STUDY ON EFFECT OF HEAT INPUT ON MICROSTRUCTURE AND MECHANICALPROPERTIES OF GAS TUNGSTEN ARC WELDED AISI 316 STAINLESS STEEL PLATES

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A PROJECT REPORT

Submitted by

KARTHICK. B (0810103016)

PRASANTH .V. S (0810103034)

RAJ PANDIAN. R (0810103039)

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DEPARTMENT OF MECHANICAL ENGINEERING

PROJECT WORK

This is to certify that the project entitled

STUDY ON EFFECT OF HEAT INPUT ON THE ICROSTRUCTURE AND MECHANICAL PROPERTIES OF .S TUNGSTEN ARC WELDED AISI 316 STAINLESS STEEL PLATES

is the bonafide record of project work done by

KARTHICK B	(Register No: 0810103016)
PRASANTH V S	(Register No: 0810103034)
RAJ PANDIAN R	(Register No: 0810103039)

of B.E. Mechanical Engineering during the year 2011-2012

11/4/2012

Prof.R.Sudhakaran
PROJECT GUIDE

Dr.N.Mohandas Gandhi
HEAD OF DEPARTMENT

Submitted for the End semester examination held on 12/4/12

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ABSTRACT

Influence on heat input on the microstructure and mechanical properties of a gas tungsten arc welded 316 Stainless Steel (SS) plates was studied. Five different heat input were selected from the operating window of the gas tungsten arc welded process and weld bead was made on the plates. These plates were then subjected to microstructure evaluations and tensile testing so as to analyse the effect of thermal arc energy on the microstructure and the mechanical properties of the plates. The results of the investigation indicate that the bead made using low heat input exhibited higher ultimate tensile strength and hardness then those beads made from other heat inputs. From this study, it has been inferred that the heat input has significant effect on Ultimate Tensile Strength, Hardness and Microstructure on AISI 316 SS GTAW plates.

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LIST OF ABBREVIATIONS

HAZ	Heat Affected Zone
SMAW	Shielded Metal Arc Welding
GTAW	Gas Tungsten Arc Welding
TIG	Tungsten Inert Gas Welding
VHN	Vickers Hardness Number
AWS	American welding Society
ASTM	American Society of Testing Materials
DCEN	Direct Current Electrode Negative
DCEP	Direct Current Electrode Positive
SAE	Society of Automotive Engineers
RPM	Rotation per Minute

1. INTRODUCTION:

1.1 CONCEPT OF THE PROJECT:

The concept of the project is that by introducing the heat and increasing the heat input of any metal its microstructure and mechanical properties of the metal changes automatically. This heat input can be given to the metal by various modes. This heat input can vary by changing the current and by calculating with voltage that is noted during the heat input. The voltage and current which are noted helps in finding out the heat input given to the material. After the heat input is given the specimens should be prepared according to the standard dimension as per the standard testing norms and tensile strength can be calculated. Now the specimen is machined to the size that is required to take the micro hardness, then the microstructure of the specimen can be revealed by applying the etchants on it and its changes on the microstructure and mechanical properties of the metal are revealed and the results are analyzed.

1.2 SCOPE OF THE PROJECT:

In the present world every manufacturing industry has a metallurgical division in order to analysis the metals and materials which are used in the factory outlet components. This project helps to analyze the metals which are used various climatic conditions and their variation in the mechanical properties like tensile strength, compression and hardness of the metal used. This project also helps to reveal the variation in the microstructure of the metal due to its climatic conditions. This microstructure study helps in revealing the dendrites formation and grain formation in the metal which helps to visualize the properties like ductility, brittleness. malleability etc. which helps to analyze about the metal and information about suitable application of the metal and helps in gaining the better results for those applications.

1.3 OBJECTIVES OF THE PROJECT:

The main objectives of the project is when the heat input is given to the metal by welding process, the mechanical properties like tensile strength, micro hardness and microstructure of the metal changes. Grade 316 is the standard molybdenum-bearing grade, second in importance to 304 amongst the austenitic stainless steels. The molybdenum gives 316 better overall corrosion resistant properties than Grade 304, particularly higher resistance to pitting and crevice corrosion in chloride environments. It has excellent forming and welding characteristics. It is readily brake or roll formed into a variety of parts for applications in the industrial, architectural, and transportation fields. Grade 316 also has outstanding welding characteristics. This heat input can be given to the metal by various modes. This heat input can vary by changing the current and by calculating with voltage that is noted during the heat input. The voltage and current which are noted helps in finding out the heat input given to the material. After the heat input is given the specimens should be prepared according to the standard dimension as per the standard testing norms and tensile strength can be calculated. Now the specimen is machined to the size that is required to take the micro hardness, then the microstructure of the specimen can be revealed by applying the etchants on it and its changes on the microstructure and mechanical properties of the metal are revealed and the results are analyzed. This microstructure study helps in revealing the dendrites formation and grain formation in the metal which helps to visualize the properties like ductility, brittleness, malleability etc. These changes can be reveled and analyzed by using the tensile test machine, Vickers hardness tester and optical microscope and the results are analyzed and studied. From this study to show the impact of the heat input on the micro structure and the mechanical properties of the metal.

2. LITERATURE REVIEW:

2.1 INTRODUCTION:

Before starting the project various literacy are reviewed and various information regarding the project are collected. These literacy reviews are helpful to do the projects successfully. The literacy which are reviewed are said below

2.2 STUDIES ON 316 STAINLESS STEEL:

316 stainless steel contains an addition of molybdenum that gives it improved corrosion resistance. This is particularly apparent for pitting and crevice corrosion in chloride environments. The austenitic structure of 316 Stainless steel gives excellent toughness, even at cryogenic temperatures.

Grade 316 is the standard molybdenum-bearing grade, second in importance to 304 amongst the austenitic stainless steels. The molybdenum gives 316 better overall corrosion resistant properties than Grade 304, particularly higher resistance to pitting and crevice corrosion in chloride environments. It has excellent forming and welding characteristics. It is readily brake or roll formed into a variety of parts for applications in the industrial, architectural, and transportation fields. Grade 316 also has outstanding welding characteristics. Post-weld annealing is not required when welding thin sections.

These properties are specified for flat rolled product (plate, sheet and coil) in ASTM A240/A240M. Similar but not necessarily identical properties are specified for other products such as pipe and bar in their respective specifications. It is common for 316 and 316L to be stocked in "Dual Certified" form - mainly in plate and pipe. These items have chemical and mechanical properties complying with both 316 and 316L specifications. Such dual certified product does not meet 316H specification and may be unacceptable for high temperature applications.

2.3 STUDY ON THE WELDING ENGINEERING:

In arc welding, energy is transferred from the welding electrode to the base metal by an electric arc. When the welder starts the arc, both the base metal and the filler metal are melted to create the weld. This melting is possible because a sufficient amount of power (energy transferred per unit time) and energy density is supplied to the electrode. Heat input is a relative measure of the energy transferred per unit length of weld. It is an important characteristic because, like preheat and inter pass temperature, it influences the cooling rate, which may affect the mechanical properties and metallurgical structure of the weld and the HAZ. Heat input is typically calculated as the ratio of the power (i.e., voltage x current) to the velocity of the heat source (i.e., the arc).

where,

H = heat input (kJ/in or kJ/mm)

E = arc voltage (volts)

I = current (amps)

S = travel speed (in/min or mm/min)

This equation is useful for comparing different welding procedures for a given welding process. However, heat input is not necessarily applicable for comparing different processes (e.g., SMAW and GMAW), unless additional data are available such as the heat transfer efficiency. Heat input cannot be measured directly. It can, however, be calculated from the measured values of arc voltage, current and travel speed. Varying the heat input typically will affect the material properties in the weld. An arrow pointed up, , designates that the property increases as heat input increases. An arrow pointed down, , designates that the property decreases as heat input increases. Next to the arrow is the approximate amount that property changed from the minimum to maximum value of heat input tested. Other than notch toughness, all of the mechanical properties show a monotonic relationship to heat input, that is, the mechanical property only increases or decreases with increasing heat input. Notch toughness, however, increases slightly and then drops significantly as heat input increases. The change in notch toughness is not just tied to the heat input, but is also significantly

Influenced by the weld bead size. As the bead size increases, which corresponds to a higher heat input, the notch toughness tends to decrease. In multiple-pass welds, a portion of the previous weld pass is refined, and the toughness improved, as the heat from each pass tempers the weld metal below it. If the beads are smaller, more grain refinement occurs, resulting in better notch toughness, all other factors being even.

2.4 STUDY ON VICKERS HARDNESS TEST:

The Vickers hardness test method consists of indenting the test material with a diamond indenter, in the form of a pyramid with a square base and an angle of 136 degrees between opposite faces subjected to a test force of between 1gf and 100kgf. The full load is normally applied for 10 to 15 seconds. The two diagonals of the indentation left in the surface of the material after removal of the load are measured using a microscope and their average calculated. The area of the sloping surfaces of the indentation is calculated. The Vickers hardness is the quotient obtained by dividing the kgf load by the square mm area of indentation.

Indenter Hardness Testing Machines Limited, West Midlands, DY9 8HX

$HV=1.854F/d^2$

F Load in kgf

d Arithmetic mean of the two diagonals, *d1* and *d2* in mm

HV Vickers hardness

When the mean diagonal of the indentation has been determined the Vickers hardness may be calculated from the formula. Modern digital Vickers hardness testers perform this calculation automatically and report the appropriate hardness result. The Vickers hardness should be reported like 800 HV/10, which means a Vickers hardness of 800, was obtained using a 10 kgf test force. Several different loading settings give practically identical hardness numbers on uniform material, which is much better than the arbitrary changing of scale with the other hardness testing methods.

