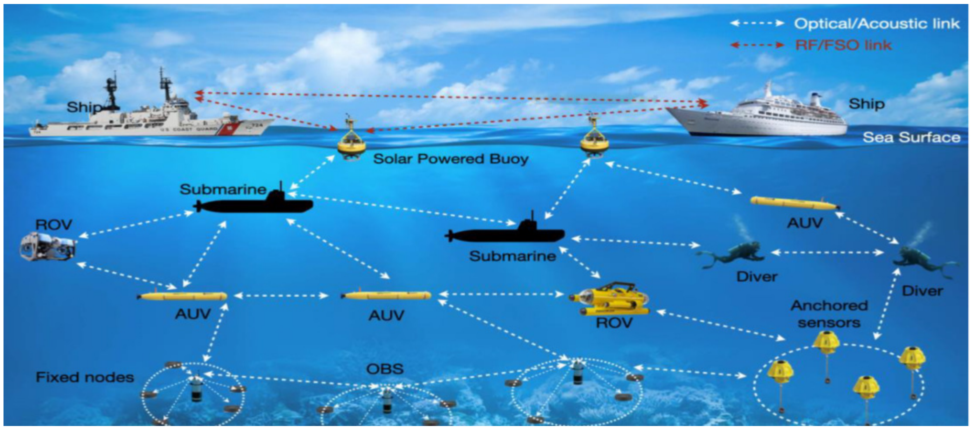


Figure 1: Architecture of an underwater wireless communication sensor network [Research Gate].

The most used asynchronous communication protocol is RS 232. RS 232 is a standard interface for linking serial devices that was authorised by the Electronic Industries Association EIA. It defines signal voltages, timing, function, a protocol for information transmission, and mechanical connections. The RS-232 interface standard was established by EIA in 1960 in order to provide dependable communication and to allow the linking of devices made by various manufacturers. It has undergone a lot of changes since then, including a name change. The following variants of this standard are EIA-232D and EIA-232E, RS-232A, RS-232B, RS-232C, and RS-232A. Due to its widespread use, the standard has been referred to as RS-232 rather than EIA-232 throughout this page.

2. System Explanation

System architecture: A frequency-doubled diode-pumped solid-state laser DPSSL producing at 532 nm and a processing electronics unit serve as the optical transmitter and receiver, respectively, in our optical transceiver system. In order to manage the laser beam divergence and spot size at the receiver, the laser beam is transmitted after reflection from two adjustment mirrors positioned immediately after the laser. A W X H X L glass water cell is constructed in the lab to replicate underwater communication. After numerous beams fold in the water cell, a route length of 10 m is reached between two transceivers. A water churning device is also preserved as a turbulence-creating option. JETIR, Volume 2, Issue 7, July 2015 ISSN: 2349-5162 www.jetir.org JETIR1507032 Journal of Emerging Technologies and Innovative Research 3165 motor. processing unit for electronics: The transmitter electronics module consists of a level converter and a buffer to adjust the level of the RS 232 signal so that it is compatible with the TTL signal operating the laser. At the receiver, the detector output is routed via a comparator to account for the attenuation of the laser beam, then through a level converter to convert the inverted TTL signal to RS 232 level compliance. Retransmission of the sequence to the initial end. If the sequence is the same, the system is in alignment and prepared to transmit the file.

Compared to other file formats, raw file formats like notepad and wordpad may be sent at greater data speeds. Additionally, protocol reliance on data rate is evident. Compared to Kermit, the Z modem protocol can handle greater baud rates, but Kermit has a lower chance of a transmission mistake. Inverted comparator is used to some degree to mitigate the effect of ambient light at the detector. Additionally, the system has separate transceiver testing capabilities without turning on the laser. The military, business, and scientific community are all very interested in underwater wireless information transfer because it is crucial for operations like tactical surveillance, pollution monitoring, oil control and maintenance, offshore explorations, monitoring of climate change, and oceanography research. There are more underwater autonomous vehicles or devices deployed to support all of these tasks, which calls for high bandwidth and high capacity for information transmission. Although audio communication underwater has made great strides, its potential is still limited by bandwidth. Because it offers faster data rates than conventional acoustic communication systems with noticeably reduced power consumption and less computational difficulties for short-range wireless networks, underwater optical wireless communication UOWC has become more popular as a result of all of this.

There are several possible uses for UOWC, from deep seas to coastal waterways. The basic properties of ocean or sea water are the largest obstacle for underwater wireless communication, and overcoming it need for a full knowledge of intricate physio-chemical biological systems. The major goal of this research is to investigate how different propagation phenomena that affect the system's performance affect the viability and dependability of high data rate underwater optical networks. An extensive account of current developments in UOWC is given in this publication. Discussions of UOWC-specific noise sources, modulation schemes, coding methods, and channel characterization follow. This study intends to propose fresh concepts that will aid in the expansion of future underwater communication in addition to providing thorough research on underwater optical communication. The existing acoustic system is supplemented with a hybrid approach to an acousto-optic communication system, resulting in high data speeds, minimal latency, and an energy-efficient system [6].

3. Water Attenuation Measurements:

In the lab, studies to assess the attenuation of genuine seawater and regular tap water were conducted. Three elements make up the experimental setup for measuring attenuation: a water cell, a laser with a known power, and a power metre. Power is gathered and forced to fall onto a power metre after the laser has passed through a water-filled cell. A number of times are run through the experiment before the R.M.S value is determined. Our source is a 200mW laser operating at 532 nm. About 3 metres separate the source from the power metre, which is situated on the other side. The bar chart displays experimental values. The attenuation factor's R.M.S. value isReadingmW received power Block schematic for the whole system Operation: Both transceiver human interfaces PCs are configured to operate in full duplex hand shaking mode while using the same baud rate and similar packet formats. The laser on-off stabilised rate is the only factor considered while choosing a baud rate. The number of missed or distorted pulses per second at a certain rate is shown by the laser on-off stabilised rate, which raises the bit error rate BER.It is fairly usual to notice that lasers often offer a slower stabilised on-off rate than the rate that is given. The designed system can handle data rates of up to 100 kbps, however the stabilised on-off rate of the laser is the limiting factor and should be examined before integrating the laser in the system. After the baud rates and data formats are same, the alignment of the two transceiver systems is verified in chat mode. From one end, a sequence of the character is broadcast, and from the other end, the character is received.

Underwater Laser Applications:

Numerous industries, including communication, sensing, imaging, materials processing, and defence and security systems, use underwater laser technology. The following are some particular uses for underwater laser technology:

1. **Underwater Communication:** High-speed communication lines between underwater vehicles, sensors, and other devices may be established using underwater laser technology. In crystal-clear water, laser beams may go great distances and can carry digital data when modified. Applications including oceanography, maritime research, and offshore drilling make good use of this technology.
2. **Underwater Sensing:** With the use of underwater laser technology, very precise sensing systems may be developed in order to find items, contaminants, and other phenomena in the underwater environment. Laser beams may be pointed at a target, and parameters like distance, speed, and composition can be determined by analysing the reflected signal. Applications for this technology include underwater surveillance, marine biology, and oceanography.
3. **Underwater Imaging:** High-resolution imaging systems for watching and mapping the underwater environment may be made using underwater laser technology. To produce 3D photographs and maps of underwater landscape, marine life, and other elements, laser beams may be pointed at a target and the reflected signal utilised. Applications for this technique include oceanography, marine biology, and underwater archaeology.
4. **Materials Processing:** Materials may be processed and moved underwater using underwater laser technology. For instance, laser beams may be utilised in submerged settings to drill, weld, or cut materials like metal, glass, or ceramics. Applications for this technique include maritime building, undersea mining, and offshore oil and gas extraction.
5. **Defence and Security Systems:** Using underwater laser technology, sophisticated defence and security systems may be built to safeguard maritime boundaries, undersea infrastructure, and other vital resources. Lasers may be used to establish networks of underwater communication and sensing devices as well as to detect and discourage intrusions. Applications for this technology include naval combat, underwater surveillance, and maritime security. underwater laser technology offers a wide range of uses in a variety of industries, and continuous research is focused on creating fresh, cutting-edge applications for this technology to solve the difficulties and possibilities presented by the underwater environment [7]–[9].

Safety:

i. Even low-power lasers may cause irreversible eye damage, making them potentially dangerous. In order to reduce the danger, classes of lasers with varying powers and wavelengths, including ones that are invisible to the human eye, have been established. Our conversation will only cover the colours green and red. When conducting launch and recovery operations, topside operators must exercise caution to ensure that lasers are off since even reflections off the ocean's surface might suddenly harm on-deck people if high-power lasers are being employed.

ii. According to ANSI Z136.1 and the Centre for Devices and Radiological Health CDRH rule 21 CFR, underwater lasers are normally Class IIIa or IIIb devices.

iii. Power output for Class IIIa ranges between 1 and 5 mW. Under the correct circumstances, particularly when used in conjunction with optics that alter the beam width or power density, these lasers may cause spot blindness, although they are often safe. A Danger label and an output aperture label must be applied to the laser and/or equipment when using a Class IIIa laser. There are no known skin or fire risks.

iv. Power output for Class IIIb ranges from 5 mW to 500 mW. This is undoubtedly a broad category. Particularly at higher power levels, class IIIb lasers are thought to be a serious eye danger and will harm the eyes. These lasers must be marked with a red DANGER label and an aperture label. When the vehicle is safely on deck, a safety device called an aperture cover cap is advised. The laser system must be launched and recovered with extreme care.

v. When operating near Class IIIb lasers, operators and deck workers must put on protective eyewear. It is wise to have a safety shutter that will close when the laser is out of water. This might be a floating polypropylene ball that has been caught in a fixture on the laser's front. The transparent ball will fall into the laser beam's path if the laser is turned on while not submerged in water, and the coherent beam will not harm anybody.

vi. For usage with Class IIIb lasers, safety eyewear that allow the beam to be viewed safely while attenuating a significant portion of the power are advised.

CONCLUSION

A GaN-based laser diode-based high data rate VLC has been demonstrated. Record data transmission rates of 4.7 Gbit/s for NRZ-OOK and 11.9 Gbit/s for 64 QAM-OFDM have been demonstrated over a 15 cm free space connection with an optical system bandwidth of 1.4 GHz. In order to optimise the power at the receiver and increase the communication range, these data rates below the surface of the water need excellent pointing precision and a collimated beam. Therefore, throughout the system design phase, the collecting optics and receiver aperture must be carefully taken into account. A smaller receiver aperture leads to a higher geometric loss and a more difficult tracking operation. While a somewhat large OBPF may be sufficient for short ranges, a small-linewidth single mode laser diode and good spectrum discrimination employing a narrow OBPF are needed for longer ranges. SNR will rise if laser output or receiver sensitivity are increased. Only the optical attenuation caused by absorption has been taken into account in the present UOCS model. It is intended to loop the procedure in order to fine-tune and make the appropriate design trade-offs in accordance with the particular situation since the key system parameters are indicative values.

REFERENCES:

[1] Y. Fu, N. Guo, Q. Cheng, D. Zhang, and J. Feng, ‘In-situ formation of laser-cladded layer on Ti-6Al-4 V titanium alloy in underwater environment’, *Opt. Lasers Eng.*, 2020, doi: 10.1016/j.optlaseng.2020.106104.

[2] N. Ren, F. Gao, H. Wang, K. Xia, S. Song, and H. Yang, ‘Water-induced effect on femtosecond laser layered ring trepanning in silicon carbide ceramic sheets using low-to-high pulse repetition rate’, *Opt. Commun.*, 2021, doi: 10.1016/j.optcom.2021.127040.

[3] X. Feng *et al.*, 'Underwater laser cladding in full wet surroundings for fabrication of nickel aluminum bronze coatings', *Surf. Coatings Technol.*, 2018, doi: 10.1016/j.surfcoat.2017.10.056.

[4] C. Song and W. Cui, 'Review of Underwater Ship Hull Cleaning Technologies', *J. Mar. Sci. Appl.*, 2020, doi: 10.1007/s11804-020-00157-z.

[5] C. Li *et al.*, 'Microstructure and corrosion resistance of underwater laser cladded duplex stainless steel coating after underwater laser remelting processing', *Materials (Basel).*, 2021, doi: 10.3390/ma14174965.

[6] C. Liu, N. Guo, Q. Cheng, Y. Fu, and X. Zhang, 'In situ formation of laser-cladded layer on thin-walled tube of aluminum alloy in underwater environment', *Materials (Basel).*, 2021, doi: 10.3390/ma14164729.

[7] J. Yong, Q. Yang, C. Guo, F. Chen, and X. Hou, 'A review of femtosecond laser-structured superhydrophobic or underwater superoleophobic porous surfaces/materials for efficient oil/water separation', *RSC Advances*. 2019. doi: 10.1039/c8ra10673h.

[8] I. Morita, K. Owaki, H. Yamaoka, and C. C. Kim, 'Study of underwater laser welding repair technology', *Weld. World*, 2006, doi: 10.1007/BF03266534.

[9] A. Khan and P. Hilton, 'Underwater laser cutting: an application technology for dismantling and size reduction of irradiated nuclear structures', *TWI*, 2014.

CHAPTER 22

INTRODUCTION ABOUT SEMICONDUCTOR LASER TECHNOLOGY

Mr. Dipendra Kumar, Associate Professor
Department of Mechanical Engineering, Jaipur National University, Jaipur, India
Email Id:dipendra1987@jnujaipur.ac.in

ABSTRACT:
A Semiconductor laser LD is an apparatus that produces laser oscillation by applying an electric current to semiconductor. An LED's light-emitting diode emission process is the same as this one. When forward current is applied to a p-n junction, light is produced. When operating under forward bias, electrons and holes enter from the n-type layer via the positive terminal attached to the p-type layer and exit through the negative terminal connected to the n-type layer. An electron enters a hole at the junction where the two come together, causing light to be released.

KEYWORDS:

Active, Conduction, Diode, Laser, LED, P-N Junction, Semiconductor.

INTRODUCTION

Voltage is delivered across the p-n junction from the electrodes, and the active layer light emission layer sandwiched between the p- and n-type clad layers is created on an n-type substrate. The active layer's two edges have surfaces that resemble mirrors.At the p-n junction, when forward voltage is supplied, electrons combine with holes to produce light. Because the refractive indices of the clad layers are lower than those of the active layer, this light is contained inside the active layer even though it is not yet a laser. The active layer also functions as a reflecting mirror at both ends, where the light bounces back and forth. After that, the stimulated emission mechanism amplifies the light, which causes laser oscillation to occur [1], [2]. A semiconductor laser, often called a diode laser, is a kind of laser in which the active medium is a semiconductor substance. A current is injected into the semiconductor material to power the laser, which releases photons to create a coherent beam of light. Numerous industries, including telecommunications, data storage, printing, medical devices, and industrial production, employ semiconductor lasers extensively.

A p-n junction, or the intersection of a p-type positive semiconductor material and an n-type negative semiconductor material, is the fundamental component of a semiconductor laser. Electrons and holes are introduced into the p-n junction when a current is provided, thereafter they combine to generate light. By establishing a feedback loop within the semiconductor material, the laser beam is created. A reflecting substance is placed on the two ends of the semiconductor material, causing it to reflect light back and forth inside itself. A coherent laser beam is produced as a consequence of the photons' stimulated emission being caused by this. Edge-emitting lasers and vertical-cavity surface-emitting lasers VCSELs are two types of semiconductor lasers that may be created. Cleaving a semiconductor wafer into discrete laser devices produces edge-emitting lasers. The device's edge is where the laser beam is released. A semiconductor wafer is grown with alternating layers of n-type and p-type material to create VCSELs. The wafer's surface is where the laser beam is released.

The smallest known lasers are semiconductor or diode lasers, which are just a minuscule portion of a millimetre in size. The laser is made of a semiconducting crystal having parallel sides at the ends that act as partly reflecting mirrors, such as gallium arsenide, lead selenide, etc. The complete laser device is quite compact and, if necessary, may be built onto an integrated circuit board. In terms of electrical conductivity, a semiconductor, as its name suggests, stands halfway between a conductor and an insulator non-metal. When a current is run through semiconducting materials containing gallium and arsenic compounds, infrared photons are seen to be produced. As a result, it may be assumed that these semiconductors turn electrical energy into photons. However, they were just regular incoherent light rays and not the result of laser activity. However, the laser activity does occur when the gallium arsenide crystal passes through it. Numerous semiconductors are utilised in lasers, and they have been engineered to lase when stimulated by electricity rather than light, as is the case with most other solid-state lasers.

Semiconductors come in two varieties n-type and p-type. Understanding the makeup of the electronic energy states present in a semiconductor is crucial in order to comprehend how these devices operate. A typical semiconductor features regions of prohibited energy gap between bands of authorised energy levels. In an intrinsic semiconductor, the conduction band, the next higher energy band, is left vacant since there are only enough electrons to occupy the highest occupied energy band valence band. In an n-type semiconductor, a little quantity of impurity is purposefully injected to cause the material to have an excess of electrons and become negative as a result. On the other hand, a p-type semiconductor may be modified to contain an excess of holes vacancy of electrons, which makes the material positive, by introducing a different sort of impurity [3]–[5].

