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Analysis of Hardness in Metal Inert Gas Welding Of Two Dissimilar Metals, Mild Steel & Stainless Steel

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Abstract : *The aim of my work is to study the hardness that affects the welding joint of dissimilar metals. Stainless Steel 304 was welded to mild steel using a metal inert gas welding which also known as gas metal arc is welding with the help of filler wire of stainless steel and 0.8 0mm diameter. Argon gas was used as shielding gas in this process. Dissimilar metals welding have great scope in advanced technology nowadays owing to their high hardness, high strength and corrosion resistance properties. The combination of mild steel and austenitic stainless steel has got large number of application in industry such as power plant, nuclear plant, and heat exchanger assembly etc. Due to the fact that low cost of mild steel and corrosion resistance property of stainless steel. All these application requires welding of the two which can perform the desired service requirement of the industry. The difference in the properties such as melting point, thermal conductivity, carbon content difference makes austenitic stainless steel and mild steel difficult to weld and gives rise to various failures in the future service life. The results indicate the optimum value of current and voltage which will be applied to developed weld for maximum hardness of welded mild steel and stainless steel 304 specimens*
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I. Introduction

Welding is a fabrication process used to join materials, usually metals or thermoplastics, together. During welding, the pieces to be joined (the work pieces) are melted at the joining interface and usually a filler material is added to form a pool of molten material (the weld pool) that solidifies to become a strong joint. In contrast, Soldering and Brazing do not involve melting the work piece but rather a lower-melting-point material is melted between the work pieces to bond them together.

A. Types of Welding

There are many different types of welding processes and in general they can be categorized as:

B. Arc Welding

A welding power supply is used to create and maintain an electric arc between an electrode and the base material to melt metals at the welding point. In such welding processes the power supply could be AC or DC, the electrode could be consumable or non-consumable and a filler material may or may not be added.
The most common types of arc welding are:

C. Shielded Metal Arc Welding (SMAW)

A process that uses a coated consumable electrode to lay the weld. As the electrode melts, the (flux) coating disintegrates, giving off shielding gases that protect the weld area from atmospheric gases and provides molten slag which covers the filler metal as it travels from the electrode to the weld pool. Once part of the weld pool, the slag floats to the surface and protects the weld from contamination as it solidifies. Once hardened, the slag must be chipped away to reveal the finished weld.

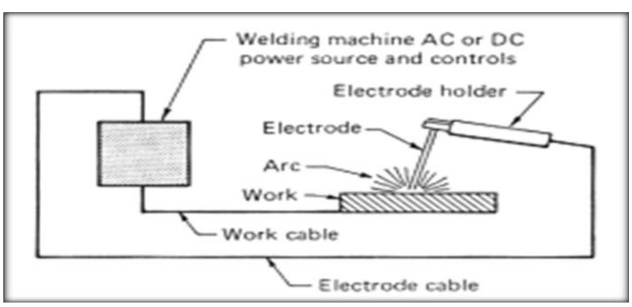


Fig 1.1 Figure of Arc Welding

D. Gas Metal Arc Welding (GMAW)

A process in which a continuous and consumable wire electrode and a shielding gas (usually an argon and carbon dioxide mixture) are fed through a welding gun.

E. Gas Tungsten Arc Welding (GTAW)

A process that uses a non-consumable tungsten electrode to produce the weld. The weld area is protected from atmospheric contamination by a shielding gas, and a filler metal that is fed manually is usually used. [7]

F. History of MIG / MAG (GMAW)

GMAW was developed during the early 1940's and technology was taken from the TIG welding process that was already around at the time. MIG (MAG) welding has the advantage of a particular gas shield that TIG has, and then adds the advantage of a continuous consumable wire electrode. At the time the MIG process was able to increase the production of war manufacturing. It has since become one of the main stages of manufacturing from that time until the present day. Through the years MIG/MAG has undergone changes in the types of wires, gases, and power sources, but the principles remain the same. With the onset of the manufacturing in the 1960's and 1970's the types of wire electrodes have been upgraded to give wire electrodes with higher deposition rates, better finishes and wires more suitable for more modern steel types. The welding gases have also evolved in the same way to make MIG welding faster, more efficient and with a better finish. One of the major changes has also been with power sources and feeders. MIG welding power sources have, over the years, gone from basic transformer types to the highly electronic power sources of the world today. [4]

G. MIG Overview

A MIG welder uses a DC voltage controlled electric power source (different from that of an arc welder), connected to a wire feeder which holds a spool of the type of wire needed to do the job. The feeder will push the wire down which is known as a MIG hand piece. This is done by feeding the wire through a set of rollers. A suitable gas mixture is also fed down the MIG hand piece. Different gases are used for different types of wire.

Basically, the MIG process uses a gas or gas mixture to displace the air around the arc that is being formed between the wire being used and the base metal. This is done by using an electric MIG power source. The electrode is still being melted with an electric arc, but in the case of MIG it is a special wire which is mechanically fed into the arc.

The feed rate is adjusted depending on the thickness of the material being welded. The voltage of the electric power source is also adjusted depending on the material thickness being welded.

H. Shielding Gas

This is a complicated area with many various mixtures available, but the primary purpose of the shielding gas in the MIG process is to protect the molten weld metal and heat affected zone from oxidation and other contamination by the atmosphere.

The shielding gas should also have a pronounced effect on the following aspects of the welding operation and the resultant weld.

I. Introduction to Dissimilar Metal Welding

Dissimilar metal welding is defined in which weldments are made from metals of different compositions. A successful weld between dissimilar metals is one that is as strong as the weaker of the two metals being joined, i.e., possessing sufficient tensile strength and ductility so that the joint will not fail in the weld. Nowadays, joining dissimilar metal is indispensable in manufacturing and constructing advanced equipment and machinery.

Different kinds of metals feature different chemical, physical, and metallurgical properties: some are more resistible to corrosion, some are lighter, and some are stronger. Joining dissimilar metals is, therefore, to compose different properties of metals in order to minimize material costs and at the same time maximize the performance of the equipment and machinery. The problem of making welds between dissimilar metals relates to the transition zone between the metals and the intermetallic compound formed in this transition zone. For the fusion type welding process it is important to investigate the phase diagram of the two metals involved. If there is mutual solubility of the two metals the dissimilar joints can be made successfully. If there is little or no solubility between the two metals to be joined the weld joint will not be successful. The intermetallic compounds that are formed, between the dissimilar metals, must be investigated to determine their crack sensitivity, ductility, susceptibility to corrosion, etc. Another factor involved in predicting a successful service life for dissimilar metals joint relates to the coefficient of thermal expansion of both materials. If these are widely different, there will be internal stresses set up in the intermetallic zone during any temperature change of the weldment. If the intermetallic zone is extremely brittle service failure may soon occur. The difference in melting temperature of the two metals that are to be joined must also be considered, since one metal will be molten long before the other when subjected to same heat source. [6]

J. Introduction to Gas Metal Arc Welding (GMAW)

The GMAW welding process is easily found in any industry whose products require metal joining in a large scale. It establishes an electric arc between a continuous filler metal electrode and the weld pool, with shielding from an externally supplied gas, which may be an inert gas, an active gas or a mixture. The heat of the arc melts the surface of the base metal and the end of the electrode. The electrode molten metal is transferred through the arc to the work where it becomes the deposited weld metal (weld bead)The quality of the welded material can be evaluated by many characteristics, such as bead geometric parameters (penetration, width and height), hardness, residual stresses and deposition efficiency (ratio of weight of metal deposited to the weight of electrode consumed). These characteristics are controlled by a number of welding parameters, and, therefore, to attain good quality, is important to set up the proper welding process parameters. Out of these properties hardness is important property because hardness determines the impact strength, toughness and crack susceptibility of welded joint. Unfortunately, an underlying mechanism connecting welding parameters and quality characteristics is usually not known. Traditionally, it has been necessary to determine the weld input parameters for every new welded product to obtain a welded joint with the required specifications. To do so, requires a time-consuming trial and error development effort, with weld input parameters chosen by the skill of the engineer or machine operator. Then welds are examined to determine whether they meet the specification or not. Finally the weld parameter scan is chosen to produce a welded joint that closely meets the joint requirements. Also, what is not achieved or often considered is an optimized welding parameters combination, since weld scan often be produced with very different parameters. In other words, there is often a more ideal welding parameters combination, which can be used if it can only determined.