The advantages of the Vickers hardness test are that extremely accurate readings can be taken, and just one type of indenter is used for all types of metals and surface treatments. Although thoroughly adaptable and very precise for testing the softest and hardest of materials, under varying loads, the Vickers machine is a floor standing unit that is more expensive than the Brinell or Rockwell machines. There is now a trend towards reporting Vickers hardness in SI units (MPa or GPa) particularly in academic papers. Unfortunately, this can cause confusion. Vickers hardness.

With modern advances in technology, PCs and software development, it is now possible to offer automatic indentation measurement. This has the benefit of eliminating any operator influence over the result, reducing R&R (repeatability and reproducibility) and uncertainty budgets. Automatic test surface focusing, motorised XY tables and automatic effective case depth determination are common place in advanced laboratories around the world who require the latest technology offering fast, reliable and traceable testing.

It was decided that the indenter shape should be capable of producing geometrically similar impressions, irrespective of size; the impression should have well-defined points of measurement; and the indenter should have high resistance to self-deformation. A diamond in the form of a square-based pyramid satisfied these conditions. It had been established that the ideal size of a Brinell impression was 3/8 of the ball diameter. As two tangents to the circle at the ends of a chord 3d/8 long intersect at 136°, it was decided to use this as the included angle of the indenter. The angle was varied experimentally and it was found that the hardness value obtained on a homogeneous piece of material remained constant, irrespective of load.[2] Accordingly, loads of various magnitudes are applied to a flat surface, depending on the hardness of the material to be measured.

2.5 STUDIES ON ETCHANTS:

Recommended Etchants

The following table lists the most commonly used etchants

Etchant	Composition	Conc.	Conditions	Comments
ASTM No. 30	Ammonia Hydrogen Peroxide (3%) DI Water	62.5 ml 125 ml 62.5 ml	Mix Ammonia and water before adding peroxide. Must be used fresh. Swab 5-45 seconds	For etching copper, copper alloys and copper-silver alloys.
Kalling's No. 2	CuCl2 Hydrochloric acid Ethanol	5 grams 100 ml 100 ml	Immersion etching at 20 degrees Celcius	For etching duplex stainless steels and Ni-Cu alloys and superalloys.
Kellers Etch	Distilled water Nitric acid Hydrochloric acid Hydrofluoric acid	190 ml 5 ml 3 ml 2 ml	10-30 second immersion. Use only fresh etchant	Excellent for aluminum and titanium alloys.
Klemm's Reagent	Sodium thiosulfate solution Potassium metabisulfite	250 ml Saturated 5 grams	Etch for a few seconds to minutes	For etching alpha-beta brass, bonze, tin, cast iron phosphides, ferrite, martensite, retained austenite, zinc and steel temper embrittlement.
Kroll's	Distilled water	92 ml		Excellent for titanium

Reagent	Nitric acid Hydrofluoric acid	6 ml 2 ml	Swab specimen up to 20 seconds	and alloys.
Nital	Ethanol Nitric acid	100 ml 1-10 ml	Immersion up to a few minutes.	Most common etchant for Fe, carbon and alloys steels and cast iron - Immerse sample up from seconds to minutes; Mn-Fe, MnNi, Mn-Cu, Mn-Co alloys.
Marble's Reagent	CuSO4 Hydrochloric acid Water	10 grams 50 ml 50 ml	Immerse or swab for 5-60 seconds.	For etching Ni, Ni-Cu and Ni-Fe alloys and superalloys. Add a few drops of H2SO4 to increase activity.
Murakami's	K3Fe(CN)6 KOH Water	10 grams 10 grams 100 ml	Pre-mix KOH and water before adding K3Fe(CN)6	Cr and alloys (use fresh and immerse); iron and steels reveals carbides; Mo and alloys uses fresh and immerse; Ni-Cu alloys for alpha phases use at 75 Celcius; W and alloys use fresh and immerse; WC-Co and complex sintered

				carbides.
Picral	Ethanol Picric acid	100 ml 2-4 grams	Seconds to minutes Do not let etchant crystallize or dry –explosive	Recommended for microstructures containing ferrite, carbide, pearlite, martensite and bainite. Also useful for magnetic alloys, cast iron, high alloy stainless steels and magnesium.
Vilella's Reagent	Picric Acid Hydrochloric acid Ethanol	1 gram 5 ml 100 ml	Seconds to minutes	Good for ferrite-carbide structures (tempered martensite) in iron and steel

2.6 Guide to Acid Concentrations

Acid / Base	Specific gravity	Concentration
Nitric (HNO_3)	1.4	68-70%
Hydrofluoric (HF)	-	40%
Hydrochloric (HCl)	-	37-38%
Ammonium Hydroxide (NH_4OH)	-	35%

2.7 INFERENCE:

For 316 Stainless Steel the heat input is given by GTAW process. Gas tungsten arc welding (GTAW), also known as tungsten inert gas (TIG) welding, is an arc welding process that uses a non-consumable tungsten electrode to produce the weld. The weld area is protected from atmospheric contamination by a shielding gas (usually an inert gas such as argon), and a filler metal is normally used, though some welds, known as autogenously welds, do not require it. A constant-current welding power supply produces energy which is conducted across the arc through a column of highly ionized gas and metal vapors known as plasma. GTAW is most commonly used to weld thin sections of stainless steel and non-ferrous metals such as aluminum, magnesium, and copper alloys. The process grants the operator greater control over the weld than competing procedures such as shielded metal arc welding and gas metal arc welding, allowing for stronger, higher quality welds. However, GTAW is comparatively more complex and difficult to master, and furthermore, it is significantly slower than most other welding techniques. A related process, plasma arc welding, uses a slightly different welding torch to create a more focused welding arc and as a result is often automated GTAW process can be well suits for Austenitic Stainless steel to get a quality weld. Heat input can be calculated by using current and voltage. Heat input increase on increase the current. Heat input is a relative measure of the energy transferred per unit length of weld. It is an important characteristic because, like preheat and inter pass temperature, it influences the cooling rate, which may affect the mechanical properties and metallurgical structure of the weld and the parental metal zone. For tensile test must be done on the machine with the capacity of 400 kN and the specimens should be prepared as per the Indian Standard and Micro hardness test can be taken in the Vickers hardness Testing machine and for the micro hardness the specimen should be machined such that it fits on the vice of the machine. Now for the microstructure study the etchant used for the microstructure study is Marble's Reagent, and it should be prepared as mentioned above and it should be applied on the specimens by immersing it in the solution. Now the micro structure can be revealed and the results are analyzed by using the microscope with the magnificent lens of 100x and 200x. By using this type magnificent glass, grows of the dendrites, grain pattern can be revealed. which helps to visualize the properties like ductility, brittleness, malleability etc. These property study of the material helps to find the right application that the material fix and the appropriate results can be gained.

3. HEAT INPUT:

In arc welding, energy is transferred from the welding electrode to the base metal by an electric arc. When the welder starts the arc, both the base metal and the filler metal are melted to create the weld. This melting is possible because a sufficient amount of power (energy transferred per unit time) and energy density is supplied to the electrode.

Heat input is a relative measure of the energy transferred per unit length of weld. It is an important characteristic because, like preheat and inter pass temperature, it influences the cooling rate, which may affect the mechanical properties and metallurgical structure of the weld and the HAZ.

If the changes in heat input are relatively small, as opposed to those of the previous table, then the mechanical properties may not be significantly changed. In another study, no significant correlation between heat input and mechanical properties was established for submerged arc welding (SAW) with typical highway bridge fabrication heat input levels of 50 to 90 kJ. In this case, the tests results did show varying properties; however, no discernabletrends were established.

3.1 HEAT INPUT METHOD:

3.1.1 WELDING:

The American welding society (AWS) defines welding process as "A localized coalescence of metals or non-metals produced either by heating the materials to the required welding temperatures, with or without the application of pressure alone, and with or without the use of filler materials".

Welding is used for making permanents joints. Application of welding involves the manufacturing of automobiles bodies, structural works, aircraft frames, machine bodies, railway wagons, tanks, furnaces, boilers, furniture, ship building, etc. Role of welding process has now almost become inevitable. Recent developments in the area of welding are robotic welding, space welding, under water welding, etc. Weld ability is the ease of a material or a combination of materials to be welded under fabrication conditions into a specific, suitably designed structure, and to perform satisfactorily in the intended service.

3.1.2 ADVANTAGES OF WELDING:

- Strong and tight joining.
- Cost Effectiveness.
- Simplicity of welded structures design
- Welding processes may be mechanized and automated.

3.1.3 DISADVANTAGES OF WELDING:

- Internal stress, distortion and changes of micro-structures in the weld region
- Harmful effects: Light, ultra violate radiation, fumes, high temperature.

.1.4 APPLICATION OF WELDING:

- Buildings and bridges structures
- Automotive, ship and aircraft constructions
- Pipelines
- Tanks and Vessels
- Steel works.
- Fabrication works

- Cutting of the metals.
- To provide heat input.

3.1.5 CLASSIFICATION OF WELDING:

Welding is one of the metal joining processes which are used to produce welds. There are three major types of welding processes.

They are:

1. Fusion welding
2. Solid state welding
3. Semi-liquid welding.

Most of the welding processes utilize heat and / or pressure for making a weld joint. A weld is made when separate pieces of material to be joined combine and form one piece when heated to a temperature high enough to cause softening or melting and flow together. Based on the method of heat generation and its application, the three major welding processes can be divided into several classes as shown in figure.