A small block of gallium arsenide that is roughly one square millimetre in size makes up the semiconductor laser. The interface turns into a p-n junction when the p- and n-type layers are produced in close proximity to one another. The electrons flow from the n-type material to the ptype material, which has more holes, when direct current is delivered across the block. Recombination occurs during this process of electrons falling into holes, which causes radiation to be emitted. As more electrons are stimulated during the transition by the photons passing through the junction area, more photons are also released. Along the line of the connection, the laser is active. The stimulated emission multiplies greatly as a result of the block's polished ends, and one of the two ends emits a coherent light beam.A few milliwatt continuous beam is simple to produce using a gallium arsenide laser. Because they generate laser energy at the intersection of two different kinds of impurities in a semiconductor, semi conducting lasers are also known as junction lasers or junction diode lasers. Because electrons are injected into the junction area, they are also known as injection lasers.

With the crucial objectives of attaining room-temperature functioning, low threshold energy, large output powers, wavelength variety, and extended lifetimes, semiconductor laser technology has experienced significant advancement. In 19.69, a gallium aluminium arsenide double heterostructure laser was able to run continuously at ambient temperature. With additional advancements, it was possible to achieve device lifetimes of tens of years with output in the tens of milliwatt range and operating wavelengths between 0.7 and 1.8 microns 1 micron = 10-4 cm. All the different gain media may be made to emit simultaneously in a phased array by building a row of p-n junctions that are next to one another in order to achieve an efficient combined power output. This has allowed for the continuous operation of gallium aluminium arsenide diode lasers at room temperature with outputs in the region of several watts. Additionally, conversion efficiencies from electrical to optical power of more than 50% have been attained. The tiny units, lightweight design, and low auxiliary equipment requirements of semiconductor lasers make them ideal for situations where large powers are not needed. They are mostly employed in communication because low-loss optical fibres can transmit near-infrared laser beams over great distances. They have also found a sizable market as CD player reading devices.

DISCUSSION

The tiny size and low power consumption of semiconductor lasers is one of their key benefits, which makes them perfect for use in portable devices and other applications where size and power are crucial considerations. Additionally, they are quite effective, with conversion rates of at least 50%. This indicates that the laser produces light mostly from the electrical energy it receives.several significant uses for semiconductor lasers exist across several disciplines. They are used in telecommunications to send data across fiber-optic cables. They are used in CD and DVD players for data storage to read and write data. They are used in medical equipment for both surgical operations and skin treatments. They are used in industrial production to cut and weld materials. The goal of ongoing research into semiconductor laser technology is to increase their effectiveness, dependability, and performance as well as provide new uses for this adaptable technology.1 Fabry-Perot semiconductor laser

Types of Semiconductor Laser:

The band gap energy of the active layer semiconductor is the main factor affecting a semiconductor laser's centre wavelength. Even if the band gap energies are the same, the details of laser spectra vary based on the LD kinds.

Fabry-Perot Semiconductor Laser:

This laser, which has the most basic structure, is used in a variety of processes, such as the excitation of fibre lasers, laser printers, and optical pickups for CDs, DVDs, and Blu-ray discs. It is distinguished by the utilisation of a laser crystal's cleavage plane for the reflection of light produced in the active layer, as seen in Figure. 1. An extraordinarily smooth crystal's cleavage plane may be utilised as a reflecting mirror. The multiple laser oscillation occurs within the gain bandwidth as illustrated in Fig. 2 because the Fabry Perot-LD lacks a method to choose a particular oscillation wavelength. Long-distance communications cannot be used because theoscillation at several wavelengths produces pulse broadening in an optical fibretransmission.A Fabry-Perot resonator, a kind of edge-emitting device, serves as the foundation for the functioning of FP lasers. A cavity with two mirrors is a Fabry-Perot resonator. The mirrors are located on the front and rear faces of the laser diode. Only photons with resonant mode frequencies may pass through the cavity. These photons are amplified by the semiconductor gain medium within the cavity as they are reflected back and forth between the two faces [6], [7].

Applying a high-reflector coating to one end and an antireflective coating to the other end of a laser device may produce reflections that are very efficient. The antireflective coated edge is where the laser beam is released. FP Single-mode and multimode laser diodes may refer to either a single spatial mode or many spatial modes, respectively. The distant field distribution in the lateral direction slow axis distinguishes the two kinds most clearly. While a multimode laser displays a distribution with many peaks, a single-mode laser simply displays a bell-shaped far field distribution. Single-mode lasers are also often greater brightness but lesser power. The main element affecting these characteristics is the emitter width, or the width of the emission zone. The slower axis is known as the fast axis, while the longer dimension is known as the slow axis. The output beam of the laser has an oval shape.

By measuring the beam radius, the characteristics of the FP laser diode output beam are categorised in one way according to how closely the laser beam can be focussed. In terms of M2, there are three primary categories of lasers. A laser with a beam quality of 1.3 is classified as a pure single-mode laser, with a value of 1 being regarded pure, 1.3 x 2 being a semi-single mode, and >2 being a multimode laser. M2, sometimes referred to as the beam propagation ratio, is a widely used indicator of the calibre of a laser output beam. The distinction between the two locations of interest in a laser beam output is its proximity to the device's edge. The point that is measured most often is the far field, whereas the point nearest to the instrument is referred to as the near field. The far field characteristics of the beams from a single-mode and multimode FP laser are contrasted in the following Figures. 1 and 2. When comparing the two, it is clear that the multimode laser shows a rabbit-ear effect on the shorter slow axis axis because several modes are supported in the gain cavity. It should be noted that driving current or, more accurately, temperature may have a substantial impact on the far-field mode shape of multimode laser diodes.

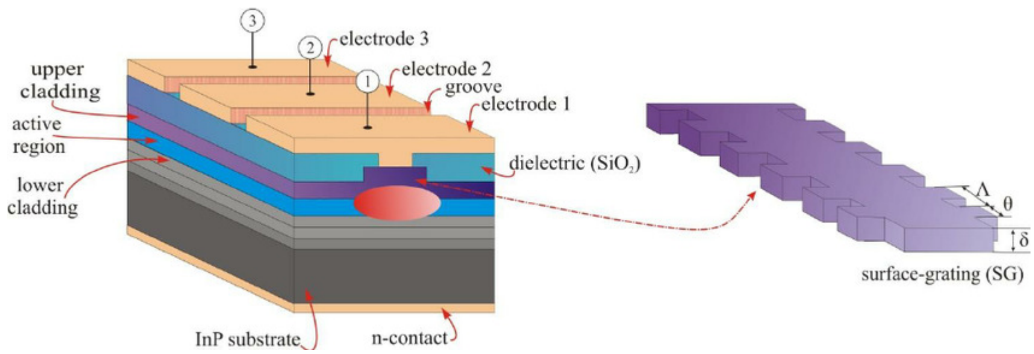


Figure 1: Represting the DFB semiconductor laser instrument [Research Gate].

DFB Semiconductor Laser:

The Distributed Feedback Laser DFB laser oscillates at a single wavelength determined by the Bragg wavelength of the grating and has a grating below or above the active layer. Figure. 1shows the general layout of the construction. It is employed as an optical signal source in long-haul optical communication because of its outstanding capabilities, which include a small spectrum breadth and low noise. DFBs are a type of semiconductor laser that uses a grating structure to provide feedback for the laser beam. The grating structure is etched into the semiconductor material, and it reflects a portion of the light back into the laser cavity. DFBs are widely used in telecommunications and sensing applications. DFB semiconductor laser In addition to a broad variety of novel applications such fibre sensing, 3D sensing, gas sensing, and illness diagnostics such as respiratory and vascular monitoring, a DFB-LD is primarily utilised as the optical signal for high-capacity long-distance optical communication. It serves as the light source for gas sensors in the area of gas sensing, which are used to detect methane gas leaks near industrial pipelines. Anritsu offers DFB-LD wavelengths between 1,270 and 1,742 nm, which have been used in a variety of ways. The RoHS regulation is complied with by Anritsu DFB-LD modules. The 14-pin butterfly-shaped module has two components: TEC for temperature management and PD for optical output monitor.

3 FBG Semiconductor Laser with Wavelength Stabilisation :

Despite the DFB laser's exceptional performance as a single wavelength oscillation, the cost is high due to production challenges. A laser diode stabilising the wavelength using FBG is a more cost-effective laser to oscillate a single wavelength. Figure 4 shows the general layout of the construction. The HR-coated end face of the active layer and the low reflectance FBG make up the laser cavity in this instance. Figure 2 simply shows the fibre core. AR coating prevents light reflection on the opposite end face of the active layer and the fiber's incident end. In order to gather the light, the incidence end of the fibre is further processed into a lens design. A single wavelength oscillation happens as a result of the FBG generated in the fibre core exclusively reflecting a certain wavelength.

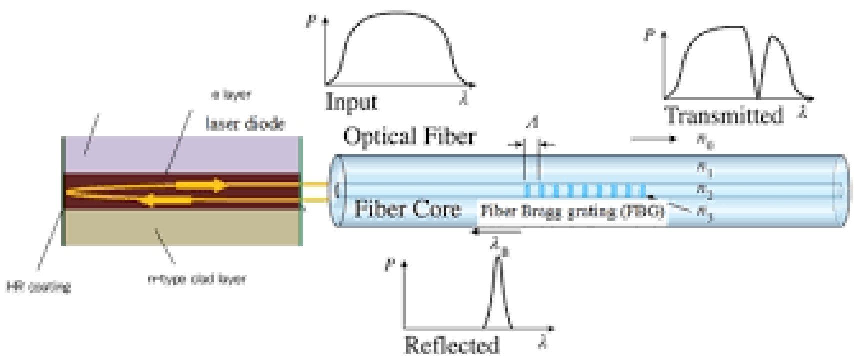


Figure 2 :Represting the FBG semiconductor laser with wavelength stabilization [Gophotonics].

A fibre Bragg grating is used by Fibre Bragg Grating FBG semiconductor lasers to offer wavelength stabilisation. By reflecting a certain wavelength range back into the laser cavity, the FBG serves as a wavelength filter. As a result, the laser starts to function at a certain wavelength that the FBG chooses. The FBG semiconductor lasers' wavelength stability is a key feature, especially for applications where the laser wavelength has to be precisely adjusted over time. This is accomplished by carefully regulating the laser's temperature, which has an impact on the refractive index of the semiconductor material and the laser's wavelength.Wide-ranging applications for FBG semiconductor lasers include optical communications, sensing, and measurement. They are especially beneficial in applications that need for great accuracy and stability, such as fibre optic sensor systems for measuring temperature, strain, and vibration. Compact size and simple integration with other optical components are two key benefits of FBG semiconductor lasers. They are perfect for use in wavelength division multiplexing WDM systems because they may be created to operate at certain wavelengths. Additionally, they may be combined with other optical elements to build intricate optical systems, including optical amplifiers, filters, and couplers.Widely used in communication, sensing, and measurement, FBG semiconductor lasers with wavelength stabilisation represent a significant technological advancement in the area of photonics.

Working of Semiconductor Diode Laser:

A PN junction serves as the semiconductor laser's active medium. In contrast to other resonators or cavities, this laser does not utilise a mirror to provide optical feedback and maintain laser oscillation.In this instance, optical feedback is provided by the reflectivity resulting from the refractive indices of two layers of a semiconductor laser. To provide optical feedback, the end faces of two different semiconductor kinds P-type and n-type are sliced and exactly parallel to one another. The term homojunction laser refers to a semiconductor laser in which the active medium or junction is constructed of a single kind of semiconductor material.On the other hand, a semiconductor laser is referred to as a heterojunction laser if the junction is constructed of many semiconductor material types.

By applying forward bias to the PN junction diode, the semiconductor diode p-n junction diode may accomplish population inversion.The carrier pairshole in the p area and electron in the n regioninject into the junction religion as a result of the forward bias voltage, where they recombine by stimulated emission. The following is an explanation of the procedure: The graphic depicts a p-n junction diode's valence band and conduction band. The Fermi level is located within the P-type semiconductor's balance band and the n-type semiconductor's conduction band at equilibrium.When a p-n junction is forward biassed, the conduction band along one side will receive electron injections, while the valence band along the p-side of the junction will create a number of holes.The conduction band will thus include more electrons than the valence band. Population inversion is thus accomplished.

Advantages:

1. Its dimensions are very tiny. The set up is straightforward and small.
2. It has excellent efficacy.
3. By adjusting junction current, the laser power may be quickly enhanced.
4. It uses less power than CO2 and ruby lasers while operating.
5. Very minimal auxiliary equipment is needed. It may generate either a continuous wave or a pulsed wave

Disadvantages:

1. It is challenging to regulate the laser's mode structure and mode pattern
2. The output is typically between 5 and 15 degrees, meaning that the laser beam has a significant divergence.
3. The monochromacity and purity of this laser are stronger than those of other lasers
4. The threshold current density 400A/mm2 is quite high.
5. It is unstable and has low coherence.

Application of Semiconductor Laser:

Due to their small size, great efficiency, and capacity to generate coherent light at diverse wavelengths, semiconductor lasers have a broad variety of applications in a number of different industries. The following are some of the most typical uses for semiconductor lasers:

1. **Telecommunications:** For data transmission and reception through fiber-optic cables, semiconductor lasers are widely utilised in the telecommunications sector. They serve

both as light sources in optical transmitters that transform electrical impulses into optical signals and as detectors that reverse the process.

2. **Industrial Manufacturing:** Materials including metals, polymers, and ceramics are cut, welded, marked, and engraved using semiconductor lasers in industrial manufacturing operations. They work at fast speeds with little waste and give excellent precision and accuracy.
3. **Medical:** Semiconductor lasers are utilised in ophthalmology, laser surgery, and cosmetic operations, among other medical fields. They may be utilised to precisely target certain tissues without causing damage to neighbouring regions and give excellent accuracy and control.
4. **Sensing:** Semiconductor lasers are used in sensing tasks like lidar laser-based radar for distant sensing and mapping and gas sensing for monitoring the environment and the identification of dangerous gases.
5. **Scientific Research:** Semiconductor lasers are used in spectroscopy, microscopy, and other imaging applications in scientific research. They may be used to investigate the molecular characteristics of materials and biological samples because of their great resolution and sensitivity.
6. **Defence:** Semiconductor lasers are used in defense-related applications such target identification, laser rangefinders, and missile guidance. They are very accurate and able to function under challenging conditions.

All things considered, semiconductor lasers are a useful and significant technology with a broad variety of applications in several industries. The goal of ongoing research and development is to increase the effectiveness, dependability, and performance of existing lasers as well as create new laser types for novel applications [8]–[10].

CONCLUSION

In conclusion, semiconductor laser technology is a flexible and quickly developing discipline with several applications in a variety of sectors. Significant breakthroughs in semiconductor laser technology have been made possible by the creation of novel materials and production methods, resulting in higher power output, more efficiency, and better wavelength stability. Future applications for these lasers are anticipated to include high-speed communication, sophisticated manufacturing, and medical diagnosis and treatment. Ongoing research and development is aimed at enhancing the performance, dependability, and cost-effectiveness of these lasers.

REFERENCES:

[1] Y. Yan, Y. Zheng, H. Sun, and J. Duan, ‘Review of Issues and Solutions in High-Power Semiconductor Laser Packaging Technology’, *Frontiers in Physics*. 2021. doi: 10.3389/fphy.2021.669591.

[2] X. Hu, L. Zhou, H. Wang, Y. Gao, and Y. Gao, ‘The Value of Photo Biological Regulation Based on Nano Semiconductor Laser Technology in the Treatment of Hypertension Fundus Disease’, *J. Nanosci. Nanotechnol.*, 2020, doi: 10.1166/jnn.2021.18698.

[3] P. Xu, B. Wang, Y. Wang, and X. Wang, 'Study and optimization of die-bonding technology for semiconductor lasers based on differential-analysis', *Optik (Stuttg).*, 2021, doi: 10.1016/j.ijleo.2021.166632.

[4] H. Shimizu, 'Scientific breakthroughs and networks in the case of semiconductor laser technology in the us and japan, 1960s-2000s', *Aust. Econ. Hist. Rev.*, 2011, doi: 10.1111/j.1467-8446.2011.00325.x.

[5] Y. Wu, B. Sun, and X. Li, 'Semiconductor laser active frequency stabilization technologies: a review', *Journal of the Korean Physical Society*. 2021. doi: 10.1007/s40042-021-00308-7.

[6] Ó. B. Helgason *et al.*, 'Dissipative solitons in photonic molecules', *Nat. Photonics*, 2021, doi: 10.1038/s41566-020-00757-9.

[7] A. S. D. Sandanayaka *et al.*, 'Toward continuous-wave operation of organic semiconductor lasers', *Sci. Adv.*, 2017, doi: 10.1126/sciadv.1602570.

[8] M. Yousefi *et al.*, 'New role for nonlinear dynamics and chaos in integrated semiconductor laser technology', *Phys. Rev. Lett.*, 2007, doi: 10.1103/PhysRevLett.98.044101.