The objective of the project to join two dissimilar metals Stainless Steel 304 and mild steel which is in line with the joining of metals SA-508 grade III and SS-304 LN by conducting experiment to develop good quality weld by changing the process parameters. To study the micro structural evaluation of successful weld metal. [3]

Scope of the present work includes characterization of dissimilar metal welding using gas metal arc welding, where the base metals are selected as mild steel and austenitic Stainless steel. The combination of mild steel and austenitic stainless steel has got large number of application in industry such as power plant, nuclear plant, and heat exchanger assembly etc. due to the fact that low cost of mild steel and corrosion resistance property of stainless steel. All these application requires welding of the two which can perform the desired service requirement of the industry. The difference in the properties such as melting point, thermal conductivity, carbon content difference makes austenitic stainless steel and mild steel difficult to weld and gives rise to various failures in the future service life.

- Carbon migration
- Failure due to thermal stress
- Oxidation at this interface
- Dissolution of M23-C6 carbides

This work involves choosing suitable filler, setting the welding parameters to achieve good quality weld between the mild steel and austenitic stainless steel, then studying the microstructure and investing the changes.

The objective of the project to join two dissimilar metals Stainless Steel 304 and mild steel which is in line with the joining of metals SA-508 grade III and SS-304 LN by conducting experiment to develop good quality weld by changing the process parameters. To study the micro structural evaluation of successful weld metals. [11]

II. Literature Review

Many researchers and academicians of international repute have probed into the topic of study of effect of welding parameters whose name and work abstract has been given below:

M. Sireesha et al.(2000) “The studied the transition joints in power plants between ferrites steels and austenitic stainless steels which suffer from a mismatch in coefficients of thermal expansion (CTE) and the migration of carbon during service from the ferrites to the austenitic steel. The study shows the use of a trimetallic combination with an insert piece of intermediate CTE (coefficient of thermal expansion) provides for a more effective lowering of thermal stresses. In this work a trimetallic joint involving modified 9Cr+1Mo steel and 316LN austenitic stainless steel as the base materials and Alloy 800 as the intermediate piece. Nickel-based consumables produce welds exhibiting better tensile properties and improved thermal stability in relation to the austenitic steel filler materials. The absence of microstructural deterioration at high temperatures is considered particularly important in view of the usual operating conditions for these joints. From a consideration of thermal expansion coefficients also, the Inconel filler materials are seen to be superior to the stainless steel consumable”**.** [2]

P. BalaSrinivasan et al. "The studied the microstructural evolution and hardness variations in a dissimilar weld joint comprising an austenitic stainless steel and a ferrites stainless steel (FSS) produced by GTAW. Further, the different regions of this resultant weldment were characterized for the general and pitting corrosion behavior in neutral and acidic chloride solutions. Thin section sheets (1.5 mm thickness) of an austenitic stainless steel (ASS) corresponding to AISI 316 and an FSS of grade AISI 430 were used. Autogenously welded joints between an austenitic and FSS could be produced by GTAW without the problems of hot cracking as the weld metal is over matched in terms of mechanical properties in relation to the FSS parent material"**.** [4]

C.R. Das et al. "He had shown that it is difficult to simultaneously obtain good ductility, toughness and corrosion resistance in the weldment. Therefore, judicious selection of materials is an important for fabrication of DMW (Dissimilar metal weld) joints. In a nuclear power plant DMW joints are necessary for joining the different materials chosen for the various parts of the heat transfer circuit, with design life of components of up to 100 years and nominal operating temperature of 573–623 K. In this paper Weld ability of the dissimilar weld joint between austenitic 304L (N) stainless steel (SS) and martensitic 403 SS made by gas tungsten arc welding process using ERNiCr-3 filler metal has been studied. Two materials were joined using a K-type weld groove joint; with the straight edge on the 403 SS side buttered using ERNiCr-3 filler wire. Weld metal deposited by using ER308L, ER309L and ERNiCr-3 filler wires. ERNiCr-3 filler metal is preferable (to ER308L and ER 309L filler metals) for the DMW joint between 403 SS and 304L(N) SS. Buttering of 403 SS with ERNiCr-3 filler metal results in good bend ductility and high impact toughness of the HAZ. Also ERNiCr-3 weld metal has higher strength at elevated temperatures**.**" [9]

Anwar Ul-Hamid et al. "This paper reports the investigation into the failure of dissimilar weld metal joints in a piping system of a petrochemical plant. The process involved a reformed gas that passed through a water cooler followed by compression in a three stage centrifugal synthesis gas compressor. The outlet piping of the suction drum constituted weldments of carbon steel (CS) pipe and SS 304 elbow fittings. A number of cracks appeared at these weld joints after a relatively short period of service. Radiographic tests conducted on-site showed that the cracks were circumferential and developed along the weld seam adjacent to the CS pipe. The length of these cracks varied between 120 and 600 mm. Some of these joints leaked following weld repair in the past. One of these joints failed after two and half years of service following weld repair. The length of the crack formed at this point was 300 mm and it had occurred at the weld seam. Experimental results indicate that the joint between the CS pipe and the SS weld failed due to the development of a localized region of high hardness (e.g. martensitic) at its interface during cooling from welding temperature. The hydrogen rich gas transported through the pipe initiated cracking at this region. [16]

Frederick W. Brust et al. "This presented the results of investigation of PWSCC (Primary Water Stress Corrosion Cracking) in the bimetallic welds that join the hot leg to the reactor pressure vessel nozzle. The hot leg weld is a bimetallic weld joining a SA-508 (Class 2) reactor vessel nozzle with a type 304 stainless steel pipe using an Inconel weld procedure. The hot leg pipe carries reactor-heated water to the steam generator. It is then recirculated by the pump back through the 'cold leg'. Both the hot and cold leg stainless steel pipes are joined to the reactor vessel nozzles via bimetallic welds. The cracking of concern occurs in the Inconel weld only. The finite element alternating method (FEAM) was used to obtain stress intensity factors to perform the PWSCC. The analysis of the residual stress and PWSCC for inconel buttering, PWHT, weld deposition, weld grind-out and repair, hydro testing, service temperature heat up, finally service. Tensile weld residual stresses, in addition to service loads, contribute to PWSCC (Primary Water Stress Corrosion Cracking) crack growth"**.** [7]

M.D. Mathew et al.(2006) "The characterized the creep properties of the base metal, weld metal and weld joint for 316L(N) SS welds at 873 and 923K at stress levels of 100–325MPa with rupture lives in the range of 100–33,000 h. The creep strength reduction factors for the weld joints were found to be higher than the RCC-MR values implying that the actual creep strength of the weld joints is higher than the design values and that the difference between the strengths of base metal and weld metal is low. Weld strength reduction factors based on the strength of the weld metal is more conservative at 873 while at 923K at long term conditions; WSRF based on weld joint seems to be more conservative. Higher rupture life of the weld joint as compared to the weld metal is suggested to be resulting from the formation of a metallurgical notch"**.** [8]