Plastic Welding or Pressure Welding

The piece of metal to be joined are heated to a plastic state and forced together by external pressure

(Ex) Resistance welding

Fusion Welding or Non-Pressure Welding

The material at the joint is heated to a molten state and allowed to solidify

(Ex) Gas welding, Arc welding

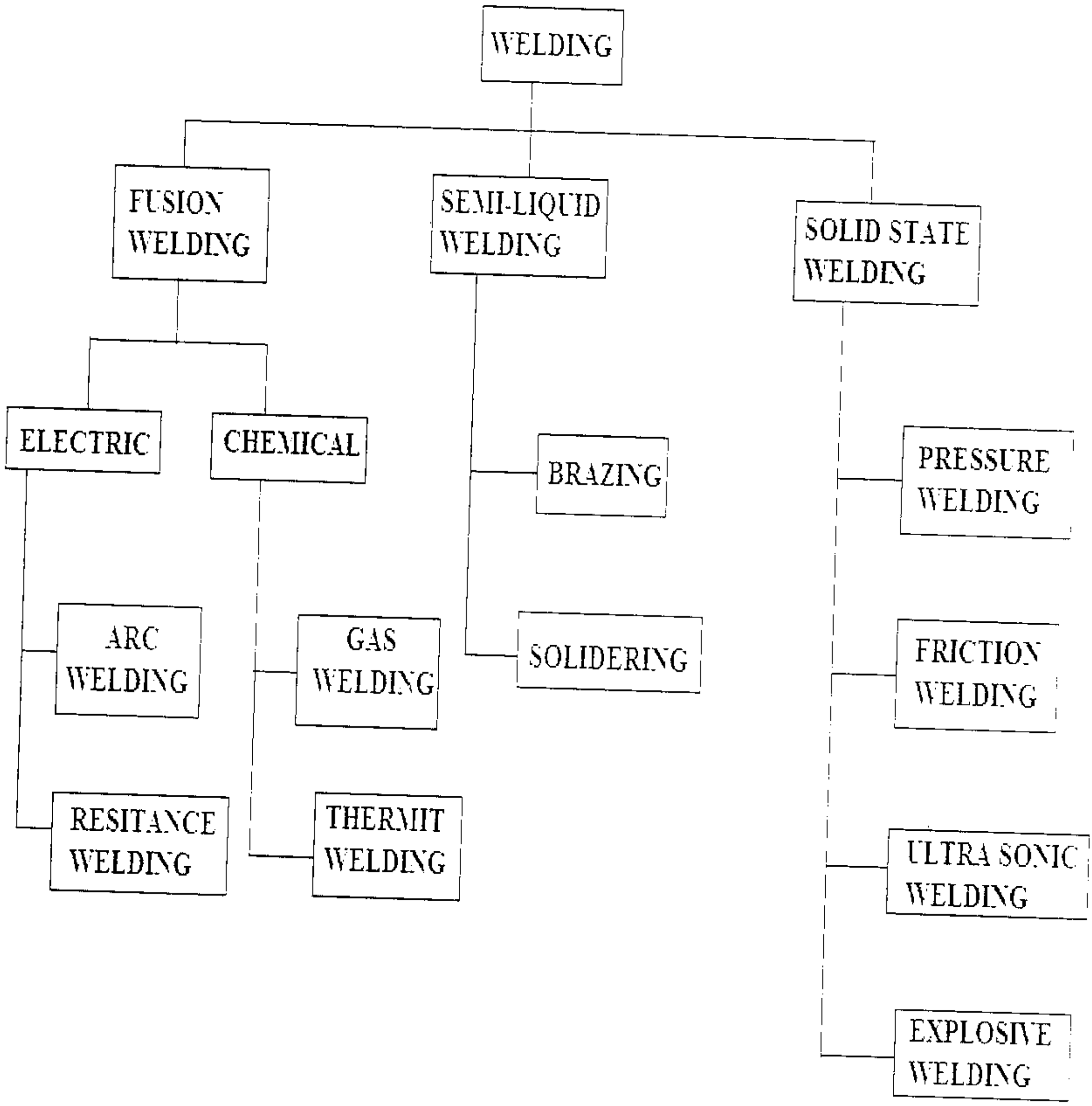


FIGURE 3.1 CLASSIFICATION OF WELDING

3.2 GAS TUNGSTEN ARC WELDING PROCESS

3.2.1 INTRODUCTION

Gas tungsten arc welding (GTAW), also known as tungsten inert gas (TIG) welding, is an arc welding process that uses a non consumable tungsten electrode to produce the weld. The weld area is protected from atmospheric contamination by shielding gas (usually an inert gas such as argon), an filler material is normally used, though some welds, known as autogenously welds, do not require it. A constant current welding power supply produces energy which is conducted across the arc through a column of highly ionized gas and metal vapors known as a plasma.

GTAW is most commonly used to weld thin sections of stainless steel and non- ferrous metals such as aluminum, magnesium and copper alloys. The process grants the operator greater control over the weld than competing procedures such as shielded metal arc welding and gas metal arc welding, allowing for stronger, higher quality welds. However, GTAW is comparatively more complex and difficult to master, and furthermore, it is significantly slower than most other welding techniques. A related process, plasma arc welding uses a slightly different welding torch to create a more focused welding arc and as a result is often automated.

A new process based on GTAW was developed, called plasma arc welding. It affords greater control and improves weld quality by using a nozzle to focus the electric arc, but is largely limited to automated systems, whereas GTAW remains primarily a manual, hand-held method. Development within the GTAW process has continued as well, and today a number of variations exist. Among the most popular are the pulsed-current, manual programmed, hot-wire, dabber, and increased penetration GTAW methods. This proved unacceptable for welding aluminum and magnesium because it reduced weld quality, and as a result, it is rarely used with GTAW today.

3.2.2 GTAW PROCESS:

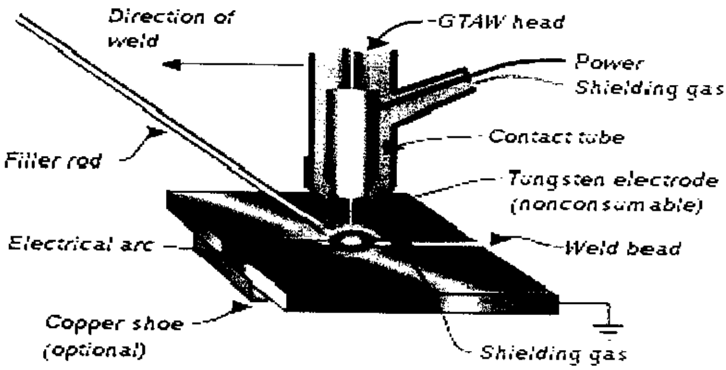


FIGURE 3.2 GAS TUNGSTEN ARC WELDING

Manual gas tungsten arc welding is often considered the most difficult of all the welding processes commonly used in industry. Because the welder must maintain a short arc length, great care and skill are required to prevent contact between the electrode and the work piece. Similar to torch welding, GTAW normally requires two hands, since most applications require that the welder manually feed a filler metal into the weld area with one hand while manipulating the welding torch in the other. However, some welds combining thin materials (known as autogenous or fusion welds) can be accomplished without filler metal; most notably edge, corner, and butt joints.

To strike the welding arc, a high frequency generator (similar to a Tesla coil) provides a spark; This spark is a conductive path for the welding current through the shielding gas and allows the arc to be initiated while the electrode and the work piece are separated, typically about 1.5–3 mm (0.06–0.12 in) apart. This high voltage, high frequency burst can be damaging to some vehicle electrical systems and electronics, because induced voltages on vehicle wiring can also cause small conductive sparks in the vehicle wiring or within semiconductor packaging. Vehicle 12V power may conduct across these ionized paths, driven by the high-current 12V vehicle battery. These currents can be sufficiently destructive as to disable the vehicle: thus the warning to disconnect the vehicle battery power from both +12 and ground before using welding equipment on vehicles.

An alternate way to initiate the arc is the "scratch start". Scratching the electrode against the work with the power on also serve to strike an arc, in the same way as SMAW ("stick") arc welding. However, scratch starting can cause contamination of the weld and electrode. Some GTAW equipment is capable of a mode called "touch start" or "lift arc"; here the equipment reduces the voltage on the electrode to only a few volts, with a current limit of one or two amps (well below the limit that causes metal to transfer and contamination of the weld or electrode). When the GTAW equipment detects that the electrode has left the surface and a spark is present, it immediately (within microseconds) increases power, a converting the spark to a full arc.

Once the arc is struck, the welder moves the torch in a small circle to create a welding pool, the size of which depends on the size of the electrode and the amount of current. While maintaining a constant separation between the electrode and the work piece, typically about 1.5–3 mm (0.06–0.12 in) apart. This high voltage, high frequency burst can be damaging to some vehicle electrical systems and electronics. because induced voltages on vehicle wiring can also cause small conductive the operator then moves the torch back slightly and tilts it backward about 10–15 degrees from vertical. Filler metal is added manually to the front end of the weld pool as it is needed.

Welders often develop a technique of rapidly alternating between moving the torch forward (to advance the weld pool) and adding filler metal. The filler rod is withdrawn from the weld pool each time the electrode advances, but it is never removed from the gas shield to prevent oxidation of its surface and contamination of the weld. Filler rods composed of metals with low melting temperature, such as aluminum, require that the operator maintain some distance from the arc while staying inside the gas shield. If held too close to the arc, the filler rod can melt before it makes contact with the weld puddle. As the weld nears completion, the arc current is often gradually reduced to allow the weld crater to solidify and prevent the formation of crater cracks at the end of the weld.