[9] Y. Yao, C. Zou, H. Yu, J. Guo, Y. Li, and J. Liu, 'The developing condition analysis of semiconductor laser frequency stabilization technology', *J. Semicond.*, 2018, doi: 10.1088/1674-4926/39/11/114004.

[10] Y. Ning *et al.*, 'Brief Review of Development and Techniques for High Power Semiconductor Lasers', *Guangxue Xuebao/Acta Optica Sinica*. 2021. doi: 10.3788/AOS202141.0114001.

CHAPTER 23

INTRODUCTION ABOUT THE FRICTION STIR WELDING FSW

Mr. Ashok Singh Gour, Assistant Professor
Department of Mechanical Engineering, Jaipur National University, Jaipur, India
Email Id:asgour@jnujaipur.ac.in

ABSTRACT:
Innovative solid-state welding technology called friction stir welding FSW connects metals without melting them. It uses a spinning tool that moves along the joint line between two metal components, creating heat and friction in the process. The material may be mechanically mixed together to create a solid-state weld since the heat softens it. FSW has several benefits, including good weld quality, less distortion, and the ability to weld metals of different compositions. It has found use in fields including shipbuilding, automotive, and aerospace. However, for best outcomes, FSW needs exact control over the process variables and tool design. Overall, FSW is a promising welding process with the potential to increase strength and structural integrity. It provides an alternative to traditional fusion-based welding techniques.

KEYWORDS:

Aluminum, Alloys, Friction, FSW, Stir, Welding,.

INTRODUCTION

A non-consumable rotating tool is gently inserted into the butting faces of the work pieces and moved along the joint line in friction stir welding FSW, a solid state joining technique developed at The Welding Institute TWI in 1991. To keep the joint faces from shifting out of place during welding, pieces must be secured. Tool friction, the surface of the probe, the tool shoulder, and material plastic deformation all produce heat. As schematically, heat created is lost to the work pieces, the tool, and the anvil. Although incipient melting has been documented for certain materials, maximum temperatures are reached near to the tool shoulder and are lower than the melting point of the materials being welded. By softening the plasticized area surrounding the tool caused by the heat generated, the tool is made easier to move along the joint line. When the shoulder of the tool and the pin come into contact, plasticized material is chaotically mixed or extruded from the advancing side to the retreating side of the tool, creating a strong phase connection between the two parts [1], [2].

A heat affected zone HAZ, which simply experiences the effects of the thermal cycle, and a thermo-mechanically affected zone TMAZ, which derives from both plastic deformation and thermal exposure of the material, both occur as a consequence of this welding process. A distinctive nugget with an onion ring appearance often forms in the Centre of the TMAZ, which is ascribed to dynamic re-crystallization or dynamic recovery of the microstructure. Although additional materials including magnesium, copper, zinc, titanium, and even steel may be welded using this method, FSW is mostly utilized in welding aluminium alloys. This method may also be used to weld polymers, metal matrix composites, and aluminium alloys from other alloy groups or still distinct materials. When compared to traditional arc welding methods, it offers a number of benefits, particularly when welding aluminium alloys. This approach avoids issues like thermal distortion, gas porosity brought on by hydrogen absorption during welding, and vulnerability to solidification cracking, which are all quite frequent in fusion welding procedures. Along with minimizing residual stress and distortion, the method also offers high strength and ductility. These characteristics of FSW are often ascribed to the process being solid-state and the alleged minimal energy input to the welded joint. Additionally, no shielding gas, no filler electrode, and little surface preparation are required. Since this technique doesn't emit any fumes, hazardous gases, or electric arc radiation, there are no environmental issues to take into account.

History of Friction Stir Welding FSW:

The Welding Institute TWI in the United Kingdom is where a group of scientists and engineers first invented friction stir welding FSW in the early 1990s. The main objective was to create a welding procedure that would be able to get over the constraints of traditional fusion welding techniques, especially for connecting aluminium alloys. Dr.Wayne Thomas and his co-workers at TWI are to be thanked for their contributions to the creation of FSW. The observation of material flow during the stirring of polymers served as the basis for the invention of friction stir welding. The group realised there was possibilities for using this idea to solid-state link metals. TWI submitted the first FSW patent in 1991, which sparked a significant amount of research and development work. Given their extensive usage in sectors like aerospace and automotive, early investigations concentrated on aluminium alloys. Aluminium plates with a 2.4 mm thickness were used for the first successful FSW trials.

TWI created a prototype Friction Stir Welding machine in 1994, and the method was still being researched and improved upon. To improve process parameters, tool design, and welding methods, the team ran a number of trials. Additionally, they looked at the impacts of different materials, such as copper, magnesium, and copper alloys. When TWI introduced the procedure at the International Institute of Welding IIW Annual Assembly in 1996, FSW made significant strides. The welding community responded well to this presentation, which sparked an increase in interest in FSW throughout the globe. Following the successful launch of FSW, TWI collaborated with business partners to show that the method could be used in practical settings. In sectors including aerospace, automotive, marine, and rail, where its distinct capabilities provided substantial benefits over conventional welding procedures, FSW was quickly adopted.

The FSW procedure has continued to evolve and be improved throughout time. These included the introduction of automated FSW systems, the creation of new tool materials, and advancements in tool design. The variety of materials that may be successfully welded with FSW has increased because to these developments, and now includes steels, titanium alloys, and even mixtures of incompatible metals [3]. Nowadays, friction stir welding is a recognised and popular welding method. It has uses across many industries and has proved especially useful in the maritime, automotive, and aerospace sectors. The method is being enhanced through ongoing research and development, which has led to improvements in machinery, tools, and process management for better weld quality, increased productivity, and a wider range of applications. The TWI team's innovative work and the major contributions they made to revolutionising the area of welding technology are shown by the success and acceptance of FSW. To make this technique more practical for industrial use, there are still a number of issues that need to be resolved. In order to drive the tool through the plasticized material, the technique uses strong forces, which wears down the tool over time, especially when welding hard materials.

Additionally, strong clamping fixtures are required to keep components in place and balance the tool's forging forces. As a result, FSW is often used in heavy-duty bespoke machine tool equipment, where weld connections are commonly restricted to shapes in two dimensions or straight lines. Industrial robots are used to extend this process' versatility by enabling the welding of three-dimensional shapes. FSW is now used to join pieces of aluminium alloys with thicknesses ranging from 0.5 to 75 mm. It is used in the shipbuilding and marine industries to create heavy profiles, platforms, and panels. in the aerospace sector to create fuel tanks, wings, and fuselages. in the railway sector to create high-speed trains. in the automotive sector to create panels and other components. and so on. The Welding Institute TWI in the United Kingdom created and developed the novel solid-state welding technique known as friction stir welding FSW in the early 1990s. It is a cutting-edge joining method that eliminates the need for melting while producing welds of excellent quality in metals. Unlike conventional fusion-based welding techniques, which entail melting the materials to connect them, frictional heat and mechanical deformation work together in FSW to fuse the components. In order to complete the operation, a spinning tool with a specific geometry and a hard material, such as tungsten carbide or polycrystalline cubic boron nitride PCBN, is usually used [4]–[6].

DISCUSSION

The following stages are part of the FSW process:

1. **Tool Plunge:** The spinning FSW tool is inserted into the joint line that abuts the two metal components that need to be linked (Figure.1). The tool is made up of a shoulder that applies downward pressure and a probe or pin that heats the material and stirs it.
2. **Heat Production:** Frictional heat is produced between the tool and the workpiece as it spins and moves along the joint line. This heat causes the material to become softer without melting it, enabling plastic deformation.
3. **Mechanical Material Stirring:** As the tool's revolving pin pierces the softened material, it vigorously mechanically stirs the mixture. In effect, a solid-state bond is produced by mixing the plasticized material from both sides of the junction.
4. **Weld Formation:** A continuous weld seam is produced by continuing to move the tool along the joint line. A high-strength weld is created when the material behind the tool consolidates and hardens.

Compared to conventional fusion-based welding techniques, FSW has the following benefits:

5. **Better Weld Quality:** FSW creates welds of outstanding quality, devoid of flaws including porosity, solidification cracking, and severe distortion. The procedure guarantees a uniform and fine-grained microstructure, leading to materials with superior mechanical characteristics.
6. **Lessened Distortion:** FSW's low heat input minimizes work piece distortion, making it especially ideal for delicate and intricate structures.
7. **Fusion Shielding Welding:** FSW may unite incompatible metals that are difficult to fuse using traditional fusion welding processes. This includes mixtures like copper to aluminium and aluminium to steel.

8. **Environmentally Friendly:** FSW consumes less energy and doesn't need consumable filler materials since it works at lower temperatures than fusion welding. Additionally, it emits very little pollutants and fumes.
9. **Enhanced Productivity:** FSW is a quick welding method that offers great productivity. Time is also saved by the lack of post-weld solidification and the requirement for less cleaning.

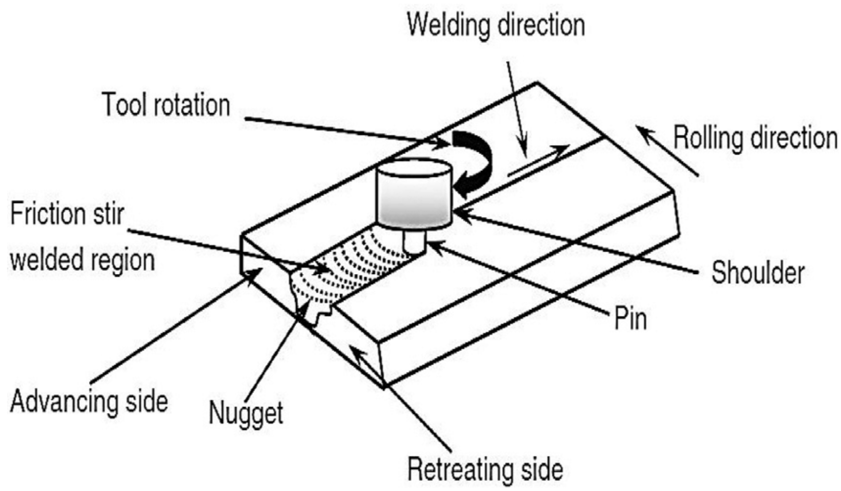


Figure 1: Schematic representation of the friction stir welding process [Research Gate].

There are several sectors, including aerospace, automotive, shipbuilding, rail, and more, where friction stir welding is used. It is used to connect parts like heat exchangers, panels, and aluminium structures where low distortion, high strength, and great weld quality are essential. Advancements in tool design, process parameters, and automation are enhancing FSW's capabilities and broadening its applications as it is further investigated and improved. The method has a lot of potential for the development of welding technology since it opens up new avenues for combining materials with greater structural integrity and functionality [7], [8].

A) Welding Equipment:

The development of high stiffness machines was the major focus in the beginning, but today's machines are standardized, versatile, and modular. Systems for welding nonferrous metals that are suitable for many industrial sectors are also being manufactured. These later systems are made up of a strong fundamental structure, a set of safety stops, a welding carriage assembly, a welding head assembly, a control system, a hydraulic unit, and the welding equipment. With vertical down pressures ranging from 6 to 200 kN, welding rates up to 2 m/min although an option up to 6 m/min exists, and tool rotation speeds between 500 and 2000 rpm, these machines may have a variety of basic configurations. These machines, as previously mentioned, are not very flexible and only produce welds in straightforward two- or three-dimensional paths. Although flexibility may be increased using robotic systems, these systems must be able to apply and sustain a strong, continuous axial force during welding, which is not an easy task. High payload robots are used for this, and they immediately measure the force and utilize feedback to keep it constant throughout the welding process. For robotic FSW, a compromise between the requirements for travel speed and axial force may need to be made since the axial force reduces with increasing tool rotation speed but rises with increasing travel speed.

The quality of friction stir welded joints is greatly influenced by the selection of the proper tool type. Cylindrical threaded pin probes are suggested for butt welding aluminium alloys up to a thickness of 12 mm, whereas Whorl and MX-Triflute probes should be used for thicker plates. These later probe types enable welding rates that are at least two times faster than those made possible by threaded pin probes. Additionally, they have flat, re-entrant, or oval cross sections that lower the probe volume static volume, enabling one to obtain an appropriate swept volume to static volume ratio. The efficiency of the probe and the route for material flow both increase as this ratio increases. Special equipment, such as Flared-Triflute and A-Skew probes, are used for lap welding of aluminium alloys, which is more challenging than butt welding because broader welds are required and oxide disruption at the sheet interface is more difficult. The quality of the weld may be improved by using these methods to boost the dynamic to static volume ratio.

Equipment of Friction Stir Welding FSW:

Material flow around the probe is influenced by the tool shoulder's bottom form, which also helps to stop plasticized material from escaping. They might have concentric or spiral grooves, be flat or concave, smooth or grooved. When opposed to a flat bottom, a concave shoulder bottom has the benefit of guiding material flow to the Centre near the probe. In general, grooved bottoms provide the same result. Knives may also be attached to shoulders to shave the weld. Although it is possible to weld without an anvil by utilizing a specific tool the bobin-tool, this welding procedure often needs access to all sides of the work pieces being welded.

B) Process Parameters:

The vertical down force, also known as tool plunge force, the tool rotation speed, and the travel speed or welding speed are the key FSW process variables that affect the quality of the welded connection. The power of the dive ensures that the probe will penetrate the plates and will create plasticized material under the shoulder. Because the mechanical power input to the tool is determined by Equation, where P is the power, M is the torque, and is the angular speed of the tool, the speed at which the tool rotates has a direct impact on the heat produced throughout the operation. Due to the possibility of ignoring plastic work, thermal losses account for the majority of the mechanical power input dissipation. Because the plunge force impacts the torque, it also has an impact on the heat produced throughout the operation. With increased tool rotational speed and plunge force, more heat is produced. The metal flow around the probe is influenced by travel speed, which also affects the specific heat input per unit weld length.

The amount of specific heat input decreases as travel speed rises, resulting in less material softening near the probe and more challenging plastic flow. Defects like cavities might be brought on by fast travel. For certain aluminium alloy welds, exterior flaws may emerge when the tool rotates at a low speed, plunges at a low force, and travels at a fast speed. Defects are moved into the weld's core as the plunge force increases. Sometimes it is possible to discern between hot welds with a high ratio and cold welds with a low ratio by looking at the ratio between tool rotation speed and travel speed. In aluminium alloys, hot welds may show more dramatic changes in microstructure and mechanical characteristics than cold welds, although they are less susceptible to fault development.

In addition to the various geometric features of the tool mentioned in the preceding section, additional essential factors include the tool's indentation time and shoulder angle. The interval between the tool's first contact with the work piece and the moment it starts to move along the joint is known as the tool's time of indentation. The heat that is produced at this time diffuses around the probe, softening the surrounding material and stabilizing its flow. The first portion of the weld may develop faults if this time frame is too short. Typically, the range of time is 5 to 30 seconds. The pressure applied to the top surface of the welding plates may be gradually increased thanks to the tool shoulder angle, which also aids in controlling the material flow. Angles up to 3o are typical for tools.

C) Process Variants:

There have been several FSW process variations created during the last few years. One of these variations is thermal aided FSW, which preheats and softens the material by applying heat before using the FSW tool in the joint . This boosts travel speed while lowering welding forces, welding power, and tool wear. When welding steel and other high strength materials, this variation might be helpful. Spot FSW is another variation that was created for lap joints and results in spot welds with greater mechanical strength than those made by resistance spot welding. The development of this process's robotic applications. The reversal stir welding process Re-StirTM, created by TWI, is a recent innovation in which tool rotation is applied as both angular reciprocating reversal is imposed within one revolution and rotary reversal reversal is imposed after one or more revolutions, rather than continuous rotation as is the case in conventional FSW. Re-Stir is fundamentally a cyclic, symmetrical process. TWI Re-stirTM may end up being the preferable choice for several applications including butt, lap, compound lap, spot welding, and material processing.

D) Safety and Health:

High-voltage electricity, which may burn people and cause serious injuries, toxic chemicals and gases, electric arc radiation, which can burn skin and eyes, and noise that can damage hearing are the main potential risks of arc welding procedures. All electrical tools and work pieces should be connected to an appropriate electrical ground to avoid severe electric shocks that may be caused by exposure to the high open-circuit voltage of power supply. All electrical lines must be insulated and dry, and they must be designed to carry the maximum current. All arc welding techniques produce fumes and vapors, but the flux cored arc welding process produces them at a high rate. The health effects of arc-formed gases such carbon monoxide, ozone, and nitrogen oxides are far worse than those of metal vapors like nickel, chromium, zinc, lead, or cadmium, for example. To keep fumes and gases out of the crew breathing zone, employ enough ventilation, exhaust at the arc, or both.