S.S.M. Tavares et al. (2006) "The characterized the microstructure, chemical composition, corrosion resistance and toughness of a multipass weld joint of super duplex stainless steel UNS S32750. A 9.0mmthick, 900mmdiameter pipe of super duplex UNS S32750 stainless steel was welded using GTAW (Gas Tungsten Arc Welding, root pass) and SMAW (Shielded Metal Arc Welding, filler passes) processes. High purity argon shielding gas was used in the root pass welding. The welding parameters were controlled in order to maintain the heat input in the 1.5–2.0 kJ/mm range for the root pass and 1.2–1.7 kJ/mm for the subsequent filler passes. From the microstructure and Charpy test it was concluded that, despite having lower austenite volume fraction (34.2%) the root pass presented a higher Charpy toughness (57 J) than the filler passes (10 J) at room temperature. But corrosion resistance of the root found to be slightly inferior to the filler passes in chloride media**.**" [9]

III. Methodology

A. Gas Metal Arc Welding

Gas Metal Arc Welding (GMAW), by definition, is an arc welding process which produces the coalescence of metals by heating them with an arc between a continuously fed filler metal electrode and the work. The process uses shielding from an externally supplied gas to protect the molten weld pool.

B. GMAW Equipment and Supplies

Gas metal-arc welding equipment basically consists of four units: the power supply, the wire feeding mechanism, the welding gun (also referred to as the torch), and the gas supply.

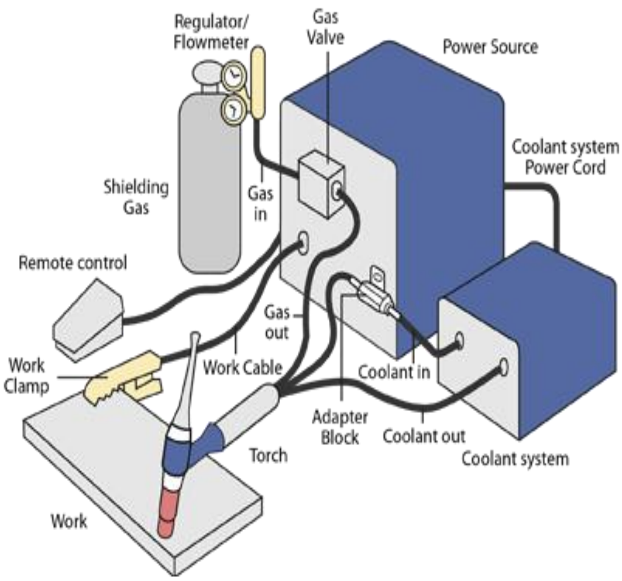


Fig 3.1 Figure of GMAW Machine

When a conventional type of welding machine is used for GMA welding, the voltage varies depending on the length of the arc. The arc length and the voltage changes accordingly whenever the nozzle-to-work distance changes. The only way to produce uniform welds with this type of power source is to maintain the arc length and voltage at a constant value. Besides producing non-uniform welds, this inconsistent voltage can cause the wire to burn back to the nozzle. [12]

C. Power Supply

A constant voltage (CV) power source was developed to overcome the inconsistent voltage characteristics of a conventional welding machine. It can be either a dc rectifier or motor generator that supplies current with normal limits of 200 to 250 amperes. The CV type power source has a nearly flat volt-ampere characteristic. This means that the machine maintains the same voltage regardless of the amount of current used. With this type of power source, you can change the wire-feed speed over a considerable range without causing the wire to burn back to the nozzle. When the wire-feed speed is set at a specific rate, a proportionate amount of current is automatically drawn. In other words, the current selection is based on the wire-feed speed. The current increases as the wire fed faster and decrease when wire fed slower. With this type of power supply, variations in the nozzle-to-work distance will not change the arc length and burn back is virtually eliminated In gas metal-arc welding , direct-current reverse polarity (DCRP) is recommended. DCRP produces excellent cleaning action and allows for deeper penetration.

D. Wire Feed Drive Motor

The wire feed drive motor is used to automatically drive the electrode wire from the wire spool through the gun up to the arc point. You can vary the speed of the wire feed by adjusting the controls on the wire-feed control panel. The wire feeder can be mounted on the power unit or it can be separate from the welding machine. [13]

E. Welding Gun

Welding guns for MIG welding are available for manual manipulation (semiautomatic welding) and for machine or automatic welding. Because the electrode is fed continuously, a welding gun must have a sliding electrical contact to transmit the welding current to the electrode. The gun must also have a gas passage and a nozzle to direct the shielding gas around the arc and the molten weld pool. Cooling is required to remove the heat generated within the gun and radiated from the welding arc and the molten weld metal. Shielding gas, internal circulating water, or both, is used for cooling. An electrical switch is needed to start and stop the welding current; the electrode feed system, and shielding gas flow.

F. Semiautomatic Guns

The word "data" is plural, not singular. Semiautomatic, hand-held guns are usually similar to a pistol in shape. Sometimes they are shaped similar to an oxyacetylene torch, with electrode wire fed through the barrel or handle. In some versions of the pistol design, where the most cooling is necessary, water is directed through passages in the gun to cool both the contact tube and the metal shielding gas nozzle. The curved gun uses a curved current-carrying body at the front end, through which the shielding gas is brought to the nozzle. This type of gun is designed for small diameter wires and is flexible and maneuverable. It is suited for welding in tight, hard to reach corners and other confined places. Guns are equipped with metal nozzles of various internal diameters to ensure adequate gas shielding. The orifice usually varies from approximately 3/8 to 7/8 in. (10 to 22 mm), depending upon welding requirements. The nozzles are usually threaded to make replacement easier. The conventional pistol type holder is also used for arc spot welding applications where filler metal is required. The heavy nozzle of the holder is slotted to exhaust the gases away from the spot. The pistol grip handle permits easy manual loading of the holder against the work. The welding control is designed to regulate the flow of cooling water and the supply of shielding gas. It is also designed to prevent the wire freezing to the weld by timing the weld over a preset interval. [10]

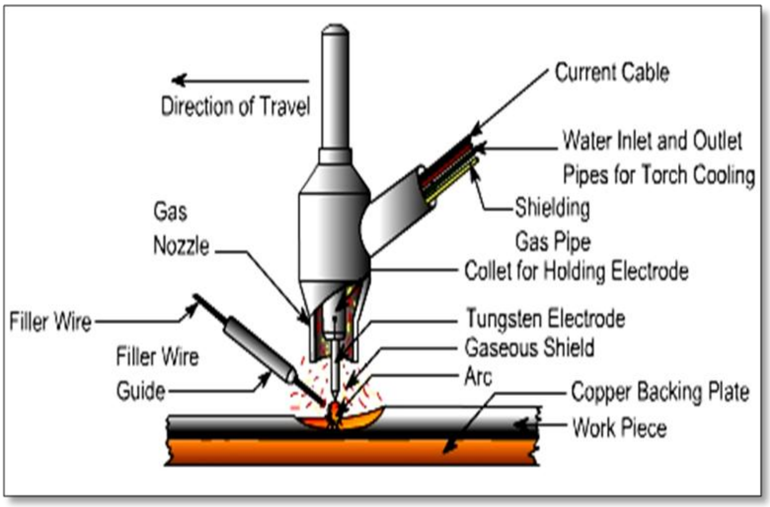


Fig 3.2 Figure of A typical semiautomatic gas-cooled, curved-neck gas metal arc welding gun

K. Air Cooled Guns

Air-cooled guns are available for applications where water is not readily obtainable as a cooling medium. These guns are available for service up to 600 amperes, intermittent duty, with carbon dioxide shielding gas. However, they are usually limited to 200 amperes with argon or helium shielding. The holder is generally pistol-like and its operation is similar to the water cooled type.