3.2.3 OPERATION MODES:

GTAW can use a positive direct current, negative direct current or an alternating current depending on the power supply set up. A negative direct current from the electrode causes a stream of electrons to collide with the surface, generating large amounts of heat at the weld region. This creates a deep, narrow weld. In the opposite process where the electrode is connected to the positive power supply terminal, positively charged ions flow from the part being welded to the tip of the electrode instead, so the heating action of the electrons is mostly on the electrode. This mode also helps to remove oxide layers from the surface of the region to be welded, which is good for metals such as aluminium or magnesium. A shallow, wide weld is produced from this mode, with minimum heat input. Alternating current gives a combination of negative and positive modes, giving a cleaning effect and imparts a lot of heat as well.

3.2.4 EQUIPMENT USED:

Figure 3.3 GTAW torch with various electrodes, cups, collets and gas diffusers

The equipment required for the gas tungsten arc welding operation includes a welding orch utilizing a non-consumable tungsten electrode, a constant-current welding power supply, ınd a shielding gas source.

3.2.5 WELDING TORCH

GTAW welding torches are designed for either automatic or manual operation and are equipped with cooling systems using air or water. The automatic and manual torches are similar in construction, but the manual torch has a handle while the automatic torch normally comes with a mounting rack. The angle between the centerline of the handle and the centerline of the tungsten electrode, known as the head angle, can be varied on some manual torches according to the preference of the operator. Air cooling systems are most often used for low-current operations (up to about 200 A), while water cooling is required for high-current welding (up to about 600 A). The torches are connected with cables to the power supply and with hoses to the shielding gas source and where used, the water supply.

The internal metal parts of a torch are made of hard alloys of copper or brass in order to transmit current and heat effectively. The tungsten electrode must be held firmly in the center of the torch with an appropriately sized collet, and ports around the electrode provide a constant flow of shielding gas. Collets are sized according to the diameter of the tungsten electrode they hold. The body of the torch is made of heat-resistant, insulating plastics covering the metal components, providing insulation from heat and electricity to protect the welder.

The size of the welding torch nozzle depends on the amount of shielded area desired. The size of the gas nozzle will depend upon the diameter of the electrode, the joint configuration, and the availability of access to the joint by the welder. The inside diameter of the nozzle is preferably at least three times the diameter of the electrode, but there are no hard rules. The welder will judge the effectiveness of the shielding and increase the nozzle size to increase the area protected by the external gas shield as needed. The nozzle must be heat resistant and thus is normally made of alumina or a ceramic material, but fused quartz, a glass-like substance, offers greater visibility. Devices can be inserted into the nozzle for special applications, such as gas lenses or valves to improve the control shielding gas flow to reduce turbulence and introduction of contaminated atmosphere into the shielded area. Hand switches to control welding current can be added to the manual GTAW torches.

3.2.6 POWER SUPPLY

Gas tungsten arc welding uses a constant current power source, meaning that the current (and thus the heat) remains relatively constant, even if the arc distance and voltage change. This is important because most applications of GTAW are manual or semiautomatic, requiring that an operator hold the torch. Maintaining a suitably steady arc distance is difficult if a constant voltage power source is used instead, since it can cause dramatic heat variations and make welding more difficult.

3.2.7 GTAW POWER SUPPLY

The preferred polarity of the GTAW system depends largely on the type of metal being welded. Direct current with a negatively charged electrode (DCEN) is often employed when welding steels, nickel and other metals. It can also be used in automatic GTA welding of aluminum or magnesium when helium is used as a shielding gas. The negatively charged electrode generates heat by emitting electrons which travel across the arc, causing thermal ionization of the shielding gas and increasing the temperature of the base material. The ionized shielding gas flows toward the electrode, not the base material. Direct current with a positively charged electrode (DCEP) is less common, and is used primarily for shallow welds since less heat is generated in the base material. Instead of flowing from the electrode to the base material, as in DCEN, electrons go the other direction, causing the electrode to reach very high temperatures. To help it maintain its shape and prevent softening, a larger electrode is often used. As the electrons flow toward the electrode, ionized shielding gas flows back toward the base material, cleaning the weld by removing oxides and other impurities and thereby improving its quality and appearance.

Alternating current, commonly used when welding aluminium and magnesium manually or semi-automatically, combines the two direct currents by making the electrode and base material alternate between positive and negative charge. This causes the electron flow to switch directions constantly, preventing the tungsten electrode from overheating while maintaining the heat in the base material. Surface oxides are still removed during the electrode-positive portion of the cycle and the base metal is heated more deeply during the electrode - negative portion of the cycle. Some power supplies enable operators to use an unbalanced alternating current wave by modifying the exact percentage of time that the current spends in each state of polarity, giving them more control over the amount of heat and cleaning action supplied by the power source. In addition, operators must be wary of rectification, in which the arc fails to reignite as it passes from straight polarity (negative electrode) to reverse polarity (positive electrode). To remedy the problem, a square wave power supply can be used, as can high-frequency voltage to encourage ignition.

3.2.8 ELECTRODE

The electrode used in GTAW is made of tungsten or a tungsten alloy, because tungsten has the highest melting temperature among pure metals, at 3,422 °C (6,192 °F). As a result, the electrode is not consumed during welding, though some erosion (called burn-off) can occur. Electrodes can have either a clean finish or a ground finish—clean finish electrodes have been chemically cleaned, while ground finish electrodes have been ground to a uniform size and have a polished surface, making them optimal for heat conduction. The diameter of the electrode can vary between 0.5 and 6.4 millimetres (0.02 and 0.25 in), and their length can range from 75 to 610 millimetres (3.0 to 24 in).

Filler metals are also used in nearly all applications of GTAW, the major exception being the welding of thin materials. Filler metals are available with different diameters and are made of a variety of materials. In most cases, the filler metal in the form of a rod is added to the weld pool manually, but some applications call for an automatically fed filler metal, which often is stored on spools or coils. Pure tungsten electrodes (classified as WP or EWP) are general purpose and low cost electrodes. They have poor heat resistance and electron emission. They find limited use in AC welding of e.g. magnesium and aluminium. Cerium oxide (or ceria) as an alloying element improves arc stability and ease of starting while decreasing burn-off. Cerium addition is not as effective as thorium but works well, and cerium is not radioactive. Using an alloy of lanthanum oxide (or lanthana) has a similar effect. Addition of 1% lanthanum has the same effect as 2% of cerium. Thorium oxide (or thoria) alloy electrodes were designed for DC applications and can withstand somewhat higher temperatures while providing many of the benefits of other alloys. However, it is somewhat radioactive. Inhalation of the thorium grinding dust during preparation of the electrode is hazardous to one's health. As a replacement to thoriated electrodes, electrodes with larger concentrations of lanthanum oxide can be used. Larger additions than 0.6% do not have additional improving effect on arc starting, but they help with electron emission. Higher percentage of thorium also makes tungsten more resistant to contamination.

Electrodes containing zirconium oxide (or zirconia) increase the current capacity while improving arc stability and starting and increasing electrode life. Zirconium-tungsten electrodes melt easier than thorium-tungsten.

In addition, electrode manufacturers may create alternative tungsten alloys with specified metal additions, and these are designated with the classification EWG under the AWS system.

3.2.9 SHIELDING GAS

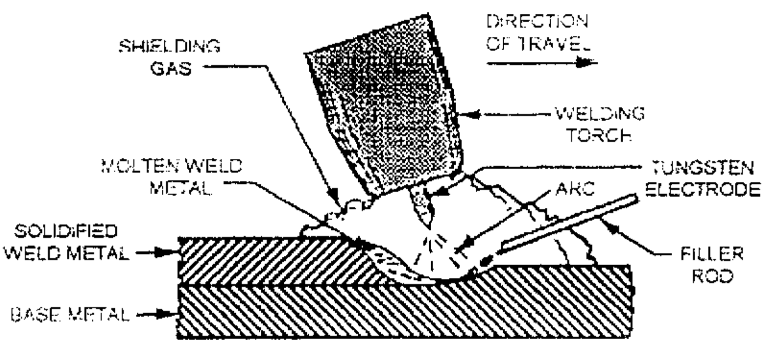


FIGURE 3.4 GTAW WITH SHIELDED GAS

As with other welding processes such as gas metal arc welding, shielded gas are necessary in GTAW to protect the welding area from atmospheric gases such as nitrogen and oxygen, which can cause fusion defects, porosity, and weld metal embrittlement if they come in contact with the electrode, the arc, or the welding metal. The gas also transfers heat from the tungsten electrode to the metal, and it helps start and maintain a stable arc.

The selection of a shielding gas depends on several factors, including the type of material being welded, joint design, and desired final weld appearance. Argon is the most commonly used shielding gas for GTAW, since it helps prevent defects due to a varying arc length. When used with alternating current, the use of argon results in high weld quality and good appearance. Another common shielding gas, helium, is most often used to increase the weld penetration in a joint, to increase the welding speed, and to weld metals with high heat conductivity, such as copper and aluminium.

3.2.10 HEAT INPUT BY BEAD ON PLATE METHOD:

It is the method widely used where a single pass or multi pass bead is coated on the plate according to the requirement and this method can be used as the heat input method in order to provide heat to the plate. This method can provide a vast change in the mechanical properties and microstructure of the 316 Stainless Steel plates. This bead on plate method provides better changes in the properties of the metal. This method provides equal distribution of heat throughout the bead area as shown in figure 3.5.