Intense radiation is emitted in the visible, infrared, and ultraviolet ranges by the electric arc used in GTAW and GMAW procedures. A brief eye burn from UV radiation is often seen and may be uncomfortable for 48 hours. The operator should use a filter glass to block off visible light while absorbing radiation at risky wavelengths so he can view the junction during welding. Permanent filters and photosensitive filters, which darken quickly in response to incoming light from the arc, are the two main categories of filter . With rising current, filters' optical densities rise. Operators must wear leather, wool, or aluminium coated clothes to shield them from the UV, which also causes skin irritation and reddening. Enclosures with windows and filters for seeing the weld area are often used to safeguard robotic welding equipment. When there is too much noise around the work area, ear protection should be used. High-pressure and liquid petrol cylinders must be handled and used with extreme caution. they should always be kept upright and fastened with chains when in use. Because they may trigger a catastrophic fire, lubricants and other flammable substances shouldn't be used in pressure-reducing regulators or other components of the oxygen circuit.

In many ways, the potential risks associated with laser beam welding are comparable to those seen with arc welding. High voltage is used in laser power supply, which may result in fatal electric shocks. Additionally, laser welding produces harmful metal vapors, the composition of which varies on the metals being welded, necessitating local exhaust ventilation. However, exposure to direct or reflected laser beams must be avoided since laser beams might result in irreversible eye damage. Laser welding technologies need to be used in areas with limited access that are transparent to the laser's wavelength. Personnel operating close to the laser source may need to wear personal laser eye protection. The skin may get thermally burned if it comes into contact with main laser beams. The prevention of electric shock and molten metal splash are the main causes of worry while resistance spot welding. The utilization of enclosures and splash-less resistance spot welding devices may enhance the working environment.

Type of Friction Stir Welding FSW:

Friction Stir Welding FSW has undergone several modifications throughout the years to accommodate various welding applications and needs. Here are some examples of FSWs that are often used:

1. **Conventional Friction Stir Welding:** This is the most common and traditional FSW technique. A cylindrical rotating tool with a shoulder and pin is used. As the pin pierces the work piece, frictional heat is produced, which causes the material to become plastic. The shoulder exerts downward pressure to promote consolidation and material flow.
2. **Bobbin Tool Friction Stir Welding:** Compared to traditional FSW, this version uses a tool with a pin that is bobbin-shaped and has a wider diameter. This design makes it possible to weld larger or more challenging-to-weld materials by increasing material flow and heat output.
3. **Friction stir welding using a trifle tool:** The pin of the trifle tool has three flutes or grooves along the length of it. This design encourages better material flow and mixing, which leads to better weld quality and higher production.
4. **Friction stir welding:**using a pin that has threads or grooves along the length of it is known as threaded pin friction stir welding. The threads aid in greater heat production and material mixing, which improves the weld propertiesespecially for difficult materials.
5. **Stationary Shoulder Friction Stir Welding:** In this kind, the tool traverses and rotates while the shoulder stays still. The fixed shoulder may improve control over material flow and heat input by helping to localize heat production. Self-Reactive Friction, sixth Stir-Plug Welding, also known as self-reactive FSW, involves incorporating a reactive substance inside the pin. During the welding process, the reactive material reacts exothermically, adding more heat input and enabling the joining of materials that are challenging to weld, including high-strength steels. In terms of weld quality, process control, and material compatibility, these FSW variants provide versatility. The material being welded, the joint design, the required weld qualities, and production needs are just a few examples of the variables that must be taken into consideration while choosing the best FSW variant. It's important to keep in mind that these variants may have various titles and characteristics depending on the study or business developments in question. To

accomplish a solid-state weld, they all use spinning tools to produce frictional heat and physically agitate the material. This builds on the fundamental ideas of FSW [9], [10].

CONCLUSION

In conclusion, Friction Stir Welding FSW is a cutting-edge solid-state welding process that provides a number of benefits over conventional fusion-based welding techniques. FSW can connect a variety of materials, including aluminium, steel, and other metals, since it produces high-quality welds with less deformation. It improves structural integrity and makes it possible to combine materials that aren't compatible. Numerous sectors, including aerospace, automotive, marine, and rail, have found extensive use for FSW because of its special characteristics to improve weld quality, boost output, and minimize environmental effect. The expansion of FSW's possible applications is facilitated by the creation of multiple FSW variants as well as improvements in tool design and process control.

REFERENCES:

[1] B. Meyghani, M. Awang, and C. S. Wu, ‘Finite element modeling of friction stir welding (FSW) on a complex curved plate’, *J. Adv. Join. Process.*, 2020, doi: 10.1016/j.jajp.2020.100007.

[2] B. Meyghani, M. B. Awang, S. S. Emamian, M. K. B. Mohd Nor, and S. R. Pedapati, ‘A comparison of different finite element methods in the thermal analysis of friction stir welding (FSW)’, *Metals*. 2017. doi: 10.3390/met7100450.

[3] M. V. da S. Salgado *et al.*, ‘Processing and characterization of high aluminum multicomponent (Co,Ni)-based superalloys for friction stir welding (FSW) tools’, *Mater. Today Commun.*, 2020, doi: 10.1016/j.mtcomm.2020.101282.

[4] A. R. Patel, C. G. Dalwadi, and H. G. Rana, ‘A Review: Dissimilar Material Joining of Metal to Polymer using Friction Stir Welding (FSW)’, *IJSTE -International J. Sci. Technol. Eng.*, 2016.

[5] P. Lacki, W. Wieckowski, G. Luty, P. Wieczorek, and M. Motyka, ‘Evaluation of usefulness of AlCrN coatings for increased life of tools used in friction stir welding (FSW) of sheet aluminum alloy’, *Materials (Basel).*, 2020, doi: 10.3390/ma13184124.

[6] TWI, ‘What is Friction Stir Welding (FSW)? - Process and Applications - TWI’, *FAQs*, 2020.

[7] N. Dialami, M. Cervera, and M. Chiumenti, ‘Numerical modelling of microstructure evolution in friction stir welding (FSW)’, *Metals (Basel).*, 2018, doi: 10.3390/met8030183.

[8] D. G. Mohan *et al.*, ‘Ac ce pte d M us pt’, *Mater. Today Proc.*, 2019, doi: 10.1080/14484846.2018.1432089.

[9] A. R. Eivani, H. Vafaeenezhad, H. R. Jafarian, and J. Zhou, ‘A novel approach to determine residual stress field during FSW of AZ91 Mg alloy using combined smoothed particle hydrodynamics/neuro-fuzzy computations and ultrasonic testing’, *J. Magnes. Alloy.*, 2021, doi: 10.1016/j.jma.2020.11.018.

[10] B. Meyghani, M. B. Awang, M. Momeni, and M. Rynkovskaya, ‘Development of a Finite Element Model for Thermal Analysis of Friction Stir Welding (FSW)’, in *IOP Conference Series: Materials Science and Engineering*, 2019. doi: 10.1088/1757-899X/495/1/012101.

CHAPTER 24

AN OVERVIEW ON RESISTANCE SPOT WELDING RSW

Mr. Ranveer Singh, Associate Professor
Department of Mechanical Engineering, Jaipur National University, Jaipur, India
Email Id:ranveer@jnujaipur.ac.in

ABSTRACT:
Metal sheets are joined using heat and pressure using the popular welding process known as resistance spot welding RSW. The metal is melted at the places of contact when an electric current is sent through the sheets, creating a weld nugget. RSW is often used in the automotive and aerospace sectors and is quick and economical. It generates neat, robust welds and can unite various metals. However, it may not work well with thicker or more conductive materials and works best with thin sheets. In all types of manufacturing and assembly operations, RSW is essential.

KEYWORDS:

Automotive, Aerospace Sectors, Electric Current, Heat, Metal Sheet, Resistance Spot.

INTRODUCTION

According to Joule's law, which is represented, where H is the heat generated, I is the current, and t is the time of current flow, resistance spot welding RSW is one of the resistance welding processes in which heat is produced by electric current flowing through the bodies to be joined. The same category includes other welding techniques as high-frequency welding, flash or upset welding, projection welding, resistance seam welding, and projection welding. The resistance welding method most often utilised in robotic applications worldwide is spot welding, the globe and is discussed in some length here. The process variations section analyses the main characteristics of the resistance seam welding process, which is also somewhat relevant to industrial robots [1], [2].In resistance spot welding, copper electrodes are used to provide electric current and pressure in the weld zone, to connect overlapping sheets of metal. Due to its excellent heat conductivity and low electrical resistance, copper is utilised for electrodes. The squeezing, welding, and holding phases make up the three steps of a spot welding procedure.

Before welding, the workpieces are squeezed to impart the weld force to them in order to create the proper amount of pressure. When welding, heat is produced when an electric current travels through the workpieces while the welding force is maintained. During the holding stage, current is turned off while the weld force is kept constant, enabling the weld to forge and cool under pressure. The electrical current, duration, and electrical resistance of the materials between electrodes all have a role in how much heat is produced. This interelectrode resistance is made up of five distinct resistances. Because they promote heating and subsequently electrode deterioration, resistances R1 and R5 are undesirable. The workpieces' resistances, R2 and R4, play a particularly significant role in the last stages of the weld. Low resistive materials are challenging to weld because less heat is produced inside the components. The establishment of the weld depends on nugget formation, which makes resistance R3 the most crucial factor, the nugget is a volume of melted material that develops in the interface of workpieces with an electrode-like diameter. Nugget penetration should be at least 20% but not more than 80% of the same thickness of the thinnest sheet member [31]. After applying stress to the electrodes, current starts to flow, raising the temperature at the interface and creating a molten nugget.

The workpieces experience plastic deformation in the last stages of welding, resulting in a noticeable and long-lasting depression. Melted material may be expulsed splashed to space if current or pressure are sufficiently high. Since carbon steels have a greater electrical resistance and a lower thermal conductivity than copper electrodes, the technique finds widespread utility in welding carbon steels. Because aluminium alloys' electrical resistivity and thermal conductivity are closer to those of copper, welding these materials is challenging and calls for greater current levels, which might harm the electrode tips. This method may also be used to weld other materials such reactive metals, galvanised steels, and heat-resistant alloys. The method is heavily used in the manufacturing of industrial and household equipment as well as the automotive and aerospace sectors because to its high level of competition [3], [4].

High welding speed and low thermal distortion, which are quicker and lower than in traditional arc welding methods, appropriateness for automation, the need for low-skilled operators, and the lack of joint preparation or filler metal are the main benefits of this procedure. The need for lap joints in thin materials, typically up to a thickness of 4 mm, the joints' lack of tightness, and their weak tensile and fatigue strengths are some of this process's drawbacks. The initial equipment expenses are greater than those of traditional arc welding equipment, therefore this is something else to consider. With the use of heat, pressure, and a welding method called resistance spot welding RSW, two or more metal sheets may be bonded together. It is largely utilised in the automotive and aerospace sectors to attach thin metal sheets or components together.The fundamental idea behind Resistance Spot Welding is to weld metal sheets by running an electric current across them. The heat produced by the electric current melts the sheets at their places of contact, creating a weld nugget. The metal's resistance to the passage of electric current causes the heat to be produced. A detailed explanation of the Resistance Spot Welding procedure is given below:

1. **Setting Up:** The joining metal sheets are thoroughly cleaned and positioned. This guarantees strong electrical contact and raises the weld's calibre.
2. **Electrode Placement:** On each side of the metal sheets are two electrodes, commonly constructed of copper. These electrodes squeeze the sheets together while also delivering electric current.
3. **Current and Pressure Application:** An electric current flows through the electrodes when they are pushed on the metal sheets. The metal at the contact sites melts and forms a weld nugget as a result of the heat produced by the resistance to the current flow.
4. **Cooling and Solidification:** The current is cut off and the pressure is held for a brief period of time to enable the weld nugget to solidify. In doing so, a solid connection between the metal sheets is ensured.

The electrical current, pressure, welding duration, electrode design, and welding characteristics of the metal being welded are some of the variables that affect the effectiveness of resistance spot welding. To get the best weld quality and strength, these factors need to be carefully controlled. RSW has a number of benefits, including quick welding, cheap cost, and the capacity to weld metals that aren't compatible. Additionally, it creates a weld that is smooth and tidy with little deformation. However, it may not be appropriate for thick or highly conductive materials since it is mainly designed for thin sheets.Overall, resistance spot welding is a commonly used and effective welding technique that is essential to the production and assembly of diverse metal parts for a variety of industries [5]–[7].

DISCUSSION

Welding Equipment:

The main welding equipment to consider in resistance spot welding are the welding power sources and the electrodes. Those pieces of equipment will be considered next in detail.

A) Energy Sources:

A mechanical system is utilised to provide welding power, and spot welding equipment primarily consist of an electrical circuit that supplies welding current, a control circuit that manages welding current and welding duration, and a welding circuit. The workpieces and electrodes are connected together in the secondary circuit of a step-down transformer, which makes up the electrical circuit Input AC current with high voltage and low amperage is converted by the transformer into output AC current with high amps and low voltage in the secondary winding. These transformers have low internal impedance because the size of the secondary winding's current is directly correlated with the secondary circuit's open voltage and inversely proportional to impedance. Many people utilise single-phase AC equipment that can produce current up to 50 kA. Spot welders may also provide DC with constant polarity, AC with alternating polarity pulses, or AC in pulsed mode There are single-phase and three-phase machines, but single-phase is more often employed since it is easier to use and has lower startup and maintenance expenses for almost similar performance.

The rectifier, the frequency converter, and the stored energy machines are the three main categories of direct current machines. Unlike machines that use stored energy, which are powered by single-phase systems, the rectifier and frequency converter machines are fed by three-phase systems. These later devices gradually release a pulse of current to weld metal after storing energy for a while. Low frequency welds may be made using these welders. RSW may use medium-frequency 400-2000 DC inverters. These inverters enhance the capacity to precisely regulate the welding process [60]. High-frequency DC inverters are being created to enhance process control even further, the placement of the secondary circuit in multiple spot welding depends on whether the welds are direct or in series. The welding circumstances for the three electrodes shown in Figure 2.20a are identical to those for direct multiple-spot welding. however, in series multiple-spot welding, each of the two transformer secondary circuits produces two welds.

Most spot welders can accept welding data input and are computer controlled. The most basic control determines welding duration and current strength. More advanced controls enable for the provision and control of preheat and post-heat processes, as well as the regulation of welding current. In order to stop the electrodes from deforming too soon, electrode clamping force is supplied via hydraulic, pneumatic, magnetic, or mechanical methods at a high regulated pace. Due to the fast rates of heating and cooling throughout the welding cycle, the material clamped by the electrodes expands and contracts quickly, yet working pressure must be maintained. The electrodes must react when heated metal begins to soften in order to maintain appropriate pressure on the sheet surfaces. The electrode-workpiece contact resistances rise, electrodes are overheated, and electrodes may degrade if pressure lowers during welding. The clamping force may change during the cycle. If the metal has a high rate of shrinkage during solidification, more effort may be required to forge the nugget after the current has passed. All phases of the spot welding process may be controlled by contemporary technology. The attachment of RSW to robotic systems is made easier by new portable gun modules that combine the power transformer and actuator onto a single platform.

B) Electrodes:

To avoid degradation of the workpiece and electrodes, electrodes must acquire low electric contact resistance and high electrical and thermal conductivities. They also need to be strong enough to withstand wear and distortion at high temperatures. They are produced from copper that includes alloying metals including zirconium 0.08%, beryllium 0.5%, cobalt 1-2%, and chromium 0.6-0.9%. The electrode cap or tip, the electrode body, and the cooling system are the three components that make up an electrode. Although a range of tip forms pointed, flat, dome, and radius is utilised to get access with difficult joints, the majority of electrodes are cylindrical with the tip machined to a truncated cone with an angle of 30o. Equation 2.6, where t is the thickness of the sheet in contact with the electrode, may be used to predict the electrode tip diameter d when welding thin sheets. Equation 2.7 estimates the electrode tip diameter for thicknesses greater than 1 mm: When joining sheets of different thicknesses, the electrode diameter for the thinner material should be provided. The electrode diameter D and the weld diameter D should be comparable. The electrode tip deteriorates as a result of many heating and cooling cycles as well as the collection of metal particles. A tip's maximum diameter is limited to 1.3 times its beginning diameter. The electrode tip should be changed or redressed to the original diameter when it reaches this diameter.

C) Method Parameters:

The criteria for welding, according to Joule's law, are current, time, and electric resistance. Electric resistance is a result of various factors, including clamping force, sheet metal surface quality, and electric resistivity of materials. When welding, one property of the materials that fluctuates with temperature is electric resistance. The cleanliness and roughness of sheet material surfaces affect the quality of the material's surface. The welding machine has three programmable parameters: welding power, welding time, and current. The kind of welding equipment used as well as the thickness and physical characteristics of the metals being welded affect the choice of welding conditions.

D) Current and Time for Welding:

When welding, heat is generated in a linear relationship with time and current squared. Despite the fact that both factors generate heat, the weld heating rate is solely dependent on the current since heat loss to the workpiece and copper electrodes rises with welding duration. Heat loss from the workpiece widens the thermal distortion and heat affected zone, and heat within the electrodes may deteriorate the material, all of which are unwanted consequences. Any metal's electrical and thermal resistivities have a tendency to be inversely correlated with the amount of current needed. With rising current, the weld nugget's size grows quickly how welding time should be reduced when welding a certain material and thickness if current is increased in order to avoid ejection of molten material and electrode damage Figure. 1. The maximum amount of useful current is determined by the material's ejection [8]–[10].