Three general types of air-cooled guns are available.

A gun that has the electrode wire fed to it through a flexible conduit from a remote wire feeding mechanism. The conduit is generally in the 12 ft (3.7 m) length range due to the wire feeding limitations of a push-type system. Steel wires of 7/20 to 15/16 in. (8.9 to 23.8 mm) diameter and aluminum wires of 3/64 to 1/8 in. (1.19 to 3.18 mm) diameter can be fed with this arrangement.

A gun that has a self-contained wire feed mechanism and electrode wire supply. The wire supply is generally in the form of a 4 in. (102 mm) diameter, 1 to 2-1/2 lb (0.45 to 1.1 kg) spool. This type of gun employs a pull-type wire feed system, and it is not limited by a 12 ft (3.7 m) flexible conduit. Wire diameters of 3/10 to 15/32 in. (7.6 to 11.9 mm) are normally used with this type of gun.

A pull-type gun that has the electrode wire fed to it through a flexible conduit from a remote spool. This incorporates a self-contained wire feeding mechanism. It can also be used in a push pull type feeding system. The system permits the use of flexible conduits in lengths up to 50 ft (15 m) or more from the remote wire feeder. Aluminum and steel electrodes with diameters of 3/10 to 5/8 in. (7.6 to 15.9 mm) can be used with these types of feed mechanisms.

L. Water-Cooled Gun

Water-cooled guns for manual MIG welding similar to gas-cooled types with the addition of water cooling ducts. The ducts circulate water around the contact tube and the gas nozzle. Water cooling permits the gun to operate continuously at rated capacity and at lower temperatures. Water-coded guns are used for applications requiring 200 to 750 amperes. The water in and out lines to the gun add weight and reduce maneuverability of the gun for welding.

M. Regulators

The same type of regulator and flow meter should be used for gas metal-arc welding as that for gas tungsten-arc welding. The gas flow rates vary, depending on the types and thicknesses of the material and the joint design. At times it is necessary to connect two or more gas cylinders (manifold) together to maintain higher gas flow. For most welding conditions, the gas flow rate is approximately 35 cubic feet per hour (cfh). This flow rate may be increased or decreased, depending upon the particular welding application. Final adjustments usually are made on a trialed - error basis. The proper amount of gas shielding results in a rapidly crackling or sizzling arc sound. Inadequate gas shielding produces a popping arc sound and results in weld discoloration, porosity, spatter.

N. Fundamentals of the Process

The GMAW process incorporates the automatic feeding of a continuous, consumable electrode that is shielded by an externally supplied gas. After the initial settings of the operator, the equipment provides, the equipment provides for automatic self regulation of the electrical characteristics of the arc. Therefore the only manual control required by the welder for semiautomatic operation is the travel speed and direction and gun positioning. The process shown in Fig.

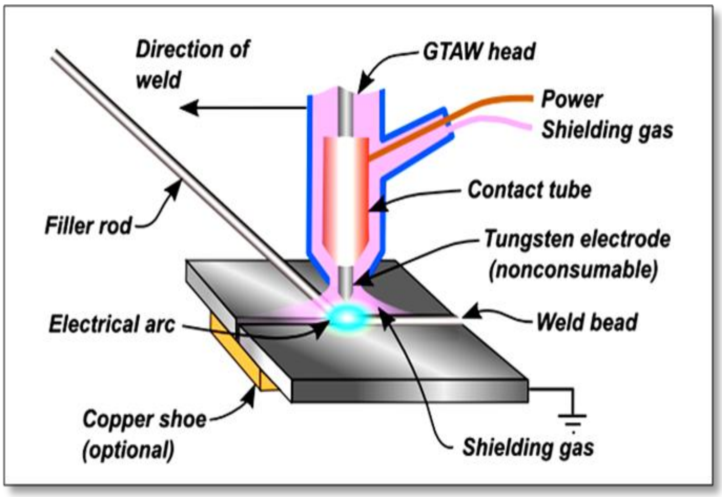


Fig 3.3 Figure of GMAW PROCESS

G. Modes of GMAW Transfer

GMAW transfer mode is determined by variables such as shielding gas type, arc voltage, arc current, diameter of electrode and wire feed speed.

Short circuit transfer refers to the welding wire actually "short circuiting" (touching) the base metal between 90 - 200 times per second. With short circuit transfer, wire feed speeds, voltages, and deposition rates are usually lower than with other types of metal transfer such as spray transfer. This makes short circuit transfer very versatile allowing the welder to weld on thin or thick metals in any position.

Limitations of short circuit transfer

- A relatively low deposition rate.
- Lack of fusion on thicker metals.
- More spatter.
- Short circuit transfer usually has a crackling (bacon frying) sound when a good condition exist.

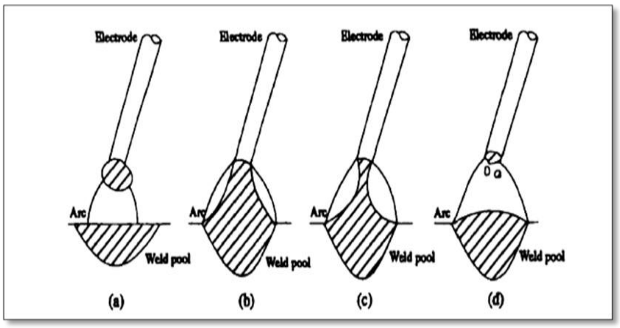


Fig 3.4 Figure of Short circuit transfer and Short Circuit Cycle

- Globule of molten metal builds up on the end of the electrode
- Globule contacts surface of weld pool
- Molten column pinches off to detach globule
- Immediately after pinch-off, fine spatter [11]
-

H. Globular Transfer

After Globular transfer refers to the state of transfer between short-circuiting and spray arc transfer. Large globs of wire are expelled off the end of the electrode wire and enter the weld puddle. Globular transfer can result when welding parameters such as voltage, amperage and wire feed speed are somewhat higher than the settings for short circuit transfer.

Limitations of globular transfer

- Presence of spatter.
- Less desirable weld appearance than spray arc transfer.
- Welding is limited to flat positions and horizontally fillet welds.
- Welding is limited to metal 1/8 inch (3 mm) or thicker.

I. Spray Arc Transfer

Spray arc transfer “sprays” a stream of tiny molten droplets across the arc, from the electrode wire to the base metal. Spray arc transfer uses relatively high voltage, wire feed speed and amperage values, compared to short circuit transfer. To achieve a true spray transfer, an argon rich shielding gas must be used. When proper parameters are used, the spray arc transfer produces a characteristic humming or buzzing sound.