FIGURE 3.5 HEAT INPUT BY BEAD ON PLATE METHOD

4. EXPERIMENTAL SETUP AND EQUIPMENTS:

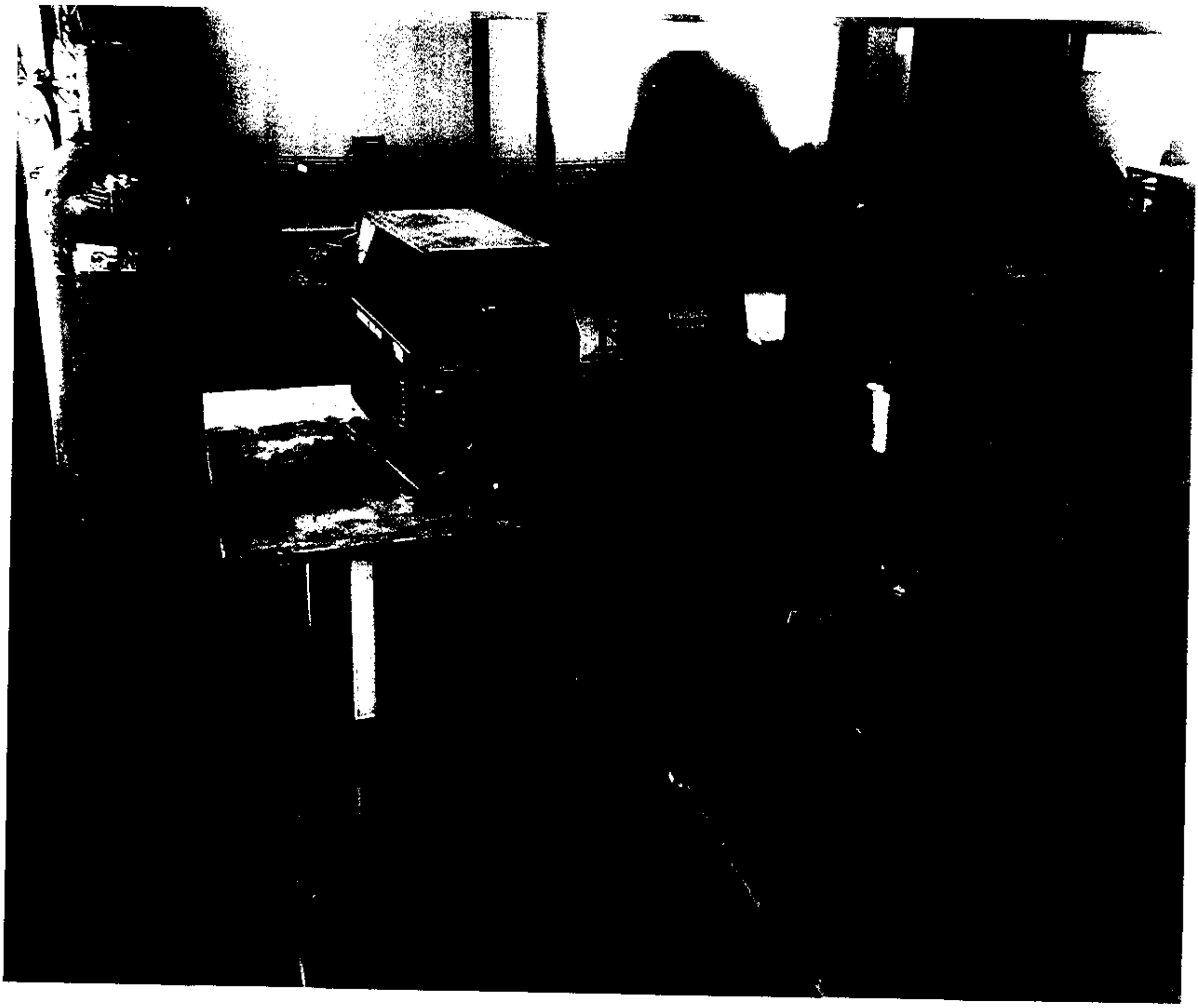


FIGURE 4.1 EXPERIMENTAL SETUP OF GAS TUNGSTEN WELDING

4.1 EXPERIMENTAL SETUP:

This experimental setup has the following components:

1) TIG welding Transformer
2) TIG Welding Inverter
3) Argon Gas Cylinder
4) Work Table
5) Welding Fixture
6) Welding Equipment

4.1.1 TIG Welding Transformer:

A transformer style welding power supply converts the high voltage and low current electricity from the utility mains into a high current and low voltage, typically between 17 to 45 volts and 55 to 590 amps. A rectifier converts the AC into DC on more expensive machines.

This design typically allows the welder to select the output current by variously moving a primary winding closer or farther from a secondary winding, moving a magnetic shunt in and out of the core of the transformer, using a series saturating reactor with a variable saturating technique in series with the secondary current output, or by simply permitting the welder to select the output voltage from a set of taps on the transformer's secondary winding. These transformer style machines are typically the least expensive.

The trade against being the least expensive is that pure transformer designs are often bulky and massive because they operate at the utility mains frequency of 50 or 60 Hz. Such low frequency transformers must have a high magnetizing inductance to avoid wasteful shunt currents. The transformer may also have significant leakage inductance for short circuit protection in the event of a welding rod becoming stuck to the work piece. The leakage inductance may be variable so the operator can set the output current.

4.1.2 TIG Welding Inverter:

Since the advent of high-power semiconductors such as the insulated gate bipolar transistor (IGBT), it is now possible to build a switched-mode power supply capable of coping with the high loads of arc welding. These designs are known as inverter welding units. They generally first rectify the utility AC power to DC; then they switch (invert) the DC power into a step-down transformer to produce the desired welding voltage or current. The switching frequency is typically 10 kHz or higher. Although the high switching frequency requires sophisticated components and circuits, it drastically reduces the bulk of the step down transformer, as the mass of magnetic components (transformers and inductors) that is required for achieving a given power level goes down rapidly as the operating (switching) frequency is increased. The inverter circuitry can also provide features such as power control and overload protection. The high frequency inverter-based welding machines are typically more efficient and provide better control of variable functional parameters than non-inverter welding machines.

The IGBTs in an inverter based machine are controlled by a microcontroller. so the electrical characteristics of the welding power can be changed by software in real time, even on a cycle by cycle basis, rather than making changes slowly over hundreds if not thousands of cycles. Typically, the controller software will implement features such as pulsing the welding current, providing variable ratios and current densities through a welding cycle, enabling swept or stepped variable frequencies, and providing timing as needed for implementing automatic spot-welding; all of these features would be prohibitively expensive to design into a transformer-based machine, but require only program memory space in a software-controlled inverter machine. Similarly, it is possible to add new features to a software-controlled inverter machine if needed, through a software update, rather than through having to buy a more modern welder. The transformer may also have significant leakage inductance for short circuit protection in the event of a welding rod becoming stuck to the work piece

4.1.3 Argon Gas Cylinder:

The gases described in the previous heading can be obtained in cylinders of various sizes. They are manufactured to Interstate Commerce Commission (ICC) specifications. Some gases are stored in cylinders as a gas. Some gases may also be stored as liquids in thermos-like tanks: the quantity of gas in the cylinder is determined by special mixing chamber and fed to the welding torch through a final flow meter.

4.1.4 Work Table:

This operating work table works automatically and this can be adjusted in both Y axis and Z axis according to requirements and this table also helps in fixing the welding torch and also holds the work in the table and this table also provides earth to the Welding process.

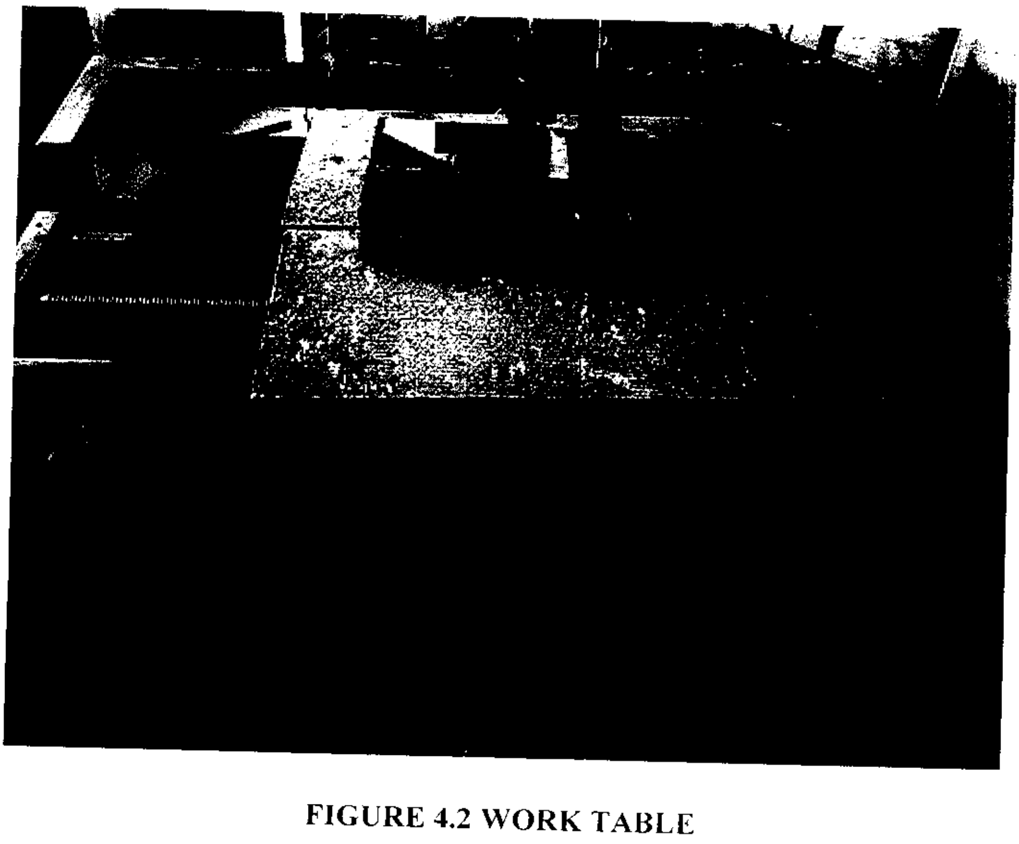


FIGURE 4.2 WORK TABLE

4.1.5 Welding Fixture:

This welding fixture is made of wood which helps in providing a stable holding of the welding torch at the required place. This welding fixture should be made up of wood in order to avoid the metal contact with the torch. Moreover this welding fixture can be positioned at any inclination in order to get accurate weld gun angle. This welding fixture is stationary and only table is movable.