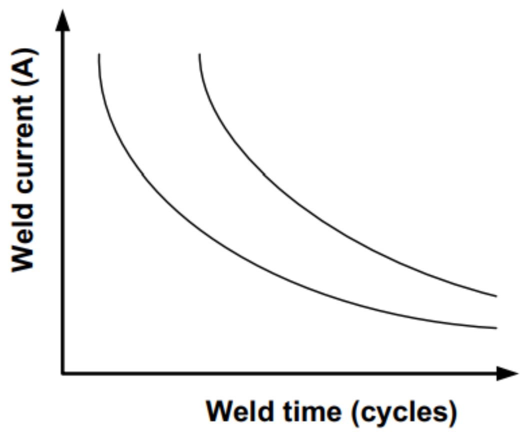


Figure 1: Schematic representation of current-time relationship for RSW [Modela para].

Welding currents typically vary between 4 and 20 kA for carbon steels, but they may range from 20 to 100 kA for light alloys. Time is measured in cycles of a 50 Hz supply, and it ranges for steels between 5 and 100 Hz and for light alloys between 5 and 20 Hz in sheets up to 3 mm thick, illustrates how the geometries of weld current cycles may vary depending on the materials being welded. The simplest case is represented by a cycle of constant current magnitude, which is suited for welding mild steels. A modulated welding current with a rising time tr and a fall time, may be utilised to enable progressive heating and cooling of the weld for high strength steels susceptible to cold cracking. An extra current cycle of magnitude Ia, c, might be helpful to anneal the weld in the case of materials that are prone to the formation of brittle structures in the weld. When spot welding thick materials above 3 mm, the employment of several current pulses is beneficial.

E) Welding Force:

Because it encourages the expansion of the contact area owing to the deformation of surface asperities and ultimately the rupture of surface oxide coatings, an increase in welding force lowers contact resistance. High electrode clamping pressures are necessary to minimise the amount of heat produced at the electrode/workpiece contact, especially when welding low resistivity metals. Unless some of the nugget's molten material can be evacuated, electrode force must be raised as current increases. Inadequate mechanical support and poor fit are two other aspects that lead to material evacuation. The weld should be more than 1.5 D from the edge of the sheets, where D is the diameter of the weld. Extremely high pressures are also undesirable because they may harm the electrodes and indent the workpieces' surfaces significantly. As workpiece thickness and strength increase, so does the clamping force of the electrode. For plate thicknesses up to 3 mm, forces between 1000 and 15,000 N are typical. however, steel sheets up to 6 mm thick may employ values as high as 20,000 N.

The clamping force begins before the current begins to flow and continues after the current is stopped. In order to forge the weld, more force may sometimes be provided following current passage, Process Changes When a continuous seam is needed, resistance seam welding RSEW is utilised. This seam is made up of a succession of overlap spot welds. Similar to resistance spot welding, but using powered wheels or rollers that travel around the joint in lieu of the electrodes. While the wheels remain still, intermittent electrical current flows without the welding head having to be raised or lowered. Between-spot overlap ranges from 25 to 50%. Spot welds may be created using the method with a simple time change. In continuous welds, the weld width ranges from 2 to 5 t, where t is the thickness of a single sheet. Due to constant use, the track has a tendency to distort, hence a device is required to rectify the curvature of the wheel edge. RSEW devices can be circular in shape, with the electrode wheel's axis of rotation at a right angle to the machine's front, longitudinal in shape, with the electrode wheel's axis of rotation parallel to the machine's front, or universal in shape, allowing the electrode wheel's axis of rotation to be adjusted .

For welding huge workpieces that are challenging for traditional equipment to handle, portable devices are also available.Electrode wheels may have internal or external cooling and are built of the same materials as RSW electrodes. Their diameters range from 50 to 610 mm. Internal cooling could be more expensive to operate and does not cool the weld. The maximum welding current in normal RSEW machines typically ranges from 20 to 30 kA, while light alloy welding may use welders up to 100 kA. For steels, clamping forces between 2000 and 16000 N and welding rates between 1 and 12 m/min are utilised. however, aluminium alloys need lower clamping forces and welding speeds. At the moment, this method is used to weld coated, carbon, low-alloy, and stainless steels. Due to their reduced electrical resistance and lower melting temperature, welding with light alloys needs extra care.

In hard-to-weld aluminium alloys, one may accelerate welding and lower joint preparation costs using a novel technique called conductive heat resistance seam welding. RSEW is extensively utilised in the production of heat exchangers, non-pressurized tanks, and other container types, as well as in the automobile sector. The ability to create gas- and liquid-tight welds as well as the potential to reduce the overlap width of the sheets are the main benefits of this technology over resistance spot welding. The thermal distortion may be more than with resistance spot welding, and the weld must advance in a straight line or a line that is evenly curved with a wide radius. There are a number of variations of this procedure, including mash-seam welding, butt seam welding, high frequency resistance welding, and high frequency induction welding , but they are not covered in this introduction.

Type of Resistance Spot Welding RSW:

Depending on the particular needs of the welding application, Resistance Spot Welding RSW may be employed in a variety of ways. RSW may have many common forms, including:

1. The conventional method of RSW, known as spot welding, involves pressing two electrodes against the metal sheets to be welded. The electrodes are subjected to an electric current, which produces heat at the electrodes' sites of contact and forms the weld nugget.
2. In projection welding, raised or embossed regions on the metal sheets are referred to as projections or bumps. By concentrating the heat and pressure during the welding process, these projections enable stronger and more dependable welds.
3. When metal sheets overlap, seam welding is utilised to create continuous welds throughout their length. Rotating wheel-shaped electrodes that carry current and exert pressure to form a continuous weld seam are used in this process.

4. This RSW version is utilised to connect bigger, more intricate pieces. The metal sheets are brought together in this procedure, and a strong electric current is then sent through them, creating a controlled arcing or flashing. The flashing eliminates surface impurities and welds the sheets together.
5. This sort of RSW is used when either one or both of the metal sheets being welded have a coating of paint, zinc, or galvanization. To achieve a successful weld without harming the coating, certain welding settings and electrode materials are employed. These are a few of the Resistance Spot Welding versions that are most often utilised. Each kind has distinct benefits and uses that make it possible to weld a variety of materials and satisfy certain specifications in different sectors [11], [12].

CONCLUSION

Finally, Resistance Spot Welding RSW is a quick, affordable, and trustworthy way to connect metal sheets. It is often utilised in sectors like automotive and aerospace because it creates welds that are sturdy and attractive to the eye. RSW's usefulness in industrial applications is further enhanced by its adaptability and capacity to combine metals of different compositions. But for thin sheets, it works best, and for the best results, welding settings must be carefully controlled. RSW generally ensures rapid and precise production of high-quality welded joints, which is essential for effective industrial operations.

REFERENCES:

[1] L. Habib, Z. Abdelkader, B. Habib, and B. F. Benallel, ‘Experimental study of tensile test in resistance spot welding process’, *Lat. Am. J. Solids Struct.*, 2016, doi: 10.1590/1679-78252271.

[2] K. Zhou and P. Yao, ‘Overview of recent advances of process analysis and quality control in resistance spot welding’, *Mechanical Systems and Signal Processing*. 2019. doi: 10.1016/j.ymssp.2019.01.041.

[3] *et al.*, ‘Optimization of Resistance Spot Welding (RSW) Parameters by using Taguchi Method’, *Int. J. Innov. Technol. Explor. Eng.*, 2020, doi: 10.35940/ijitee.c9215.019320.

[4] M. Huang, Q. Zhang, L. Qi, L. Deng, and Y. Li, ‘Effect of external magnetic field on resistance spot welding of aluminum alloy AA6061-T6’, *J. Manuf. Process.*, 2020, doi: 10.1016/j.jmapro.2020.01.005.

[5] L. Qi, Q. Zhang, Y. Ma, Y. Xu, X. Han, and Y. Li, ‘A comparative study on mechanical performance of traditional and magnetically assisted resistance spot welds of A7N01 aluminum alloy’, *J. Manuf. Process.*, 2021, doi: 10.1016/j.jmapro.2021.04.006.

[6] C. DiGiovanni and E. Biro, ‘A review of current LME test methods and suggestions for developing a standardized test procedure’, *Weld. World*, 2021, doi: 10.1007/s40194-020-01050-7.

[7] X. Sun, Q. Zhang, S. Wang, X. Han, Y. Li, and S. A. David, ‘Effect of adhesive sealant on resistance spot welding of 301L stainless steel’, *J. Manuf. Process.*, 2020, doi: 10.1016/j.jmapro.2020.01.033.

[8] U. Eşme, ‘Application of taguchi method for the optimization of resistance spot welding process’, *Arab. J. Sci. Eng.*, 2009.

[9] M. Raut and V. Achwal, ‘Optimization of spot welding process parameters for maximum tensile shear strength’, *Int. J. Mech. Eng. Robot. Res.*, 2014.

[10] H. Jo, D. Kim, M. Kang, J. Park, and Y. M. Kim, ‘Effects of surface roughness and force of electrode on resistance spot weldability of aluminum 6061 alloy’, *Appl. Sci.*, 2019, doi: 10.3390/app9193958.

[11] Z. Wan, H. P. Wang, N. Chen, M. Wang, and B. E. Carlson, ‘Characterization of intermetallic compound at the interfaces of Al-steel resistance spot welds’, *J. Mater. Process. Technol.*, 2017, doi: 10.1016/j.jmatprotec.2016.11.017.

[12] P. Sivaraj, M. Seeman, D. Kanagarajan, and R. Seetharaman, ‘Influence of welding parameter on mechanical properties and microstructural features of resistance spot welded dual phase steel sheets joint’, in *Materials Today: Proceedings*, 2020. doi: 10.1016/j.matpr.2019.08.201.

CHAPTER 25

ROBOTICS AND AUTOMATION IN WELDING

Mr. Robin Khandelwal, Assistant Professor
Department of Mechanical Engineering, Jaipur National University, Jaipur, India
Email Id:robinkh16@jnujaipur.ac.in

ABSTRACT:
Metals are joined through welding. With the technology we now have, welding joins metals or other materials at the molecular level. Since so many military forces depend on welding technology to produce their defence goods, I add at the moment since there are still welding techniques we don't know about. There are four parts to a weld, according to what we know about contemporary welding. The metals themselves, a heat source, filler material, and some kind of air protection make up the four elements. Forge welding was the only method of joining metals until the end of the 19th century. Blacksmiths had been using this method for centuries to pound and melt iron and steel together. Late in the century, arc welding and oxyfuel welding were among the first processes to develop, and electric resistance welding shortly after.

KEYWORDS:

Automation, Control System, Forces ,Robot Welding Welding Automation.

INTRODUCTION

Robotics and automation have completely changed the welding business, making welding more accurate and efficient. In many industrial sectors, including automotive, aerospace, and construction, welding is a crucial activity. Robotics and automation have greatly increased the quality and productivity of welding processes.Typically, robotic welding systems consist of a robot arm with a welding tool attached, a controller, and a power source. The controller controls the welding parameters, such as voltage, current, and wire feed speed. The robot arm is designed to move the welding tool along a specified route. This enables the production of accurate and consistent welds on a range of materials [1], [2]. There are several advantages to robots and automation in welding. They include enhanced production, better welding quality, and lower labour expenses. Robotic welding systems can operate without becoming tired for extended periods of time, which may result in increased throughput and quicker production timelines. Robotic systems may also be trained to operate in dangerous or challenging locations, improving safety and lowering the possibility of harm coming to human employees.The ability to maintain uniformity in weld quality is another benefit of robotic welding. Welds are created with a high degree of precision and reproducibility thanks to robots' programming, which minimises the need for rework or repairs.Overall, robots and automation in welding have had a big influence on the industrial sector, offering a more dependable and efficient way to weld that boosts both quality and production.

The early 20th century saw a considerable growth in welding technology as the need for durable and affordable joining techniques increased due to World Wars I and II. Following the conflicts, a number of contemporary welding techniques were created, including semi-automatic and automated processes like GMAW, SAW, FCAW, and ESW as well as manual techniques like

SMAW, which is now among the most used welding techniques. In the later half of the century, advancements continued with the advent of laser beam welding, electron beam welding, magnetic pulse welding MPW, and friction stir welding. The science is still evolving today. Robotic welding is used in industrial settings, and researchers are always developing novel welding techniques and understanding weld quality. Automation has been adopted to welding technology due to the ongoing need for high production rates, accuracy, and labour costs. Mechanised, automatic, and semi-automated MIG-MAG systems served as the foundation for the initial automation applications. A examination of welding expenses indicates that around 70 to 80% of the total cost may be accounted for by the human factor. Many conventional welding processes are labor-intensive. By substituting part or all of the human labour with an automated system, welding automation is a way for lowering the total cost of the welding procedure. However, there may be much more significance to the adoption of automation than just its main impact on labour costs. in particular, its impact on the following elements must be taken into account: safety and health. product quality. and supply flexibility [3], [4].

Historical Perspective:

Metal item construction, production, and maintenance all need the usage of welding. Although other types of materials can also be joined using this skill, this book only focuses on welding processes used to join metal objects. This skill is essential for a number of industries, including consumer goods, shipbuilding, building and bridge construction, transportation, building and aerospace The author Karel Capek originally coined the term robot in 1921 in his book Rossum's Universal Robots, which is derived from the Czech robota, which implies relentless labour. But because most of them took the time to dream, develop, and create robots that might imitate some of the human skills, robotics was in the thoughts of the most brilliant brains of our shared past. Building obedient, tireless robots that might take over for people in monotonous, repetitive labour is one of man's greatest aspirations. A concept that Nicola Tesla articulated in his diary. Welding robotics and automation have a long history dating to the early 1960s. George Devol and Joseph Engelberger created the Unimate, the first industrial robot, in 1959. The Unimate was created to move and handle hot metal components in a die-casting facility. Although this early robot was not created with welding applications in mind, it provided the foundation for their creation.

The first robotic welding devices were created in the early 1960s. These devices were created to streamline human labour and automate the welding process. The automobile sector was the first to deploy robotic welding equipment to join body panels and other vehicle components. Robotic welding systems began to be used outside of the automobile sector in the 1970s. Numerous sectors, including shipbuilding, construction, and aircraft, utilised these technologies. Robotic welding systems got more sophisticated and capable of carrying out increasingly difficult jobs as technology evolved. The usage of robotic welding systems grew significantly in the 1980s and 1990s. As the price of the technology dropped, small and medium-sized firms started using these systems more often. Robotic welding systems have expanded as a result of the development of new welding techniques including gas metal arc welding GMAW and gas tungsten arc welding GTAW. The automotive, aerospace, construction, and industrial sectors are just a few that employ robotic welding systems today. These technologies have progressed and are now capable of carrying out intricate welding jobs with increased accuracy and effectiveness. Robotic welding systems have helped organisations become more productive, produce better work, and save expenses.

DISCUSSION

Robotics:

There are a few things we may learn from our current position if we go back on the lengthy history of robotics. Robotics may be traced back to the water clocks created by the Greek civil engineer Ctecibius around 270 BC. Phylo of Byzantium, the author of the book Mechanical Collection 200 BC, Hero of Alexandria 85 BC, and Marcus Vitruvius 25 BC were all admirers of his work. The Arab Badas-zaman al-Jazari 1150–1220, who lived in the twelfth century, recorded some of the Greek innovations in his book The Science of the Ingenious Devices Figure 1, which is how they made it to our day. In those early times, the issue was on mechanics, namely how to create and transfer motion. Thus, the focus was mostly on mechanics and creative mechanical gadgets. Then, in the fourteenth century, Leonardo da Vinci indirectly demonstrated that the primary issue at the time was the lack of accuracy and a reliable power supply. He created several motion-generating and motion-transmitting machines, as well as various means of temporarily storing mechanical energy. However, he lacked the tools necessary to create such mechanisms precisely, and there was no permanent power source electrical, pneumatic, or hydraulic accessible.

It's possible that this is what caused him to abandon his plans to complete a knight robot from the fourteenth century for the Salle delle Asse of the Sforza family castle in Milan, Italy. It wasn't adequate. Or maybe it was such a ground-breaking notion for the period that he reasoned that it would be preferable to make it go away [5], [6]. Then there was Nicola Tesla's contribution at the beginning of the nineteenth century. He considered controlling an automaton using Henrich Hertz's discovery of radio waves, which came after James Clerk Maxwell's research on electromagnetic phenomena. To illustrate his theories, he constructed one and displayed it in 1905 at Madison Square Garden in New York, USA. The absence of artificial intelligence was the issue there. To do the desired duties, robots should be able to carry out preprogrammed actions and display some level of autonomy. When that became feasible, robots quickly advanced. the first industrial robot debuted at the start of the 1970s and quickly grew to be a multi-million dollar industry.