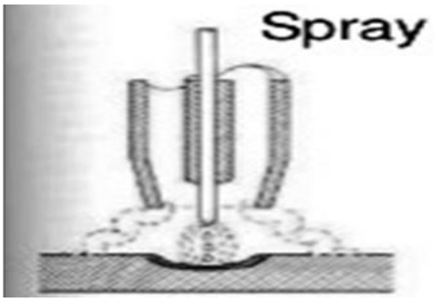


Figure 3.5 Figure of Spray Arc Transfer

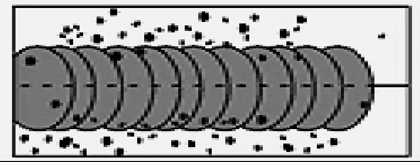
Advantages of spray arc transfer:

- High deposition.
- Good fusion and penetration.
- Good bead appearance.
- Capability of using larger diameter wires.
- Presence of very little spatter.
-

J. GMAW welding trouble shooting

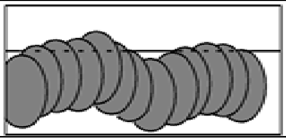
Excessive Spatter

Table 3.1 Table of Excessive Spatter

	**Excessive Spatter- scattering of molten metal particles that cool to solid from near weld bead**
Possible Causes	**Corrective Actions**
Wire feed speed too high	Select lower wire speed
Voltage too high	Select lower voltage range
Electrode extension (stick out) too long	Use shorter electrode extension (stick outs)
Work piece dirty	Remove all grease, oil, moisture, rust, paint, undercoating, and dirt from work surface before welding
Insufficient shielding gas at welding arc	Increase flow of shielding gas at regulator/ flow meter and or prevent drafts near wielding arc
Dirty welding wire	Use clean , dry welding wire

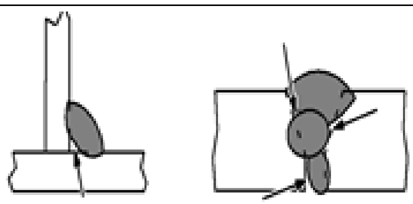
Waviness of Bead

Table 3.2 Table of Waviness of Bead

	**Waviness of bead-weld metal that is not parallel and does not cover joint formed by base metal**
Possible Cause	**Corrective Actions**
Welding wire extends too far out of nozzle	Be sure welding wire extends not more than ½ in (13 mm) beyond nozzle
Unsteady hand	Support hand on solid surface or use two hands

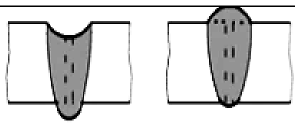
Incomplete Fusion

Table 3.3 Table of Incomplete Fusion

	Incomplete fusion-failure of weld metal to fuse completely with base metal or a proceeding weld bead
Possible Cause	**Corrective Actions**
Work piece dirty	Remove all grease, oil, moisture, rust, paint, coatings, and dirt from work surface before welding
Insufficient heat input	Select higher voltage range and adjust feed speed
Improper welding technique	Adjust work angle or widen groove to access bottom during welding
	Momentarily hold arc on groove side walls when using weaving technique
	Keep arc on leading edge of weld puddle
	Use correct gun angle of 0 to 15 degrees
	Place stringer bead in proper location at joint during welding.

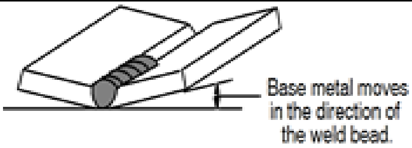
Excessive Penetration

Table 3.4 Table of Excessive Spatter

	**Excessive Penetration-weld metal melting through base metal and hanging underneath weld**
Possible Cause	**Corrective Actions**
Excessive heat input	Select lower voltage range and reduce wire feed speed. Increase travel speed

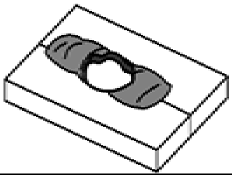
Distortion

Table 3.5 Table of Distortion

	Distortion-contraction of weld metal during welding that forces base metal to move
Possible Cause	**Corrective Actions**
Excessive heat input	Use restraints clamp to hold base metal in position
	Make track welds along joint before starting welding operation
	Select lower voltage range or reduce wire feed speed
	Increases travel speed
	Weld in small segments and allow cooling between welds

Incomplete Fusion

Table 3.6 Table of Burn Through

	Burn through - weld melting completely through base metal resulting in holes where no metals remain
Possible Cause	**Corrective Actions**
Excessive heat input	Select lower voltage range and reduce wire feed speed
	Increase and maintain steady travel speed

K. Discussion about Weld Characteristic

i) Poor Weld Bead Characteristics

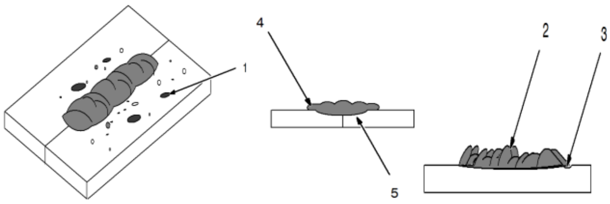


Figure 3.6 Figure of Poor Weld Bead Characteristics

- Large Spatter Deposits.
- Rough, Uneven Bead.
- Slight Crater during Welding.
- Bad Overlap.
- Poor Penetrations.

ii) Good Weld Bead Characteristics

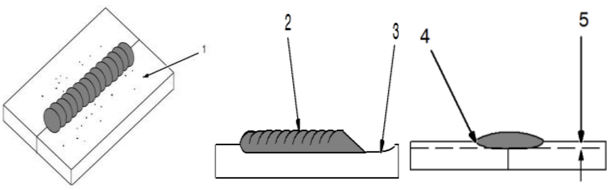


Figure 3.7 Figure of Good weld bed

- Fine Spatter.
- Uniform Bead.
- Moderate Crater during Welding Weld a new bead or layer for each 1/8 in (3.2 mm) thickness in metals being welded.

- No Overlap.
- Good penetration in to base metal.

IV. Experimental Work

A. Information to the Base Metals

***Mild Steel**:* Mild steel is the most common form o steel because its price is relatively low while it provides material properties that are acceptable for many applications. Mild steel contains 0.16–0.29%carbon; therefore it is neither brittle nor ductile. Mild steel has a relatively low tensile strength, but it is cheap and malleable; surface hardness can be increased through carburizing. It is often used when large amounts of steel are needed, for example as structural steel. The density of mild steel is approximately 7.85 g/cm^3 (0.284 lb/in^3) and the Young's modulus is 210,000 MPa (30,000,000 psi).

***Austenitic steels**:* Type 304 Stainless Steels are well known in reference literature and more information can be obtained in this way.304 is a variation of the basic 18-8 grade Type 302, with a higher chromium and lower carbon content. Lower carbon minimizes chromium carbide precipitation due to welding and its susceptibility to inter granular corrosion. 304L is an extra low-carbon variation of Type 304 with a 0.03% maximum carbon content that eliminates carbide precipitation due to welding.

Table 4.1 Table of compression

COMPOSITION	TYPE 304 (%)	TYPE 304 L (%)
Carbon	0.08 max	0.03 max.
Manganese	2.00 max	2.00 max.
Phosphorus	0.045 max	0.045 max.
Sulfur	0.030 max	0.030 max.
Silicon	0.75 max	0.75 max
Chromium	18.00-20.00	18.0-20.0

Mechanical Properties

- *Corrosion Resistance:* These steels exhibit excellent resistance to a wide range of atmospheric, chemical, textile, and petroleum and food industry exposure.
- *Oxidation Resistance:* The maximum temperature to which Types 304 and 304L can be exposed continuously without tap preciable scaling is about 1650°F (899°C). For intermittent exposure, the maximum exposure temperature is about 1500°F (816°C).
- *Heat Treatments:* Type 304 is non-harden able by heat treatment. Annealing: Heat to 1900-2050°F (1038 - 1121°C), then cool rapidly. Thin strip sections may be air cooled, but heavy sections should be water quenched to minimize exposure in the carbide precipitation region. Stress Relief Annealing: Cold worked parts should be stress relieved at 750°F (399°C) for 1/2 to 2 hours.
- *Formability Types:* 304 and 304L have very good draw ability. Their combination of low yield strength and high elongation permits successful forming of complex shapes. However, these grades work harden rapidly. To relieve stresses produced in severe forming or spinning, parts should be full annealed or stress relief annealed as soon as possible after forming.
- *Weld ability:* The austenitic class of stainless steels is generally considered to be wieldable by the common fusion and resistance techniques. Special consideration is required to avoid well “hot cracking” by assuring formation of ferrite in the weld deposit. Types 304 and 304L are generally considered to be the most common alloys of this stainless class. When weld filler is needed, AWS E/ER 308, 308L or 347 are most often specified. Types 304 and 304L Stainless Steels are well known in reference literature and more information can be obtained in this way.