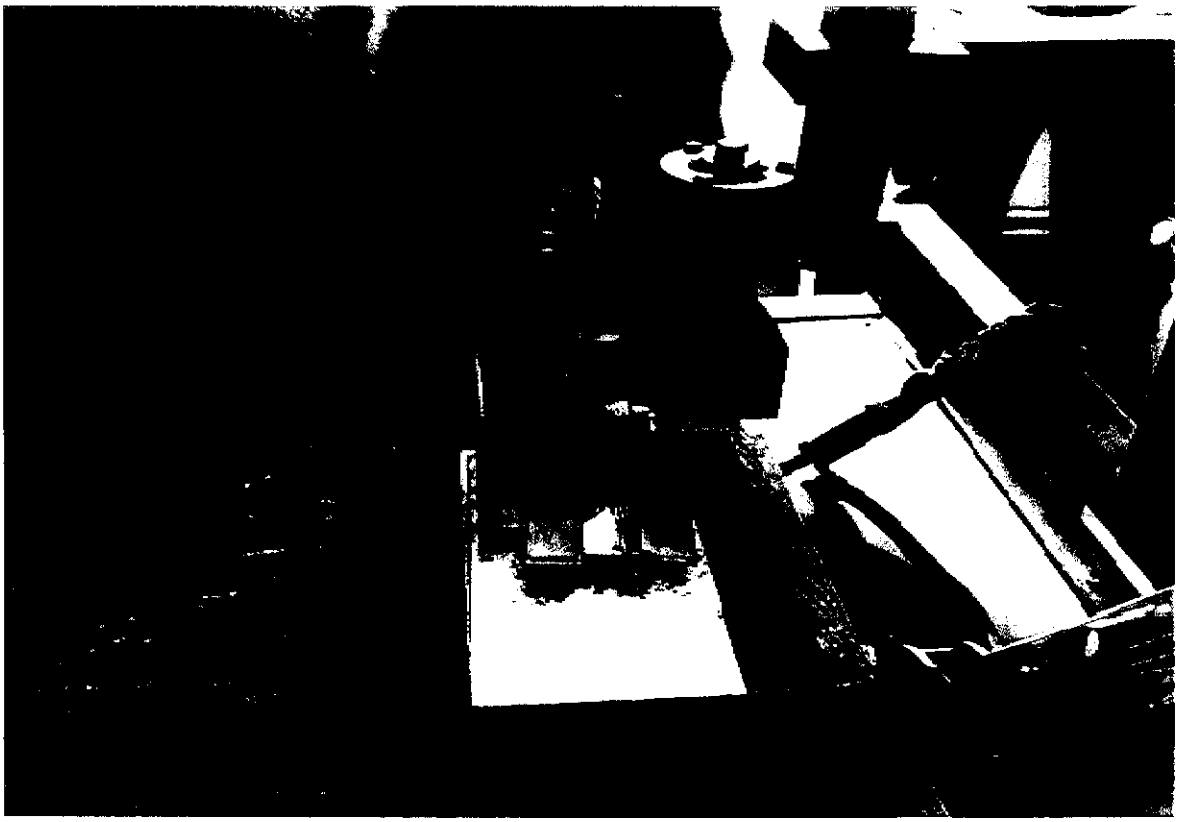
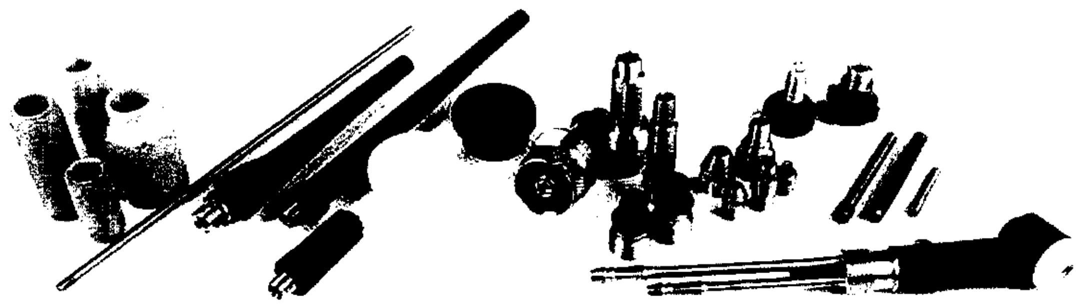


FIGURE 4.3 WELDING FIXTURE

4.1.6 Welding Equipment:



Gas tungsten arc welding torches come in many different designs, sizes, amperages, and shapes. Torches designed for lower amperages and light-duty use are cooled by the shielding gas flowing through the torch.Current capacity for the largest shielding gas cooled torches is about 200A. Torches used for higher amperages and those that are used to do a lot of welding at lower amperages are water-cooled. Most torches used in production and most torches used for continuous automatic welding are water cooled.

Gas nozzles are used to direct the shielding gas over the tungsten electrode and to cover the weld area with shielding gas. Nozzles must be able to withstand very high temperatures because they are very close to the arc. Different designs are available to meet the requirements of different welding jobs Nozzles are made from different materials. Most commonly, nozzles are made from a ceramic material. Other materials used include metal-jacketed ceramics, metal, and fused quartz. One end of a gas nozzle must attach to the end of the torch. Different designs are necessary to properly attach to different manufacturers' torches. The nozzle may be threaded onto the torch or held by friction.

4.2 MATERIAL USED:

4.2.1 ASTM A 240 / SAE 316 STAINLESS STEEL

Type 316 is an austenitic chromium nickel stainless steel containing molybdenum. This addition increases general corrosion resistance, improves Resistance to pitting from chloride ion solutions, and provides increased Strength at elevated temperatures. Properties are similar to those of Type 304 Except that this alloy is somewhat stronger at elevated temperatures.

Corrosion resistance is improved, particularly against sulphuric, hydrochloric, acetic, formic and tartaric acids; acid sulphates and alkaline chlorides. A stainless steel type 1.4401 is known as grades 316.Grade 316 is an austenitic grade second only to 304 in commercial importance. 316 stainless steel contains an addition of molybdenum that gives it improved corrosion resistance. This is particularly apparent for pitting and crevice corrosion in chloride environments.

The austenitic structure of 316 stainless steel gives excellent toughness, even at cryogenic temperatures.

4.2.2 Designations:

Euronorm 1.4401 / UNSS31600 /SAE 316S31/ EN58H/ GRADE 316

Possible alternative grades to 316 stainless steel.

316Ti Better resistance to temperatures of around 600-900°C is needed.

316N Higher strength than standard 316.

317 L Higher resistances to chlorides than 316L, but with similar resistance to stress corrosion cracking.

904L Much higher resistance to chlorides at elevated temperatures, with good formability

2205 Much higher resistance to chlorides at elevated temperatures, and higher strength than 316

4.2.3 Chemical Composition:

Iron	- 67.56%
Carbon	- 0.025%
Silicon	- 0.342%
Manganese	- 1.38%
Phosphorous	- 0.0246%
Sulphur	- 0.0269%
Chromium	- 16.5%
Molybdenum	- 2.23%
Nickel	- 11.4%
Copper	- 0.342%
Niobium	- 0.0117%
Titanium	` 0.023%
Vanadium	- 0.115%

4.2.4 Mechanical Properties:

Tensile Strength	- 515 MPa
Compression Strength	-170 MPa
Proof Stress 0.2 %	- 205 MPa
Elongation	- 40 %
Rockwell Hardness	- 95
Vickers Hardness	- 225
Brinell Hardness	- 217

4.2.5 Physical Properties:

Density	8.00 g/cm3
Melting Point	1375-1400°C
Modulus of Elasticity	193 GPa
Electrical Resistivity	0.074x10-6 Ω.m
Thermal Conductivity	16.3 W/m.K at 100°C
Thermal Expansion	15.9x10-6 /K at 100°C

4.2.6 Corrosion Resistance:

Grade 316 has excellent corrosion resistance when exposed to a range of corrosive environments and media. It is usually regarded as "marine grade" stainless steel but is not resistant to warm sea water. Warm chloride environments can cause pitting and crevice corrosion. Grade 316 is also subject to stress corrosion cracking above around 60°C. Types 316 and 316L Stainless Steels exhibit better corrosion resistance than Type 304. They provide excellent pitting resistance and good resistance to most chemicals involved in the paper, textile and photographic industries.