Since there was a lot to accomplish and the existing computers were strong enough to execute the necessary tasks, evolution was not as great as it might have been. Because manufacturers were generally satisfied with their robots, industrial robots remained position-controlled, challenging for normal workers to programme, and not very interesting equipment. Due to a certain lack of interest from the robot production business, features that are today prevalent in research labs hadn't reached industry yet. But there was a sizable progression, which may be summed up as follows. The first electrical drive trains that could be used as actuators for robot joints were available in 1974. The first commercially accessible microprocessor-controlled robots also debuted that year. Robot controllers began to include features like Cartesian interpolation for route planning about 1982, and many of them could connect to other computer systems through serial and parallel interfaces. The same year, several manufacturers unveiled taught pendant menu interface and joystick control for simpler programming.

Automation Options:

Welding automation may vary from simple positioners to fully integrated systems. For clarity, the various possibilities will be described under the following headings:

1. Simple mechanization.
2. Dedicated and special-purpose automation.
3. Robotic welding.
4. Modular automation.
5. Programmable control.
6. Remote-control slave and automated systems.

Static Weld Stations:

Relatively small components may be moved under a fixed welding head or even a manually held flame using basic welding lathes and rotary positioners. This kind of automation may be readily justified for relatively modest batch quantities using simple jigging. Although fixed linear slides are also available for straight seams, they are more suitable for circular weld routes. Facilities for synchronising power source switching and welding crater filling may be included in even inexpensive systems. Column and boom positioners, motorised beams, roller beds, and turntables are available for larger workpieces. These units, like tractor systems, are adjustable to a variety of applications limited only by the size and weight of the components being connected. They are best suited for basic geometric forms and consumable electrode operations. The ability to weld with one hand down allows for greater deposition rates and better quality, which is the main benefit of this kind of technology. Despite the expensive initial cost of the positioning equipment, these benefits are particularly noticeable on heavier sections and may lead to large cost savings. These systems' typical configurations are shown. The construction of pressure vessels and power generating equipment's longitudinal and circumferential seams is the most common use for columns and booms, roller beds, and heavy turntables. Additionally, very large pieces have been used to build power generating system drums and circumferential joints in submarine hull sections.

Dedicated Automation:

Creating a special welding system specifically for a certain application is what dedicated automation involves, and the equipment that results could not be adaptable to changes in joint or component design. Typically, only high production quantities of components with a long design life are justified for this kind of automation. For automotive parts like road wheels and exhaust systems, dedicated automation has traditionally been used with a variety of welding techniques such resistance spot, GTAW, and GMAW. A carousel design with a single-load-unload station is often used in situations where the welding head is just one station of a multi-station automation system that prepares the component for welding and also performs finishing activities. When smaller production volumes and shorter product life cycles are anticipated, but the welding environment is very hostile or the quality of the completed product is a top priority, dedicated welding systems have also been used.

The nuclear industry has many instances of this kind of application, including the processing of radioactive materials and the production of significant fabrications. The advanced gas-cooled reactor AGR standpipe joints on the Heysham II and Torness UK power station projects are an example of the kind of equipment used for this later usage. The adoption of expensive dedicated automation with a complex power source1 and control system was justifiable on the grounds that faults were unacceptable and performance could not be repeated. The cost of such equipment is often high since specialised systems must be purpose-built around a particular component, and many dedicated automation applications are increasingly being handled utilising the modular or robotic method [7].

Special-Purpose Automation Systems:

For certain applications, where equivalent joints must be done on a variety of component sizes, special-purpose automation has been created. Simple seam welders, orbital welding setups, and the GMAW stitch welder are a few examples. A transistor series regulator was utilised as the power source, and it included features for pulsed GTAW, preprogrammed touch starting, and arc length control. A vision system for remote monitoring of the weld area was also included in the welding head.

Stitch Welders:

It has been often required to seam weld sheet metal utilising the GTAW, plasma, and GMAW techniques to create straightforward cylinders or continuous strips. Conventional automated equipment that clamps the adjacent edges and moves a welding head along the seam has been developed to handle this kind of application. Although the equipment is dedicated to longitudinal seam welding, it is suitable for a variety of material thicknesses and workpiece sizes.

Systems for Orbital Welding:

A variety of orbital welding methods, including as tube-to-tube heads, tube-to-tube plates, and internal bore welders, are used to generate circumferential welds in pipe and tube manufacturing applications. These are typically mobile systems that position a GTAW head around the junction on or in the tube to be joined. Smaller systems use a horseshoe clamp arrangement, while larger devices may be tractor-mounted on a circumferential track similar to the straightforward tractor systems discussed above. In the welding head, wire feeding and arc length control may be employed, and more sophisticated systems may enable the welding parameters to be progressively changed as the torch moves over the seam. Boiler tube joints and tube-to-tube plate welds are two common applications for these methods in the building of power plants.

The use of orbital welding methods to produce more than 60 000 butt welds in stainless-steel pipework at the BNFL reprocessing facility is a noteworthy example of the productivity savings that may be achieved with these techniques as compared with human welding. The use of orbital welding equipment, in conjunction with better pipe preparation and purging processes, resulted in a higher first-pass rate for each weld from 50–60% to 87–90% and a more than halving of the labour hours required per weld. The use of a preplaced consumable socket enabled for single-pass welding to be used, provided joint alignment, allowing for simple square-edge pipe preparations to be used, and removed the need for a wire feed system. Similar to several other applications of this kind, additional advantages were obtained by adapting the automation approach to the application.

Stitch Welder for GMAW:

The GMAW stitch welder is a ground-breaking tool that places a GMAW welding flame on a tiny motor-driven slide. The assembly is installed in a head that mechanically sets the torch height and angle and automatically locates in the weld seam. With this equipment, the user may adjust the weld length and welding speed up to a maximum of 150 mm, and a single button push initiates the welding process. The tool has been designed to be simple to use and is ideal for making fillet welds of a constant size. It may be held vertically or horizontally.

Robotic Welding:

Industrial robots, as defined by the British Robot Association, are not humanoid welders. Instead, they are An industrial robot is a machine that may be reprogrammed to operate and move parts, tools, or specialised production implements using variable programmed movements to complete predetermined manufacturing tasks. The 'tools or specialised production implements'3 in the context of welding robots include welding heads, wire feed systems, and tracking gadgets. Robot welding systems are now available for GMAW, FCAW, SAW, GTAW, plasma, resistance spot, laser, and NVEB welding, among other processes. A mechanical arm or manipulation system, a welding package, and a control system make up the typical industrial robot welding system.

Systems for Mechanical Manipulation:

These are some of the widespread manipulating system setups that have developed throughout time. The articulated arm, often with six or more axes of movement, is the configuration used most frequently for general-purpose welding robots. The flexible nature of the articulated arm is a benefit. Karel Capek used the term robot for the first time in his play Rossum's Universal Robots, which was initially released in 1920. The idea of computer-controlled humanoids has persisted in science fiction, and if anything, Asimov and Adams' 'Marvin the Paranoid Android' further humanised the robot. Industrial robots are typically computer-controlled actuators that can be programmed, yet sometimes they may be given human characteristics, especially when they perform poorly. Unfortunately, the fictional representation has a tendency to skew our understanding of industrial robots and may have raised our hopes or impacted how we judge their usefulness. Often referred to as end effectors, they have the ability to access difficult-to-reach places the fact that they resemble human arms may not be a coincidence. Although the SCARA Selective Compliance Assembly Robot Arm configuration has limited positional capabilities and has historically been used for assembly tasks, some manufacturers have used it as the foundation for a straightforward, easily teachable four to five-axis machine for small batch production.

The rehabilitation of used crusher hammers has also been accomplished with the aid of a SCARA robot system. Due of the unanticipated wear profile, this application of robots is not typical. In this case, the FCAW process' tolerance was used in conjunction with the human selection of one of three preprogrammed jobs based on a visual evaluation of the wear to account for the variations in wear. Other applications of robotic wear replacement have required that the worn item be pre-machined to a predetermined profile prior to robotic build-up. For applications requiring extremely tiny, high-precision movements and very large working envelopes, cartesian or gantry robots have been developed. These conventional configurations may be altered to suit particular purposes. for instance, articulated arm robots are often suspended from overhead gantries for better access, and it is possible to create unique robot configurations by rearranging the axes. The latter system provides a significant capability for reprogrammability to fit various applications, even though it may not seem to be connected to the traditional welding robot. The use of a linear slide to allow the whole robot to travel the length of a component or weld seam is one variation to the standard architecture. For welding massive projects, small, portable, and rail-mounted robots of this kind have been developed.

Drive Mechanisms:

Actuators that are pneumatic, hydraulic, or electrical may move the arm. Resistance spot welding may be done using hydraulic power systems, which are suitable for applications needing high load carrying capacity and precise speed control. However, the majority of fusion welding robots nowadays come with DC servo motor drives. For tiny precision systems, stepper motor drives have been used. they have the benefit of providing built-in feedback on output shaft position but suffer from a lack of power.

Health and Safety during the Operation:

The majority of welding techniques have the potential to be dangerous since they produce particle smoke, toxic fumes, noise, and a variety of electromagnetic radiation, ranging from ultraviolet radiation with arc techniques to x-rays with electron beam welding. These dangers are widely understood, and solutions have been developed. The measures that must be taken to safeguard the welder and supporting workers, however, are expensive and may complicate the welding process or call for the employment of bulky protective gear. Human mistake is another issue that might put nearby people and welders at needless risk. There are risks linked with the application as well as these process-related dangers, such as welding in confined spaces, under water, or in radioactive environments. Automation allows for the operator to be protected from process- and application-related risks while also providing the opportunity to have more control over the welding environment [8], [9].

CONCLUSION

For many industrial companies, robotic welding is an essential tool because it makes it possible to create high-quality goods more quickly and effectively than was previously possible with human processes. Metals are joined by welding. With the technology we have today, welding combines metals or other materials at the molecular level. Since so many armed forces depend on welding technology to construct their military goods, I say at the moment since there are still welding methods we don't know about. There are four parts to a weld, according to what we know about contemporary welding. The metals themselves, a heat source, filler material, and some kind of air protection make up the four elements. Forge welding was the only method of joining metals until the end of the 19th century. Blacksmiths had been using this method for centuries to press and melt iron and steel together. Late in the century, arc welding and oxyfuel welding were among the first technologies to emerge.

REFERENCES:

[1] B. T. Gibson *et al.*, ‘Friction stir welding: Process, automation, and control’, *J. Manuf. Process.*, 2014, doi: 10.1016/j.jmapro.2013.04.002.

[2] S. L. Canfield, J. S. Owens, and S. G. Zuccaro, ‘Zero moment control for lead-through teach programming and process monitoring of a collaborative welding Robot’, *J. Mech. Robot.*, 2021, doi: 10.1115/1.4050102.

[3] J. Ogbemhe and K. Mpofu, ‘Towards achieving a fully intelligent robotic arc welding: A review’, *Ind. Rob.*, 2015, doi: 10.1108/IR-03-2015-0053.

[4] H. Amrutha, J. Ajinkya, and M. Surabhi, ‘Application of failure modes and effects analysis (FMEA) in automated spot welding process of an automobile industry: A case study’, *J. Eng. Educ. Transform.*, 2021, doi: 10.16920/jeet/2021/v34i0/157156.

[5] J. Muhammad, H. Altun, and E. Abo-Serie, ‘Welding seam profiling techniques based on active vision sensing for intelligent robotic welding’, *Int. J. Adv. Manuf. Technol.*, 2017, doi: 10.1007/s00170-016-8707-0.

[6] R. Bogue, ‘Vision-assisted robotic welding’, *Ind. Rob.*, 2018, doi: 10.1108/IR-04-2018-0072.

[7] J. Norberto Pires, ‘Robotic Welding, Intelligence and Automation’, *Ind. Robot An Int. J.*, 2009, doi: 10.1108/ir.2009.04936bae.005.

[8] C. Loukas *et al.*, ‘A cost-function driven adaptive welding framework for multi-pass robotic welding’, *J. Manuf. Process.*, 2021, doi: 10.1016/j.jmapro.2021.05.004.

[9] Y. Xu, G. Fang, N. Lv, S. Chen, and J. Jia Zou, ‘Computer vision technology for seam tracking in robotic GTAW and GMAW’, *Robot. Comput. Integr. Manuf.*, 2015, doi: 10.1016/j.rcim.2014.09.002.

CHAPTER 26

SENSORS FOR WELDING ROBOTS IN INDUSTRY

Mr. Ashok Singh Gour, Assistant Professor
Department of Mechanical Engineering, Jaipur National University, Jaipur, India
Email Id:asgour@jnujaipur.ac.in

ABSTRACT:
There are several different kinds of sensors for welding robots, including vision sensors, force/torque sensors, temperature sensors, and seam tracking sensors. Robots using vision sensors can precisely find weld connections, compensate for differences in the parts, and assure correct weld placement. Feedback on welding forces is provided by force/torque sensors, allowing adaptive control and reducing flaws. Temperature sensors keep track of heat input and support the preservation of ideal welding conditions. Real-time monitoring of the weld joint using seam tracking sensors corrects for errors and ensures constant weld quality.

KEYWORDS:

Automated Welding, Force, Gas Flow, Robotic Welders, Sensors,Torque Sensors.

INTRODUCTION

Automation and welding processes using new and sophisticated materials have raised the requirement for enhanced control and sensing in welding. To achieve the required weld in terms of productivity and quality, careful welding process management is necessary. As a result, several technologies are required to properly regulate the process with regard to the various welding operating parameters. As the main source of input to the control system that manages and controls the behavior and output of the welding system, sensors play a significant role in this process. In this context, the word sensor refers to apparatuses that monitor welding-related observable characteristics in order to regulate the welding process in accordance with predetermined specifications [1]–[3]. In general, the MIG/MAG process or GMAW Gas Metal Arc Welding is the basis for the majority of robotized welding techniques that result in a continuous weld. The usage of sensors in this application area has been rather limited. However, the creation and use of novel welding techniques like high-speed welding and laser welding highlight the need of precise process control.

New materials with the potential to reduce thicknesses are also used in the creation of new goods. This necessitates the ability to operate with tighter tolerances. As a result, there is a growing need for sensors that can satisfy the standards of new processes and products, and these sensors are often a must. The primary function of the sensors is to provide the control system information it needs to make appropriate actions that will result in a result that complies with predetermined requirements. This is not as simple to do in welding as we may believe. Two subsystemsthe welding apparatus and the robotperform the bulk of the work in the welding process. The devices that transmit the energy from the welding power source, such as the wire feed system, conduit, welding torch, and others, are included in the welding equipment. Through a welding torch connected to the end effector mounting plate, the robot creates the relative location of the welding energy and the work piece that has to be joined.

Both the robot and the welding apparatus are crucial from a control perspective to create the weld with the required quality and productivity. The welding power supply and the robot arm are typically controlled by two separate and loosely connected control systems. The sensors and the reason for using them to regulate the welding process will both be covered in the sections that follow. For the purpose of using sensors, the information can preferably be used for both controlling the welding power source and the robot arm, as will be discussed later in this Chapter. Sensors are typically used for one of the control systems, the welding equipment, or the robot. However, the sensor's specification will depend on its use and purpose. As a result, sensors can be categorized into two groups: technological sensors and geometric sensors. Technological sensors measure parameters related to the welding process, while geometric sensors measure parameters related to the geometry of the weld joint.

History of Sensors for Welding Robots:

A Along with the advancement of robotic welding technology, the usage of sensors in welding robots has changed. The development of industrial robots and their incorporation into welding applications may be linked to the history of sensors for welding robots. Let's examine the progression of sensors in welding robots. In the 1960s and 1970s, welding robots first appeared. Early robotic welding systems mostly used limit switches and basic proximity sensors as its sensors. These sensors provided fundamental input on the location and motion of the robot. In order to detect contact between the welding tool and the work piece and to enable basic force control, force sensors were also added. Developments in Vision Sensing in the 1980s. Vision sensing technologies started to be used into welding robots in the 1980s. In order to offer visual input for weld seam identification, component placement, and alignment, cameras and vision systems were employed. Robotic accuracy and weld quality were improved because to vision sensors that enabled robots to adjust to changes in work piece location and geometry.

Temperature Sensing and Monitoring 2000s. Temperature sensors began to be added into welding robots to track the heat input during welding procedures. Robots might optimise welding conditions, avoid overheating, and guarantee constant weld quality by monitoring and adjusting the temperature. Sensor Technology and Integration Advancements Present and Future. In recent years, sensor technology has advanced, leading to the creation of smaller, more precise, and more dependable sensors. Robotic systems are rapidly integrating sensors, allowing for smooth data interchange and communication for better process control, quality assurance, and predictive maintenance. The development of sensors for welding robots is a reflection of the constant drive for better automation, better weld quality, and higher output. We may anticipate further developments in sensing capabilities, AI integration, and the use of sensor data analytics in welding robots as sensor technology continues to evolve. Geometrical parameter sensors are primarily used to provide the robot seam tracking and/or search capabilities, enabling the robot's route to be adjusted in response to geometrical deviations from the nominal path.