Information to the Filler Wire-

MIDALLOY ER309L stainless steel wire is used GMAW, GTAW, and SAW welding.

Table 4.2 Table of Typical Chemistry

C	Cr	Ni	Mo	Si	P	S	N	Cu	Mn
0.025	24.5	13.0	0.35	0.40	0.02	0.01	0.10	0.35	1.88

Table 4.3 Table of Typical Mechanical Properties

Tensile Strength	85,200 Psi
Yield Strength	59,500 Psi

Elongation Min.	36%
Impact At Room Temperature	100 Ft-Lb

Table 4.4 Table of Recommended welding parameters

Process	Diameter	Voltage	Amperage	Gas/Flux
TIG (GTAW)	1/16”	14-18	90-130	100% Ar
	3/32”	15-20	120-175	100% Ar
	1/8”	15-20	150-220	100% Ar

MIDALLOY ER309L is most often used to weld similar alloys in the cast or wrought form.

- This filler metal can also be used in welding dissimilar alloys like mild steel and the stainless steels, and also for direct overlay on mild steel for corrosion applications.
- Normal applications are for service conditions under 600F.
- MIDALLOY ER309L is an austenitic stainless steel exhibiting high strength and good toughness over a wide range of temperatures.
- In the as-welded condition made by using this filler metal reduces have less of a risk for carbide precipitation.

B. Welding Technique

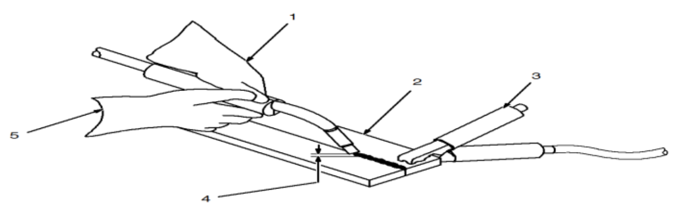
The technique of welding stainless steels does not differ greatly from that of the welding of mild steel, but as the material being handled is very expensive, and exacting conditions of service are usually involved, extra precautions and attention to detail at all stages of fabrication is desirable. In principle, all stainless steel for high-class work should be welded with a short arc. Any techniques which aim at increasing the penetration speed of travel or the use of wide weaving techniques are to be discouraged. Usually the lowest convenient current should be used. Weaving should be not wider than twice the diameter of the electrode for base material and electrodes of like composition, and even less for plate of dissimilar composition. The edges of the preparation should be free from scale. Clamps and jigs are advisable when welding sheets thinner than 3 mm (18 in) while cooling blocks are helpful with sheets 1.6mm to 2.5 mm (116 in to 332 in) thick. Tack welds, particularly on thin sheets, should be placed much closer together than is the usual practice for mild steel. This procedure is necessary as the thermal conductivity of these alloy steels is less and the coefficient of expansion is considerably greater than that of mild steel.

Notes on technique:

- Use stringer passes rather than wide weaves.
- Ensure that the surface of the material in the weld area is clean and free from foreign matter.
- Use the edge preparation shown in Table 4.1 over the page.
- Tack at regular intervals, at about half the pitch used for mild steel.
- Maintain a short arc during welding, to avoid loss of alloying materials during transfer across the arc.
- To minimize distortion, employ back step or block sequences when welding.
- Thoroughly remove slag from welds between passes.
- When welding double V or U joints, balance the welding on each side, to minimize distortion.
- Never use emery wheels or buffs for grinding or polishing stainless if they have previously been used for mild steel.
- Do not use excessive welding current Because of the high electrical resistance and low thermal conductivity the currents used with stainless steel electrodes are somewhat lower than those used for mild steel.

a. Holding and Positioning Welding Gun

Welding wire is energized when gun trigger is pressed. Before lowering helmet and pressing trigger, be sure wire is no more than 1/2 in (13 mm) past end of nozzle, and tip of wire is positioned correctly on seam.



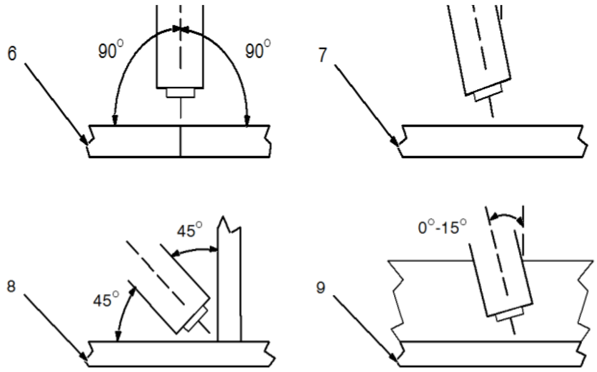


Fig 4.1 Figure of Holding and Positioning Welding Gun

- Hold Gun and Control Gun Trigger.
- Workpiece.
- Work Clamp.
- Electrode Extension (Stick out)1/4 To 1/2 in (6 To 13 mm).
- Cradle Gun And Rest Hand On Workpiece Groove Welds.
- End View of Work Angle.
- Side View of Gun Angle Fillet Welds.
- End View of Work Angle.
- Side View of Gun Angle

b. Conditions That Affect Weld Bed Shape

Weld bead shape depends on gun angle, direction of travel, electrode extension (stick out), travel speed, thickness of base metal, wire feed speed (weld current) and voltage.

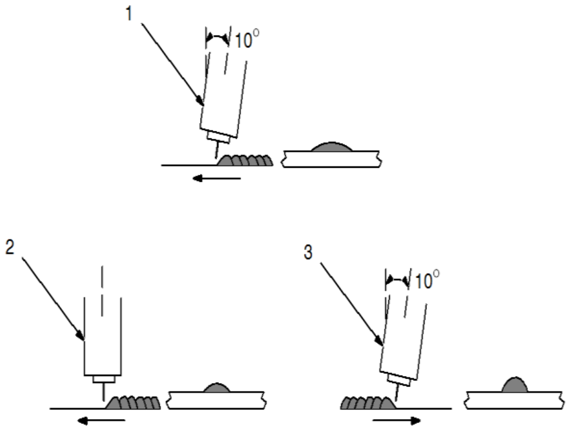
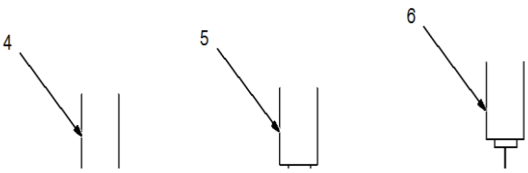


Fig 4.2 Figure of Conditions That Affect Weld Bed Shape Type 1

Gun Angles and Weld Bead Profiles:

1. Push.
2. Perpendicular.
3. Drags.



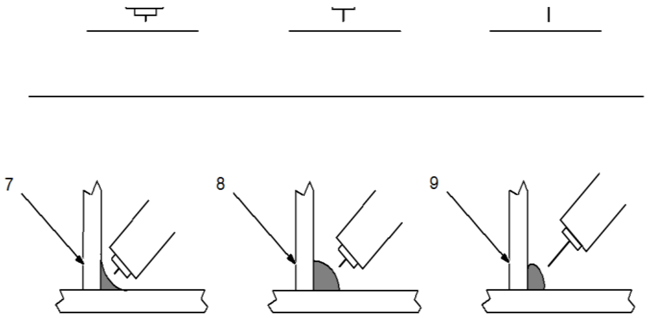


Fig 4.3 Figure of Conditions That Affect Weld Bed Shape Type 2

Electrode Extensions (Stick out)

4. Short.
5. Normal.
6. Long.

Fillet Weld Electrode Extension (Stick out)

7. Short.
8. Normal.
9. Long.

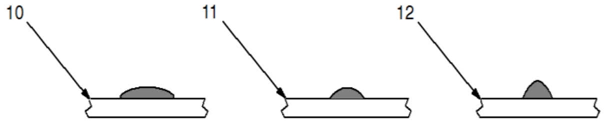


Fig 4.4 Figure of Conditions That Affect Weld Bed Shape Type 3

Gun Travel Speed

10. Slow.
11. Normal.
12. Fast.

c. Gun Movement During Welding

Normally, a single stringer bead is satisfactory for most narrow groove weld joints. However, for wide groove weld joints or bridging across gaps, a weave bead or multiple stringer beads works better.