4.2.7 Heat Resistance:

316 has good resistance to oxidation in intermittent service to 870°C and in continuous service to 925°C. However, continuous use at 425-860°C is not recommended if corrosion resistance in water is required. In this instance 316L is recommended due to its resistance to carbide precipitation. Where high strength is required at temperatures above 500°C, grade 316H is recommended. Types 316 and 316L are non-hardenability heat treatment.

Annealing: Heat to 1900 - 2100°F (1038 - 1149°C), then rapidly quench.

4.2.8 Fabrication:

Fabrication of all stainless steels should be done only with tools dedicated to stainless steel materials. Tooling and work surfaces must be thoroughly cleaned before use. These precautions are necessary to avoid cross contamination of stainless steel by easily corroded metals that may discolour the surface of the fabricated product.

4.2.9 Welding:

Fusion welding performance for 316 stainless steel is excellent both with and without fillers. Recommended filler rods and electrodes for 316 is the same as the base metal, 316 respectively. Heavy welded sections may require post-weld annealing. Grade 316Ti may be used as an alternative to 316 in heavy section welds. Oxyacetylene welding has not been found to be successful for joining of 316 stainless-steel.

4.2.10 Cold Working:

Grade 316 is readily brake or roll formed into a variety of parts. It is also suited to stamping, heading and drawing but post work annealing is recommended to relieve internal stresses. Cold working will increase both strength and hardness of 316stainless steel.

4.2.11 Hot Working:

All common hot working processes can be performed on 316 stainless steel. Hot working should be avoided below 927°C. The ideal temperature range for hot working is 1149-1260°C. Post-work annealing is recommended to ensure optimum corrosion resistance

4.2.12 Heat Treatment:

316Stainless steel cannot be hardened by heat treatment. Solution treatment or annealing can be done by rapid cooling after heating to 1010-1120°C. Types 316 and 316L are non-hardenability heat treatment. For elevated temperature applications the high carbon variant, 316H stainless-steel and the stabilized grade 316Ti stainless steel should be employed.

4.2.13 Machinability:

316 Stainless steel has good machinability. Machining can be enhanced using the following rules:

- Cutting edges must be kept sharp. Dull edges cause excess work hardening.
- Cuts should be light but deep enough to prevent work hardening by riding on the surface of the material.
- Chip breakers should be employed to assist in ensuring scarp remains clear of the work.
- Low thermal conductivity of austenitic alloys results in heat concentrating at the cutting edges. This means coolants and lubricants are necessary and must be used in large quantities.

4.2.14 Supplied Forms:

316 Stainless steel is typically supplied in a range of finishes in the following forms:

- Sheet
- Plate
- Welded mesh
- Quarto plate
- Round bar
- Flat bar and rolled edge flat bar
- Equal angle
- Square bar
- Hollow bar
- Seamless pipe
- Welded pipe
- Seamless butt weld fittings
- Welded butt weld fittings
- Flanges
- Seamless tube
- Hygienic fittings
- Round, square and rectangular

4.2.15 Applications:

Initially developed for use in paper mills 316 Stainless steel is now typically used in:

- Food processing equipment
- Brewery equipment
- Chemical and petrochemical equipment
- Laboratory benches & equipment
- Coastal architectural panelling
- Coastal balustrading
- Boat fittings
- Chemical transportation containers
- Heat exchangers
- Mining screens
- Nuts and bolts
- Springs
- Medical implants.

4.3 PROCEDURE:

4.3.1 HEAT INPUT BY WELDING:

In this present work bead on plate method is used to provide a heat input at different range to different plates. Before welding all the edges are thoroughly cleaned in order to avoid rust, dust, moisture, etc which could creep into the weld metal and later on, could result possibly into a weld defect.

Now the Plate is cut into pieces of same dimension by laser cutting machine as mentioned in the figure. Now these pieces are prepared for heat input through welding process. Meanwhile the equipment needed for the welding is prepared as said below.

First the torch is prepared by inserting the tungsten electrode into the brass holder and it is tightened by the collet and the holder. Now the torch is fitted with the ceramic which position the tungsten electrode. Now the TIG Welding Transformer is connected to the main board and then the gas cylinder is contain 99.997% pure argon is connected to the TIG Welding Transformer.

For the proper transfer of gas to the Transformer, gas regulator with the pressure gauge is attached to the cylinder. This pressure regulator can adjusted in order to have the shielding gas at the correct proportion. This regulator is connected such that it connects both the cylinder which contains shielding gas and the TIG Welding Transformer through the pipe. Take care that the pipe is well shielded and connected at both the ends in order to avoid leakage of the gas while opening the cylinder.

Now the gas regulator which is attached to the argon cylinder is kept open and the gas flow rate is adjusted to 7.5 lit per minute flow. Then the positive connection and the earth are connected to the welding system as said below. First the positive from the TIG inverter is directly connected to the work table in order to have a connection as DCEN i.e. the negative is connected to the TIG Transformer (Igniters') from the TIG Inverter and then it is connected to the Welding Torch. This Welding Torch is fixed to the welding fixture in order to put the bead on the work plate automatically by adjusting the table. Now the work table is prepared in order to get a proper bead on the plate. To ignite the spark in the torch the pedal should be pressed. To initiate the weld the gap between the torch and plate should be less than 3 mm. This gap helps to ignite the spark such that proper weld bead can be coated on the plate as to provide a heat input to the plate at the increasing order. Now the plates are kept in the order so that the bead can be formed on the plate at the required place. The working table which moves in both directions can help in putting bead on the plate. In this working table we can fix the table speed as 190 rpm. The welding fixture which can fix the weld gun angle at any angle. TIG Inverter which is attached to the welding torch as negative helps to fix and adjust the current for operating the welding torch. From the current adjusted corresponding voltage also noted.

In this picture we can see that the plates are given heat input by the TIG welding. In this welding fine bead can be arrived and by changing the current levels the specimens are heat input by different combinations.

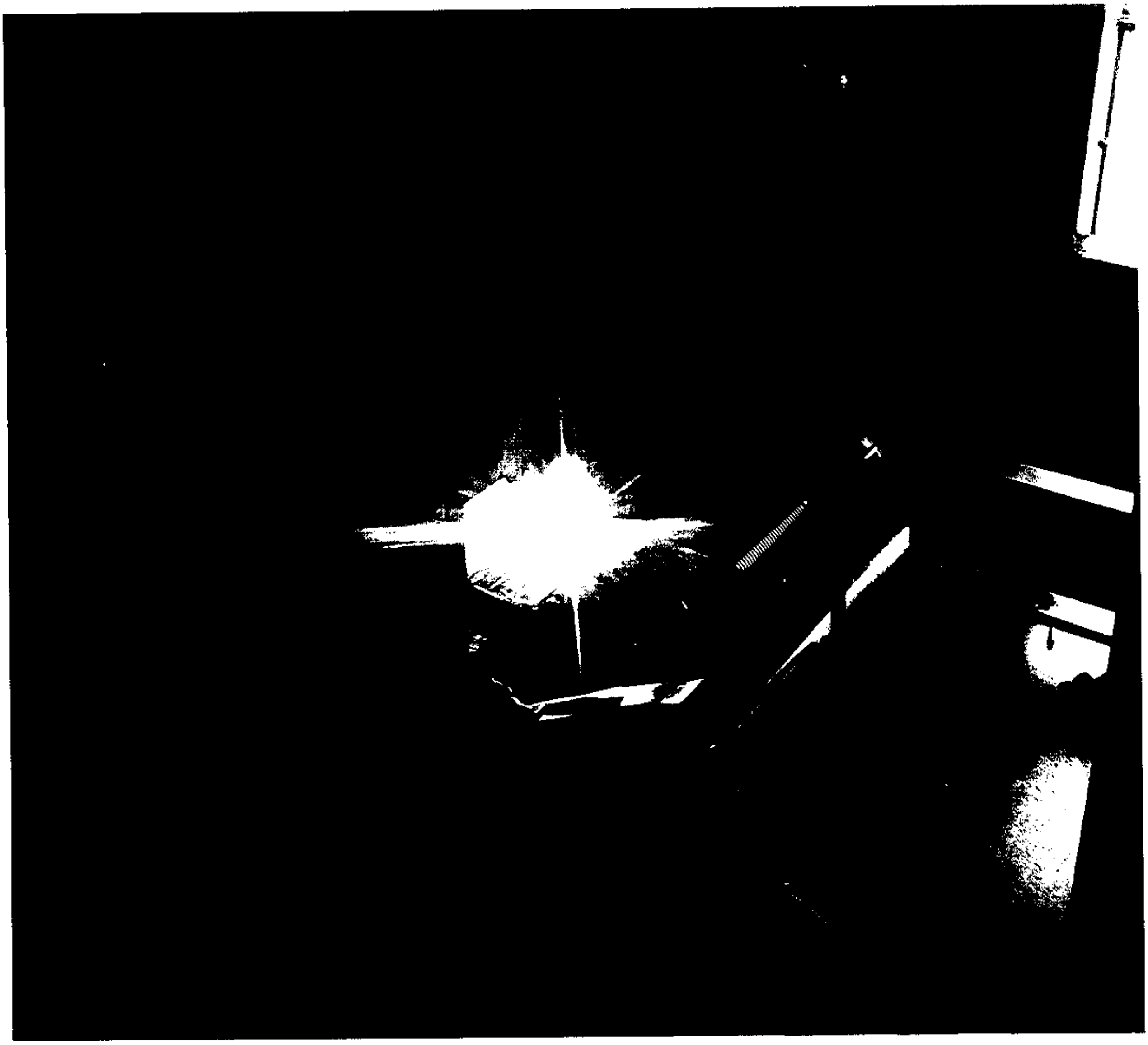


FIGURE 4.3 HEAT INPUT ON PLATES BY WELDING

Here the plates are heat input and it is given by bead on plate method and the specimens are numbered. These plates have penetration on the other side of the plate and this forms the heat affected zone.