DISCUSSION

Technological sensors are mostly utilized for monitoring and/or regulating reasons and measure factors inside the welding process to ensure its stability. As will be discussed later, data from both technological and geometrical sensors serves as a foundation for a qualitative control of the welding process, enabling conformance to requirements laid out in a WPS Welding Procedure Specification regarding quality and productivity measures. The difficulty of transferring observable parameters to controlled parameters with regard to the sensor is another significant issue. Feedback control is easy in the basic example of sensor-based seam monitoring of nearly straight welds, but utilising sensor data for integrated control linked to the WPS will need a more complex model-based control technique. This is due to the fact that a controllable parameter isn't necessarily one that a sensor can detect when welding, thus a model-based mapping must be created in order to be able to control the weld.

In this situation, a model-based method may convert a parameter or set of parameters that the sensor is unable to directly see into a known set of parameters that can be estimated from the sensor's data by a model of the welding process. Such models would, however, forecast a lot of variables not directly seen and with a degree of uncertainty since the welding process comprises numerous connected factors with associated tolerances. In reality, these models perform better when used with nominal data that is specified and in circumstances that are comparable to those predicted by the WPS. Similar to how requirements stated in the WPS are often counteracted, actions to regulate the process are also typically defined by a combination of a set of parameters. In most circumstances, there are several ways to regulate the welding process and satisfy WPS standards, thus such a collection of parameters is not unusual [4], [5]. It should be highlighted that the idea of defining the weld to be generated in a WPS document is a technique to design a protocol to describe the welding process in a consistent and reliable manner. Information about the actual weld to be produced, such as joint shape and material, as well as joint preparation, consumables like welding wire and the composition and flow of the shielding gas, nominal operating parameters, and the desired productivity and quality, should all be included.

However, most of the time we can only measure a few of the required parameters and from the available observations make decisions on how to regulate the process to meet the WPS standards. In this sense, the WPS serves as both an operational data specification nominal operating parameters and a definition of the functional requirements of the weld quality, productivity. However, using sensors requires measuring the actual process, extracting features from these measurements, and then overriding these pre-set parameters through a control action in order to meet functional specifications, where quality and productivity concerns must be balanced on a case-by-case basis. Nominal operating statistics for a typical case are established using predetermined weld quality and productivity. This is used to pre-set information about the welding power source and to provide the robot instructions on how to construct a trajectory with a certain velocity, welding torch direction in relation to the weld joint, and weld joint distance. If a sensor is used that can change one or more of these values via a feedback loop, the WPS has to contain allowable tolerances for all nominal data.

Sensors for Technological Parameters:

Technological parameters include voltage, current and wire feed speed. In this section sensors to measure those parameters are reviewed

a)Plasma Voltage:

Arc voltage measurements should, in theory, be taken as near as feasible to the welding arc. At the contact tube, where the current is fed to the wire, the arc voltage may be measured with reasonable accuracy. However, depending on the process conditions, there may be a voltage drop of up to 0.3 V between the contact tube and the wire tip where the arc begins. Measuring the real arc voltage in a production setting is challenging, if not impossible. This is also true for measuring the voltage at the contact tube in the welding torch. Measuring the voltage on the wire within the wire feeding system is a better and more accurate method. The voltage at the wire feeder will be the same as that at the contact tube since the wire does not carry a current between the feeder and the contact tube. It should be noted that measurements are performed in a setting with high currents, often between 150 and 500 A. If sensor wires are installed improperly, this might cause significant induced voltages and reading inaccuracies.

b)Welding Current:

The two main kinds of sensors used to gauge welding current are Hall Effect and Current Shunt.

c)Hall Effect Sensor:

The cast iron core of the Hall Effect sensor, through which the wire carrying the current passes, is shaped like a circle. The actual device is inserted into the opening in the iron core, which is made up of a doped silicon plate and two sets of connecting wires. The device receives a current from the first pair of wires, and in response, delivers a signal on the second pair of cables that is proportionate to the magnetic field and consequently the current. The Hall Effect device has the advantage of being a non-contact sensor and not interfering with the welding power source's current. The sensor's bandwidth is restricted to typically 100 kHz or more, and its typical slew rate is 50 A/s. If the data read I/O channels are created in line with the sensor's specifications, this is typically enough and will provide a rise time during pulsed GMA welding that is less than 1% of the peak pulse duration.

d)Current Shunt:

The basic idea is to let a resistor's current flow through it while monitoring the voltage drop across it, much as you would when using a multimeter to measure current. Despite being easy to use, the approach has certain shortcomings. Because the resistance must be kept tiny, the voltage signal being measured will be weak and noise-sensitive.

e) Speed of Wire Feed:

A key characteristic to manage in order to create a reliable welding process is the wire feed speed. The established settings for the welding power source are typically voltage and current, and the power source is often managed to provide a steady voltage. The conventional approach is to apply a constant amount of voltage and wire feed speed and let the current adjust itself as necessary. In fact, however, a current will reflect a certain wire feed speed. A smaller amount of the wire feed speed will result in a lower arc current, which will result in a quicker deposit of the wire, and vice versa. Although modern welding power sources have many different control techniques, the fundamental idea is to maintain the voltage at a predetermined constant value [6]–[8]. As a consequence, changes in the arc welding environment, such as shifting the distance between the weld flame and the workpiece, will cause the current to fluctuate during the procedure. These modifications may be brought on by the robot's motion or alterations in the weld joint's geometry. Changes in speed, meanwhile, might also come from the wire feeding system and ultimately lead to low-quality output.

A feeding device generates the wire feed speed as the wire is fed via a conduit. The wire is typically fed into the conduit by the unit's driving wheels at a predetermined pace. In most robot systems, the wire feed unit is located on the robot arm very near to the welding flame of the order of 1 m, providing a steady pushfeed of the wire. In certain circumstances, longer conduits must be utilised. however, since the wire diameter must be a little smaller than the inner diameter of the conduit, welding will produce changing wire speeds as the conduit is bent and twisted. In real life, a push-pull wire feed method needs to be used to address this issue. It is difficult to detect the speed of the wire feed, but for laboratory use, special solutions may be created that do so by measuring the speed at the contact tube. Measuring the regulated speed of the feeder unit's drive wheel is a more practical technique in a production system. However, as the feeder system's resilience is crucial to the final weld quality, this must be supplemented by ensuring its functionality and dependability.

Geometrical Parameter Sensors

Geometrical parameters sensors must be able to gather data on the weld that is relevant to the geometry of the weld joint. In order to do seam tracking and utilise this information for weld quality control, this information is crucial. There are several methods to do this, but in the majority of situations, a seam tracker is able to extract details about the weld joint in addition to the desired locations for the weld joint during welding. Departures from a nominal route, changes in direction, and gap size are a few examples of this kind of information. In general, to employ the sensors when welding is to use sensors in robotic welding. In some circumstances, sensors may be employed to determine the location and orientation of the workpiece or weld joint prior to welding.

In such situations, various location methods, such as image recognition or binary sensors to detect the position of particular plates of the work-piece, may be utilised similarly to how they would be for finding any work-piece. However, using sensors during welding is difficult. Specially designed sensors must be used due to the hard environment's high temperature, intense light, and strong currents. The two most popular applications for sensors are i optical sensors, which use a laser light source to illuminate the weld joint under investigation and a sensor with a narrow bandwidth filter to extract the relevant data, and ii through-arc sensing, which makes use of the electrical characteristics of the arc as well as knowledge of the motion of the weld torch that is controlled by the robot.

f) Optical Sensors:

During arc welding, optical sensors work on the fundamental idea of i a laser beam projected in a scanning motion over the seam and ii a CCD-array utilised to assess characteristics of the weld joint in conjunction with a laser stripe. This technique has been modified. for instance, the laser stripe on the weld junction could not be a straight line but rather a circle. In this situation, the sensor is more adaptable and can identify weld connections in corners from a single position of the torch or point of view. The triangulation technique is used to estimate the distance, which is crucial for welding.When a laser beam is directed towards an item, the distance between the sensor and the object affects how much of the object's reflection is seen through the lens of the laser sensor. The angle between the outgoing beam and the reflection via the detector's focusing lens is larger when the item is near to the sensor and smaller when it is further away. By concentrating the incoming beam on a detector, most often a CCD array, the distance between the sensor and object is determined. The array's lighted pixels may be used to determine which ones of the pixels in the array are used to determine the object's distance.

The preparation of the weld joint and geometric form may cause the laser beam to reflect like mirrors. Think of a V-groove weld joint as an example. The laser light will create a number of reflecting locations, but they will all have varying intensities based on the surfaces of the weld joint. Therefore, to filter away reflections that are not related to the location of interest, these sensors must have real-time image processing capabilities. In this regard, it should be highlighted that welding with highly reflecting materials may be problematic and that an actual test may be required to confirm the functioning. A triangulation sensor's primary purpose is to calculate the distance from the location of the target that the beam is directed towards. This may be helpful in some circumstances, such as when controlling the height during a robotized process like welding or cutting. However, triangulation is often used in welding for seam tracking, which necessitates taking weld joint geometry measurements. This is accomplished by scanning the beam over the weld joint. The sensor gathers a two-dimensional image of the joint profile during the scanning process as an array of 2D coordinates. A weld joint geometrical model that includes a complete 3D description of the joint may be built while the robot is in motion.

This joint is formed throughout the welding process as the sensor is moved along the joint. The picture data may be utilised without moving the robot if a 2D CCD array detects a laser stripe projected onto the item. In the event that the stripe is circular and pointed at a corner, this strategy may be helpful. In contrast to the more time-consuming conventional method of measuring the location of one wall at a time, the corner and its walls may then be determined from a single position of the robot. When welding in real time, optical seam trackers based on triangulation are often employed to keep the robot on track with the weld joint. However, these sensors are capable of far more than that, and information such as joint volume, gap size, misalignment, tack welds, etc. can often be obtained. In order to complete the operation in accordance with the set requirements of the welds to be generated, this information is helpful for adaptive feed-back control of both the welding power source and the robot. For instance, the robot-defined welding gun may have its travel speed adjusted in relation to both the welding power-related parameters and the weld gap.

Process of Ensors for Welding Robots:

Real-time feedback and control are made possible by a number of processes that are involved in the usage of sensors in welding robots. Here is a thorough description of how sensors are often used by welding robots:

1. **Sensor Selection:** The first step is to choose the best sensors based on the needs and the particular welding application. The kind of welding process, the material being welded, the needed measures force, temperature, vision, etc., and compatibility with the robotic system must all be taken into account.
2. **Sensor Integration:** After the sensors have been chosen, the robotic system has to include them. As part of this, the sensors must be physically mounted or installed on the robot arm or tooling, their outputs must be connected to the robot controller, and the relevant software interfaces must be configured.
3. **Calibration and Setup:** To achieve accurate data, sensors often need to be calibrated. Establishing a relationship between the sensor data and the real-world values being measured, such as force, temperature, or location, is known as calibration. Applying known forces, temperature fluctuations, or test patterns to the sensor and recording the resulting sensor values are all examples of calibration procedures. After gathering the necessary information, calibration curves or coefficients are created to ensure precise sensor readings.

4. **Data Acquisition:** Sensors continually measure and gather information about the particular parameter being monitored throughout the welding process, such as forces, temperatures, joint position, or visual feedback. Through the robot controller or special data collecting devices, the sensor data is gathered. Depending on the particular sensor and application requirements, the data collection frequency and synchronization with the robot's control cycle must be determined.
5. **Control and Real-time Processing:** After the sensor data is collected, it is processed and analyzed in real-time. The sensor data is evaluated by the robot controller or a separate processing unit to provide feedback and control signals in real time. To detect weld connections, determine exact weld pathways, and offer feedback for path correction or seam tracking, for instance, vision sensor data is analyzed. To adjust welding forces, maintain constant penetration, or find abnormalities, force/torque sensor data is analyzed. The sensor data that has been analyzed is then utilized to create control signals that modify the robot's motions, such as changing the path's speed or welding settings.
6. **Feedback and Adaptive Control:**
    a. The robotic system may use feedback control techniques based on the sensor data and real-time analysis. As a result, the robot is able to adjust to changes in the welding environment or work piece circumstances.
    b. For example, force/torque sensors offer adaptive control to maintain constant forces or identify deviations in the welding process, while vision sensors enable feedback for route correction to adjust for work piece variances.
7. **Sensor Data:** Sensor data may be collected and saved for further analysis and quality control reasons. Data Recording and Analysis. This information may be used to improve processes, ensure product quality, and provide documentation. Sensor data may be subjected to advanced data analysis methods, such as statistical analysis or machine learning algorithms, in order to find trends, spot abnormalities, or enhance process efficiency. In a continuous loop, real-time data from the sensors is analyzed and control signals are created to adapt and optimize the welding process. This is how sensors are used in welding robots. In robotic welding applications, this repetitive process enables precise control, better weld quality, and increased effectiveness.

Application of Ensors for Welding Robots:

Due to their ability to provide real-time input and enable accurate welding process control, sensors are essential to welding robots. They have several uses that improve the effectiveness, caliber, and efficiency of robotic welding. The following are some essential uses for sensors in robotic welding [9].

1. **Vision Sensors:**
    a. **Weld Seam Detection:** Vision sensors are used to find and recognize weld seams on work pieces, allowing precision weld route planning and assuring perfect weld placement.
    b. **Part Detection and Alignment:** By detecting and aligning work pieces, vision systems can account for differences in position, orientation, and form, which enhances weld quality and consistency. Joint tracking enables the robot to adjust to changes in joint position and geometry, resulting in precise weld placement. Vision sensors follow the weld joint in real-time.

2. **Sensors for Force and Torque:**
    a. **Force Control:** Force sensors gauge the welding pressures applied to the work piece, allowing for exact force management throughout the welding procedure. This keeps the penetration depth constant, avoids flaws, and enhances the weld quality.
    b. **Contact Detection:** Force/torque sensors identify the point at which the welding tool makes contact with the work piece, guaranteeing perfect alignment and avoiding collision damage.
    c. **Seam Tracking:** By observing variations in forces as the robot moves over the weld joint, force sensors may be employed for seam tracking. This aids the robot in modifying its course and preserving the best possible touch with the work piece.
3. **Temperature Sensors:**
    a. **Heat Input Monitoring:** Temperature sensors monitor the heat input by taking temperature readings during welding, which enables accurate heat input regulation. This keeps the right welding conditions in place, controls weld bead form, and helps avoid overheating.
    b. **Preheating and Post-Weld Cooling:** To ensure correct thermal conditions for welding and reduce distortion, temperature sensors are utilized to monitor preheating and post-weld cooling operations.
    c. **Devices:** Seam tracking devices, such as laser vision systems, monitor the weld joint in real-time while accounting for fluctuations in joint location and shape. In particular in complicated or irregular joint designs, this provides precise weld location and enhanced joint tracking.
4. **Arc sensors:**
    These sensors follow the joint and modify the robot's course in response to input from the welding arc. They are especially helpful for monitoring joints that are difficult to see.
5. **Sensors for Gas Flow and Quality:**
    a. **Gas Flow Monitoring:** Sensors monitor the quantity and quality of shielding gases used during welding to ensure optimum gas coverage and reduce the possibility of weld faults brought on by insufficient shielding.
    b. **Gas Composition Analysis:** Sensors examine the shielding gases' chemical make-up to look for any variations or contaminants that could have an impact on the weld quality.

CONCLUSION

In conclusion, sensors are essential to welding robots because they provide precise control of the welding process and real-time feedback. They provide better process control, fewer faults, more productivity, and better weld quality. While force/torque sensors offer fine force control and contact detection, vision sensors enable exact weld seam detection and component alignment. Heat input is monitored by temperature sensors, and precise weld location is guaranteed by seam tracking sensors. The use of shielding gas is optimised using gas flow and quality monitors. The addition of sensors improves the welding robots' flexibility, precision, and consistency, which promotes weld quality and operating effectiveness. The potential for additional improvements in welding automation and its applicability in numerous sectors is greatly enhanced by the ongoing developments in sensor technology and their integration with robotic systems.

REFERENCES:

[1] A. Gómez-Espinosa, J. B. Rodríguez-Suárez, E. Cuan-Urquizo, J. A. E. Cabello, and R. L. Swenson, 'Colored 3D Path Extraction Based on Depth-RGB Sensor for Welding Robot Trajectory Generation', *Automation*, 2021, doi: 10.3390/automation2040016.

[2] L. Yang, Y. Liu, and J. Peng, 'Advances techniques of the structured light sensing in intelligent welding robots: a review', *International Journal of Advanced Manufacturing Technology*. 2020. doi: 10.1007/s00170-020-05524-2.

[3] J. Guo, Z. Zhu, B. Sun, and T. Zhang, 'A novel field box girder welding robot and realization of all-position welding process based on visual servoing', *J. Manuf. Process.*, 2021, doi: 10.1016/j.jmapro.2020.04.054.

[4] M. Vasilev *et al.*, 'Sensor-enabled multi-robot system for automated welding and in-process ultrasonic nde', *Sensors*, 2021, doi: 10.3390/s21155077.