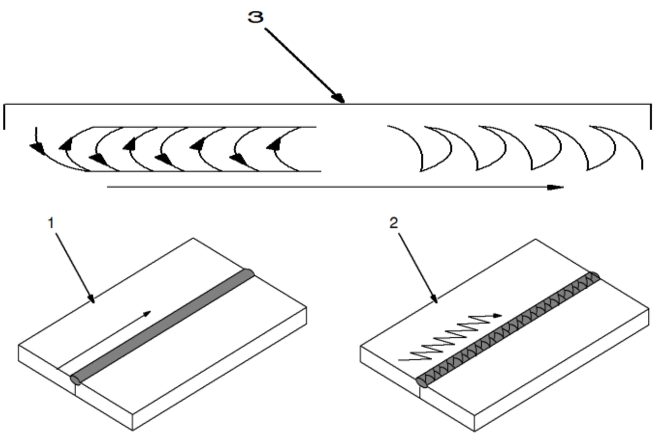


Fig 4.5 Figure of Gun movement

d. Weld Joint Design and Edge Preparation Parameter

By studying various research paper & whatever be the data available in books we have prepared the edge as following.

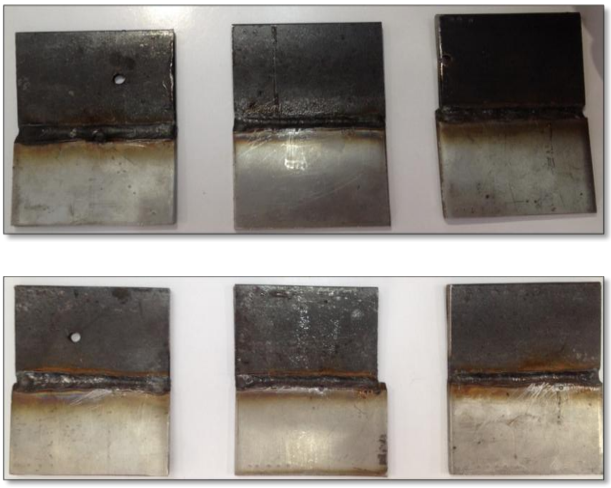


Fig 4.6 Figure of Specification of work piece and bead

TABLE 4.5 Table of Edge angle for different process with various thickness.

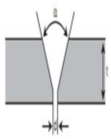
Groove	Process	Thickness	Gap	Root	Bevel
	SMAW	4-15	1-3	1-2	55-65
	GTAW	3-8	1-3	1-2	60-70
	GMAW	5-12	1-3	1-2	60-70
	SAW	9-12	0	5	80

Fig 4.7 Figure of original Specimen of work piece with V Groove

e. Parameter Selection

Material thickness determines weld parameters:

Diameter of filler wire: 0.8 mm

Angle of holding gun: 45 ^{o}

Composition of filler wire: Stainless steel

Shielding gas type: Argon and 2% Co_2

Gas flow rate: 10 to 15 liter/min.

Ampere range: 40 to 250 A

Voltage range: 21 to 26 V

TABLE 4.6 Table of Selection of Wire Size

Wire Size(dia.)	Amperage Range
.030 inch	40 − 145 A
.035 inch	50 − 180 A
.045 inch	75 − 250 A

TABLE 4.7 Table of Selection of Wire Speed (Amperage)

Wire size	Wire speed
.030 inch	250ipm
.035 inch	200ipm
.045 inch	125ipm

Selection of Voltage

- Low Voltage: wire stubs into work.
- High Voltage: arc is unstable (spatter).
- Set voltage midway between high/low voltages
- Voltage controls height and width of weld bead.

Various Testing Of Weld Bed

Testing of weld bead comprises of mechanical testing and non destructive testing. In mechanical testing ultimate tensile strength test and hardness test is being performed .nondestructive testing is being performed to inspect weld bead.

f. Hardness Testing By Rockwell Scale

Rockwell scale is a hardness scale based on the indentation hardness of a material. The Rockwell test determines the hardness by measuring the depth of penetration of an indenter under a large load compared to the penetration made by a preload. There are different scales, which are denoted by a single letter, that use different loads or indenters. The result, which is a dimensionless number, is noted by HRX where X is the scale letter.

When testing metals, indentation hardness correlates linearly with tensile strength. This important relation permits economically important nondestructive testing of bulk metal deliveries with lightweight, even portable equipment, such as hand-held Rockwell hardness testers

The determination of the Rockwell hardness of a material involves the application of a min or load followed by a major load, and then noting the depth of penetration, vis a vis, hardness value directly from a dial, in which a harder material gives a higher number. The chief advantage of Rockwell hardness is its ability to display hardness values directly, thus obviating tedious calculations involved in other hardness measurement techniques.

It is typically used in engineering and metallurgy. Its commercial popularity arises from its speed, reliability, robustness, resolution and small area of indentation.

In order to get a reliable reading the thickness of the test-piece should be at least 10 times the depth of the indentation. Also, readings should be taken from a flat perpendicular surface, because round surfaces give lower readings. A correction factor can be used if the hardness must be measured on a round surface.

Fig 4.9 Figure of a hardness tester of the Rockwell type

g. Scales and Values

There are several alternative scales; the most commonly used being the “B” and “C” scales. Both express hardness as an arbitrary dimensionless number**.**

TABLE 4.8 Table of Scale and value

Scale	**Abbreviation**	**Load**	**Indenter**	**Use**
A	HRA	60 kgf	120° diamond cone	Tungsten carbide
B	HRB	100 kgf	1⁄16-inch-diameter (1.588 mm) steel sphere	Aluminium, brass
C	HRC	150 kgf	120° diamond cone	Harder steels
D	HRD	100 kgf	120° diamond cone	
E	HRE	100 kgf	1⁄8-inch-diameter (3.175 mm) steel sphere	
F	HRF	60 kgf	1⁄16-inch-diameter (1.588 mm) steel sphere	
G	HRG	150 kgf	1⁄16-inch-diameter (1.588 mm) steel sphere	

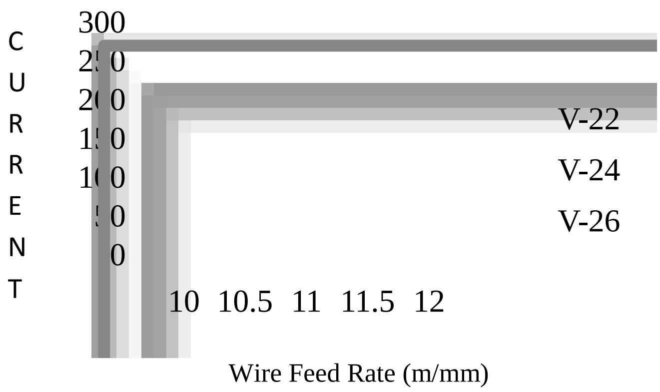
V. Result and Discussion

While performing welding on different specimen with different wire feed rate, current and voltage we obtain the optimum value of current and voltage at particular wire feed.