[5] T. Lei, Y. Huang, H. Wang, and Y. Rong, 'Automatic weld seam tracking of tube-to-tubesheet TIG welding robot with multiple sensors', *J. Manuf. Process.*, 2021, doi: 10.1016/j.jmapro.2020.03.047.

[6] L. Yang, E. Li, T. Long, J. Fan, and Z. Liang, 'Corrections to: A high-speed seam extraction method based on the novel structured-light sensor for Arc welding robot: A review (IEEE Sensors Journal(2018) 18:21 (8631-8641) DOI: 10.1109/JSEN.2018.2867581)', *IEEE Sensors Journal*. 2019. doi: 10.1109/JSEN.2018.2880893.

[7] L. Li, B. Lin, and Y. Zou, 'Study on seam tracking system based on stripe type laser sensor and welding robot', *Zhongguo Jiguang/Chinese J. Lasers*, 2015, doi: 10.3788/CJL201542.0502005.

[8] L. Yang, E. Li, T. Long, J. Fan, and Z. Liang, 'A High-Speed Seam Extraction Method Based on the Novel Structured-Light Sensor for Arc Welding Robot: A Review', *IEEE Sens. J.*, 2018, doi: 10.1109/JSEN.2018.2867581.

[9] Y. Xu, H. Yu, J. Zhong, T. Lin, and S. Chen, 'Real-time seam tracking control technology during welding robot GTAW process based on passive vision sensor', *J. Mater. Process. Technol.*, 2012, doi: 10.1016/j.jmatprotec.2012.03.007.

CHAPTER 27

SYMBOLS FOR JOINING AND INSPECTION

Mr. Ranveer Singh, Associate Professor
Department of Mechanical Engineering, Jaipur National University, Jaipur, India
Email Id:ranveer@jnujaipur.ac.in

ABSTRACT:

Without a way to transmit information from the designer to the workers, welding cannot assume its proper position as an engineering tool. Drawings can be fully detailed with welding information by using welding symbols. In this Chapter discussed about the symbols for joining and inspection in the welding technology.The arrow and the gaps above and below the reference line help the weld sign identify the two sides of a joint. The joint's arrow-pointing side is referred to pragmatically as the arrow side, and its weld be performed in accordance with the guidelines provided below the reference line.

KEYWORDS:

Arrow, ButtJoint, Symbols, Welding,Weld.

INTRODUCTION

Engineering designs must always utilize standardized symbols to represent exact welding, brazing, and soldering information. A plethora of information is communicated by welding symbols. They succinctly outline the design of the weld or welds that will be used on a particular joint. They also specify the welding procedure to be utilized, the size and length of the weld, the groove design, the shapes of the face and root, and the order of the steps, among other details. The nondestructive inspection NDE standards for brazed or welded joints are also denoted using symbols. These symbols denote the examination techniques that must be used.1 Many times, symbols alone cannot communicate all of the necessary information. As a result, additional remarks, dimensions information, or even both are frequently included on drawings to give the fabricator all the information they need. The foundations and uses of the symbols used in the welding industry are covered in this Chapter. The American Welding Society AWS committee work from the 1940s is where the origins of the welding and nondestructive examination symbols may be found.

For updates made after the publication of this Chapter, please refer to this document, which is the last authority on the proper symbols and conventions used to communicate information regarding welding, brazing, and inspection standards [1]–[3]. The reader should be aware that some of the illustrations used to support the ideas covered in this Chapter's topics use dimensions. These dimensions, unless otherwise stated, are exclusively shown in U.S. customary units for the sake of graphical simplicity. For instance, the type of weld, groove design, weld size, welding technique, face and root contours, operation sequence, duration of weld, and other information can all be specified using a welding symbol. However, there are some circumstances in which a sign cannot adequately express all of the information. Sometimes, incomplete notes, dimensions information, or both are needed to give the shop all the needs. The designer is responsible for making sure that all needs are shown in full on the drawing or specifications [4]–[6].

In ANSI A WSB1.10 Guide for the Nondestructive Inspection of Welds, methodologies, procedures, and the kinds of discontinuities that each method will show are covered. American Welding Society, Miami, Florida. most recent issue Symbols can also be used to indicate the non-destructive inspection requirements for joints that have been brazed or welded. On the symbols are the specific inspection procedures 1 that should be applied. The proper inspection techniques depend on the standards for quality in terms of discontinuities in welded or brazed connections. The most recent edition of ANSI A W. Standard Symbols for Welding, Brazing, and Nondestructive Examination, published by the American Welding Society, has a description of the entire symbol system. When really choosing the proper symbols to describe the desired joint and the inspection requirements, this publication should be consulted. In actual application, few of the many symbols that are accessible will be used by most designers. The fundamentals of the symbols are explained here, along with how to use them.Symbols for welding

There are many examinations available to ensure your qualification and certification for different types of welding symbols. Although this language seems weird, it can be learned symbol by symbol with the right knowledge. To achieve your qualification, it is essential to gradually understand these symbols. By using this symbol guide, you can advance in your job to the highest level. We'll go into more detail about the chart of welding symbols now [7]–[9].When these symbols are broken down, several of them appear to be relatively simple despite their complicated appearance. These symbols serve as an illustration of the pre-weld joint details that may be seen in the cross-section and side views.The following four portions of symbols and two methods of interpretation, systems A and B, will be explained.

1. The starting point.
2. The sign for base butt-weld.
3. Additional base symbols.
4. Additional symbols.

DISCUSSION

The design department provides the welding engineer and the welding operator with a collection of information known as welding symbols. It includes all the relevant parameters, such as the welding position, the weld's dimensions and shape, the groove/fillet's features, the welding method [10]–[12].

A basic weld symbol is made up of three components:

1. Arrow Line.
2. Tail Reference.
3. Line.

As seen in Figure.1 these welds are denoted by including a process or specification reference in the welding symbol's tail. Additional Typical Weld Symbols. The weld-all-around and field weld sign, as well as resistance spot and resistance seam welds. The tail may be omitted when there is no specification, procedure, or other symbol Figure. 1. In conjunction with a welding reference. Additional Symbols. Due to the proliferation of welding symbols, these symbols are utilized in numerous welding procedures. Collective learning is necessary for each system and division because nobody is important on their own.

Figure 1:Represting the weld-all-around and field weld symbol [Meyer Tool].

1. The Base Platform:

The basic platform is a straightforward three-part representation of the welding and surrounding elements.The horizontal reference line is where information on the type and location of welding should be placed. The leader line and arrow. To indicate where the welding will take place, the arrow with the leader line crosses the reference line.The tails line splits into two lines at the opposite end of the reference line. This line is optional and is for further information that differs from the specifics. It might include welding equipment, welding standards, welding types, and anything else unique to this project.

Two Different Drawing Methods

There are two useful systems for drawing basic symbols, and each is described differently. System A or B will be explicitly mentioned in a plan, but never both at the same time. A dashed line below the horizontal reference line designates System A. Put the weld across from the arrow since the image shows the welding symbol on the dashed line. It is recommended to position the weld on the side of the arrow when welding a symbol above the reference line.Under the horizontal reference line, System B has no dashed lines. The welding should be placed on the side of the arrow when you see the welding symbol below the reference line. If the weld sign is higher than the reference line, welding must be done in the opposite direction of the arrow [13], [14].

2.Base Butt Symbols

As soon as two plates are butted end to end, they will sit level, straight, and parallel. There are two sorts of joints.Unidirectional butt welding. Symmetrical butt welds.

Single Sided Butt Welds:

1. The butt weld symbol displays the site as shown in Figure. 2, type of weld, preparation, and requirements for welding. The symbols make it easy to identify the one-sided weld. Two plates with square ends and two square angles are shown in the square butt weld symbol. In such a case, welding preparation is not necessary.
2. The two plates are positioned at a 45-degree angle during a single V-butt weld. Each metal plate's one side is at a 45-degree angle and is fully buried in the substance.
3. With a single but here, both plates have a 45-degree weld preparation on one side. Single V Butt Weld with Broad Root Face Weld. This welding only penetrates the top 3/4 of the plate, leaving some material underneath. This joint imitates the Y symbol

4. .Single Bevel Butt Weld technique involves cutting a 45-degree angle into one side of the plate while leaving the other end square, as seen in the symbol.
5. Single Bevel Butt with Broad Root Face. The symbol depicts a 45 degree bevel on one side and a square side, but it does not extend to the base.
6. Single U Butt Weld For the single U symbol, a 1/4-moon-shaped corner is cut out of each plate, and the joint is then welded 3/4-plate gauge deep.
7. Single J Butt Weld this joint, one plate has a 1/4-moon-cut corner, while the other plate has a square end and the joint does not extend all the way to the base as in the symbol.

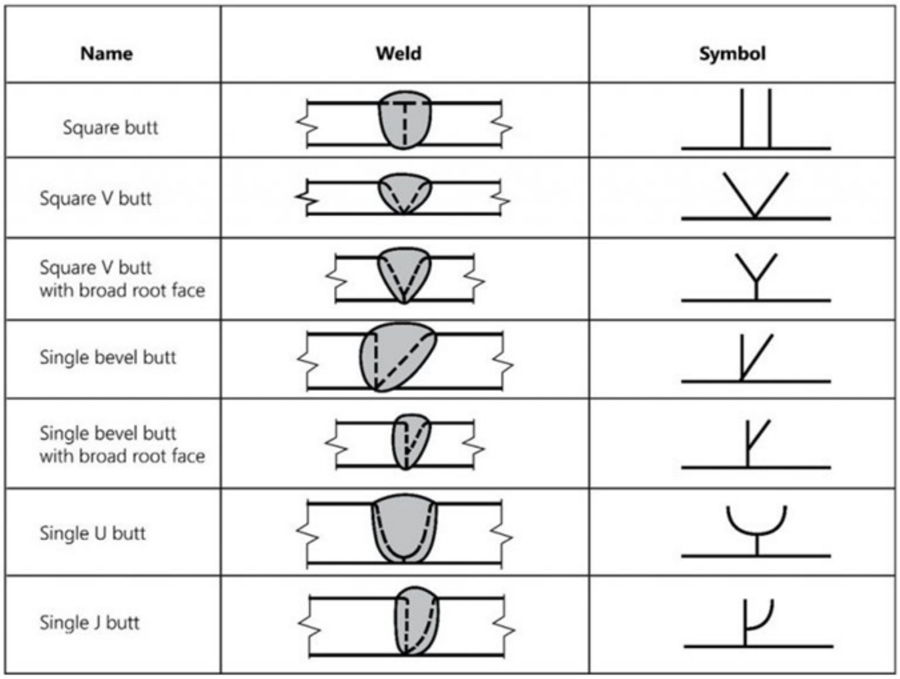


Figure 2: Represting the crux weld and their respective symbol [Water Welder].

Double Sided Butt Welds:

Similar to single-sided butt welding, but with both surfaces prepped and joined throughout the welding process (Figure. 3).Double-sided butt welds, also known as double V-groove welds, are a form of weld connection in which two pieces of metal are connected together in a V-shaped groove along their edges. This form of weld connection is often employed in construction, fabrication, and manufacturing sectors where high-strength and durable welds are needed. There are various benefits to using a double-sided butt weld over other kinds of weld connections. For starters, the bigger surface area of the weld increases joint strength. The V-shaped groove helps the weld metal to penetrate deeper, resulting in a stronger connection between the two pieces of metal. As a result, double-sided butt welds are appropriate for applications requiring great load-bearing capability.

The visual attractiveness of double-sided butt welds is another benefit. Because the weld bead is sandwiched between two pieces of metal, it is less apparent from the outside. This may be advantageous in situations where the weld's appearance is crucial, such as architectural constructions or ornamental metalwork. There are multiple processes involved in generating a double-sided butt weld. First, a V-shaped groove is cut into the margins of the two metal pieces to be linked. Depending on the thickness and kind of metal, this may be accomplished by machining, grinding, or plasma cutting. The groove angles are usually 45 to 60 degrees, with a bevel angle of roughly 30 degrees on either side. After the edges have been prepared, the two pieces of metal are aligned and temporarily fastened in place using clamps or fittings. After that, the weld seam is filled with molten weld metal, which is usually supplied by a welding electrode or filler wire. To deposit the weld metal into the groove, welding procedures such as shielded metal arc welding (SMAW), gas tungsten arc welding (GTAW), or gas metal arc welding (GMAW) may be utilized.

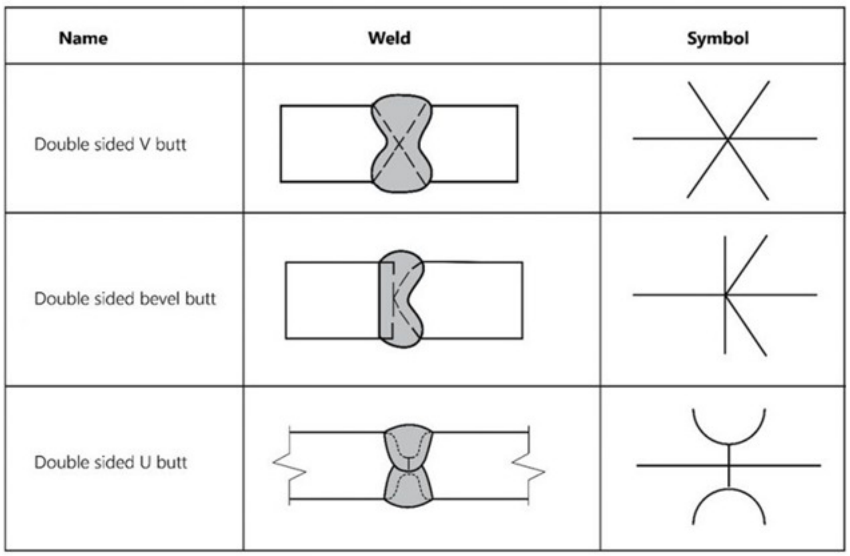


Figure 3: Represting the type of Butt Joint [Water Welder].

To create a sound and defect-free weld, it is critical to manage the heat input and maintain appropriate penetration throughout the welding process. Adjusting welding parameters such as current, voltage, travel speed, and shielding gas flow rate may help accomplish this. Depending on the metal and the required qualities of the weld joint, preheating and post-weld heat treatment may also be used. Non-destructive testing procedures like as visual inspection, ultrasonic testing, or X-ray examination may be used to guarantee the quality of the double-sided butt weld. These tests aid in detecting any faults or discontinuities, such as a lack of fusion, porosity, or fractures, that might jeopardize the weld's integrity. In conclusion, double-sided butt welds are often employed to attach metal parts along their edges because they provide great strength and an aesthetically beautiful look. Preparing a V-shaped groove, matching the metal components, and depositing the weld metal using different welding processes are all part of the process. Welds that are dependable and defect-free may be accomplished by carefully managing the welding settings and applying non-destructive testing techniques, satisfying the requirements of many industrial applications.

CONCLUSION

In this Chapter discussed about thesymbols for joining and inspection by utilizing the arrow and the gaps above and below the reference line, the weld sign may distinguish between the two sides of a joint. The weld for the joint's arrow side is performed in accordance with the guidelines provided below the reference line. This side of the joint is called quite prosaically as the arrow side.This section has to be prepared very carefully as many readers go through this section and prepare a remark on the full chapter.

REFERENCES:

[1] C. J. Holslag, Arc Welding Handbook, *Nature*, 1925, Doi: 10.1038/115416d0.

[2] C. L. Jenney And A. O'Brien, Welding Handbook_Volume 1_Welding Science And Technology, *Am. Weld. Soc.*, 1991.

[3] S. Zing, *Welding Handbook*. 1987. Doi: 10.1007/978-1-349-10624-0.

[4] Abnt *Et Al.*, Fundamental Manufacturing Processes Study Guide, DV02PUB2, *J. Mater. Process. Technol.*, 2009.

[5] W. Handbook And F. S. Welding, Welding Handbook Vol. 3 - Welding Processes, Part 2, *Am. Weld. Soc.*, 2007.

[6] American Welding Society, *Welding Handbook: Welding Science And Technology*. 2001.

[7] A. O'Brien, Welding Handbook, Volume 4 - Materials And Applications, Part 1 9th Edition, *Weld. Handbook, Vol. 4 - Mater. Appl. Part 1 9th Ed.*, 2011.

[8] M. Pearson, *Welding Handbook*. 1983. Doi: 10.1007/978-1-349-05561-6.

[9] American Welding Society, *Welding Handbook Volume 2: Welding Processes, Part 1*. 2004.

[10] C. L. Jenney And A. O'Brien, *Welding Handbook-II Part I*. 1991.

[11] C. L. Jenney And A. O'Brien, *Welding Handbook - WELDING PROCESSES, PART 1*. 1991.

[12] American Welding Society, *Welding Handbook-Materials And Applications*. 1991.

[13] A. Khan, *Mining Science And Technology*. 2004. Doi: 10.1201/9780203022528.

[14] C. L. Jenney And A. O'Brien, *WELDING PROCESSES, PART 1*. 2011.