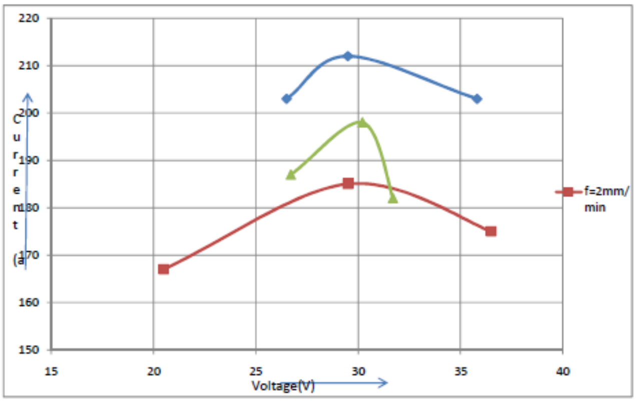
TABLE 5.1 Table of Results and Discussion

Specimen no.	**Voltage (V)**	**Current (A)**	**Wire feed rate (m / min.)**
1	**22**	**220**	**10**
2	**23**	**230**	**12**
3	**24**	**240**	**12**
4	**25**	**250**	**12.5**
5	**21**	**210**	**11**
6	**26**	**260**	**12**

GRAPH 5.1 Graph of from the previous table the variation of current with wire feed rate in graphical form



GRAPH 5.2 Graph of the variation of current with voltage for constant wire feed rate



The From above graphs

- In range of 10m/min to 12.5m/min of feed rate of MIG wire the variation of current is less. There is higher increment in current while increasing the current after 10m/min and again variation is less up to 12.5m/min while voltage is constant.
- As we increase the value of constant voltage (21V to 26V) value of current (210A to 260A) increases accordingly.
- Variation of voltage w.r.t. current increases up to 25 volt but current decreases after 30 volt while feed rate is constant.
- As we increase the value of constant feed rate of MIG wire (11 to 13) value of current increases (25 A).
- From GRAPH 5.1 it can be concluded that optimum feed rate which can be taken is about 10 m/min.
- At feed rate 10m/min good penetration can be observed experimentally and at lesser feed rate to 10 m/min penetration is low.
- Good penetration is observed in range of 10 m/min to 11 m/min.
- After 13 m/min feed rate there is excessive penetration is observed.

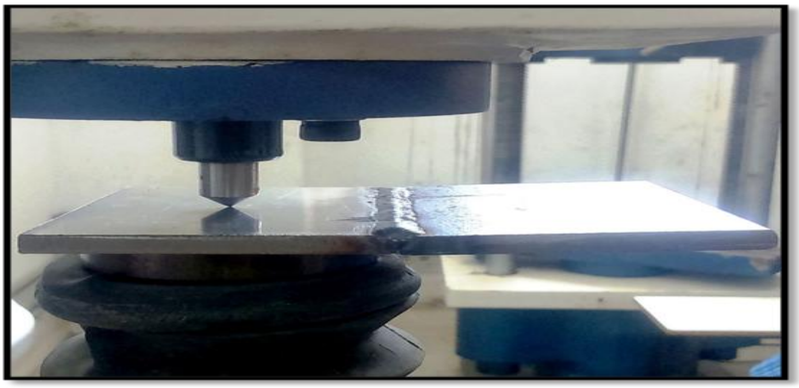


Fig 5.1 Figure of the Variation of hardness in fusion zone and heat affected zone on Stainless steel

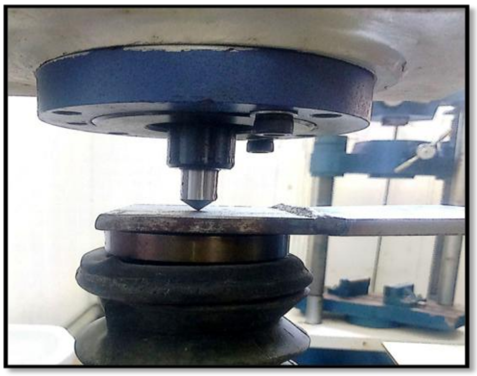
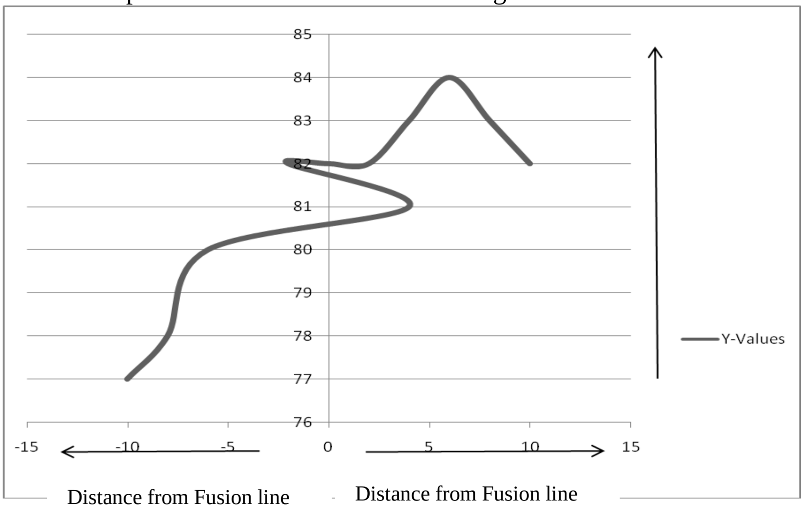


Fig 5.2 Figure of the Variation of hardness in fusion zone and heat affected zone on Mild steel

TABLE 5.2 Table of Variation of hardness in fusion zone and heat affected zone

S.No	Distance from fusion line in SS zone	Hardness in SS zone (HRB)	Distance from fusion line in MS zone	Hardness in MS zone (HRB)
1	0	82	0	82
2	2	82	2	82
3	4	83	4	81
4	6	84	6	80
5	8	83	8	78
6	10	82	10	77

GRAPH 5.3 Graph of Variation of hardness for single with distance from fusion line



From above observation we have concluded

- Hardness is maximum in HAZ of SS (88 HRB) which is greater than hardness of SS parent metal (82 HRB). Hardness is varying in HAZ with respect to distances from fusion.

VI. Conclusion

Observation of Tensile Test:

- Hardness strength of weld bead is found to be 82 HRB at 25 voltage, 12.5m/min feed rate, and 250 A current.
- During tensile testing fracture takes place from mild steel (parent metal).This shows that the weld joint has more strength than mild steel who's UTS is 497.35 MPa.
- Above result is obtained at 25 V voltages, 250 a current, 12.5 m/min MIG wire feed rate&15cm/min weld speed. This is optimum parameter which is found practically very well.
- Characterization of microstructure, mechanical properties and corrosion resistance of dissimilar welded joint between 2205 duplex stainless steel and 16MnR Shaogang Wang, Qihui Ma, Yan Li College of Material Science and Technology, Nanjing University of Aeronautics and Astronautics, Nanjing 210016, China tensile strength found was 600 Mpa which is nearer to our result

.

Comments about Penetration and Spattering

Optimum penetration is obtained at 24V to 27V voltage and about 11 m/min to 13 m/min MIG wire feed rate and if we increase voltage more than 30V there is chances of spattering and if decrease the voltage then there is lack of penetration and fusion in base metal.

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