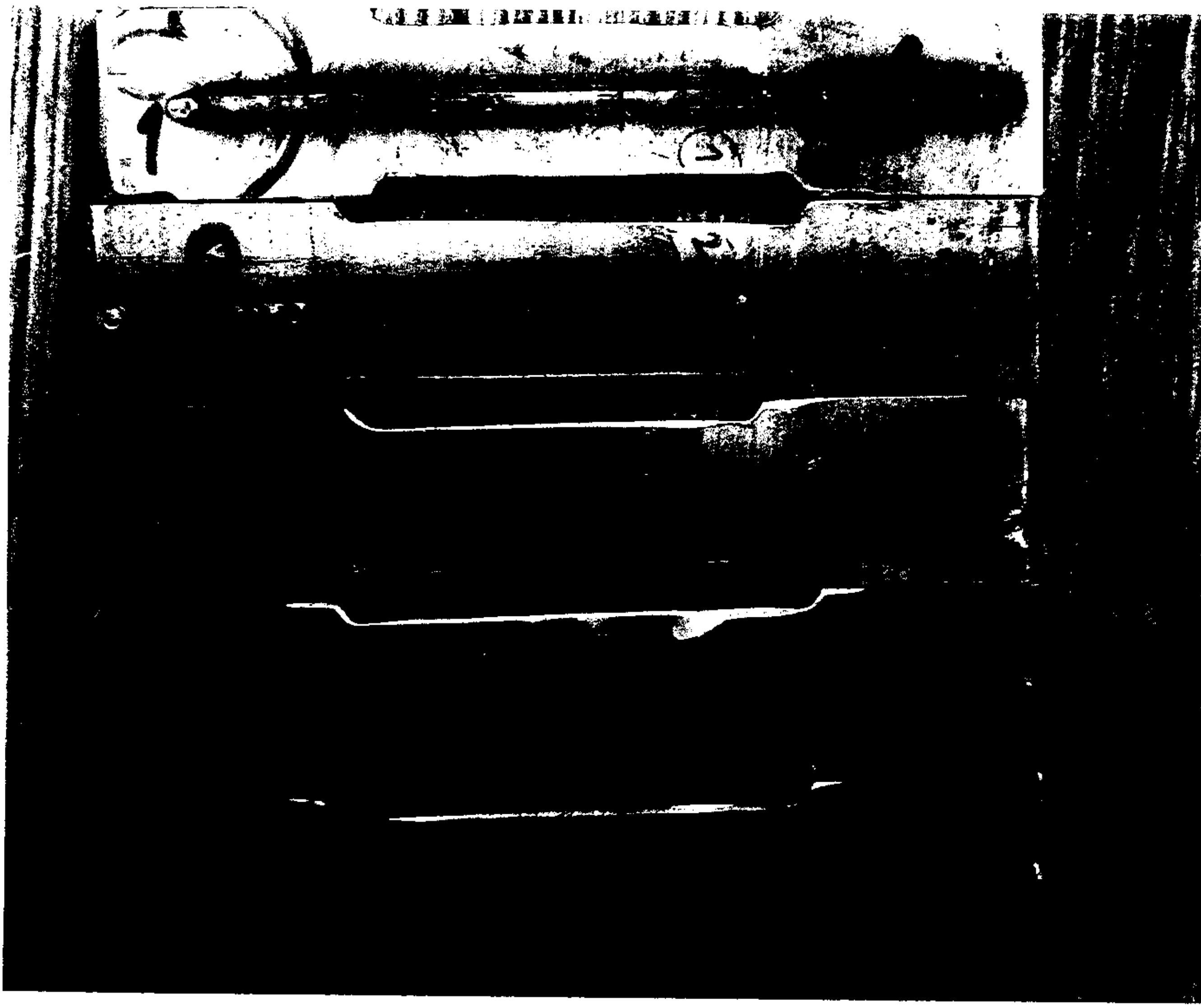


FIGURE 4.4 HEAT INPUT ON PLATES BY BEAD ON PLATE METHOD IN TIG WELDING PROCESS

4.3.2 READING NOTED DURING HEAT INPUT PROCESS

Speed of the table - 190 mm/min.

Gas Flow Rate from the Cylinder - 7.5 Litres per Minute

Weld Gun Angle - 90°

4.3.3 TABULATION FOR TENSILE TEST:

S.NO	CURRENT (AMPERE)	VOLTAGE (VOLTS)	HEAT INPUT (KJ/mm)
1.	70	10.4	728
2.	80	11.6	928
3.	90	13.1	1179
4.	100	13.6	1360
5.	110	14.5	1595

4.4 TENSILE TEST:

Specimens per heat input combinations were machined out from the plate as mentioned in the diagram. The specimens were machined at the required dimensions so that the specimens can be performed in the tensile test.

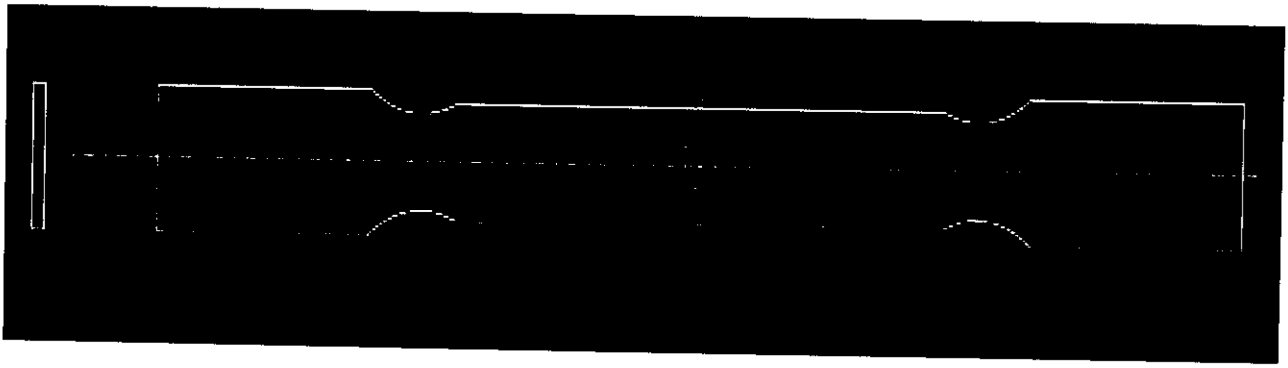
Each tensile specimen size was prepared in accordance with **IS 1608: 2005** as illustrated. The specimens were tested on 400 KN Universal Testing Machine and Electronic Extensometer.

FIGURE 4.5 400 KN Universal Testing Machine and Electronic Extensometer

This machine is provided with the Extensometer such that this extensometer has a dial and pointer and helps to measure the tensile load, yield load and helps to find the elongation of the metal at the various load conditions.

The specimens should be machined as illustrated below in order to perform a tensile test in the machine.

Thickness – 0.5mm to 3mm.



ALL DIMENSIONS ARE IN mm.

FIGURE 4.6 TENSILE TEST SPECIMEN-RECTANGULAR CROSS SECTION

The tensile machine has following specifications

Machine Model	- FUT 40
Capacity	- 400 KN
Range	- 0-40
Accuracy, %	- +or – 1.00
Ambient Temperature	- 34.50°C

The specimens who has undergone tensile test are broken at different areas on the weld region as illustrated in the figure. These specimens after the tensile test the results were taken and it is analyzed with the standard values of the 316 Stainless Steel specimens.

4.5 MICRO HARDNESS TEST:

Micro hardness is also called as Vickers hardness test. First the specimen should be cleaned and polished such that it helps to perform the test successfully. Now the specimens who have to undergone the test should be cut into small pieces which help to perform the other activates easily.

The Vickers (HV) test was developed in England is 1925 and was formally known as the **Diamond Pyramid Hardness (DPH)** test. The Vickers test has two distinct force ranges, micro (10g to 1000g) and macro (1kg to 100kg), to cover all testing requirements. The indenter is the same for both ranges therefore Vickers hardness values are continuous over the total range of hardness for metals (typically HV100 to HV1000). With the exception of test forces below 200g, Vickers values are generally considered test force independent. In other words, if the material tested is uniform, the Vickers values will be the same if tested using a 500g force or a 50kg force. Below 200g, caution must be used when trying to compare results.

4.5.1 Applications:

Because of the wide test force range, the Vickers test can be used on almost any metallic material. The part size is only limited by the testing instrument's capacity.

4.5.2 Advantages:

1. One scale covers the entire hardness range.
2. A wide range of test forces to suit every application.
3. Nondestructive, sample can normally be used.

4.5.3 Disavantages:

1. The main drawback of the Vickers test is the need to optically measure the indent size. This requires that the test point be highly finished to be able to see the indent well enough to make an accurate measurement.
2. Testing can take 30 seconds not counting the sample preparation time.

The specimens should be machined as illustrated below for the Micro hardness test i.e. it is cut into small rectangular pieces which helps in supporting the work in the vice firmly.

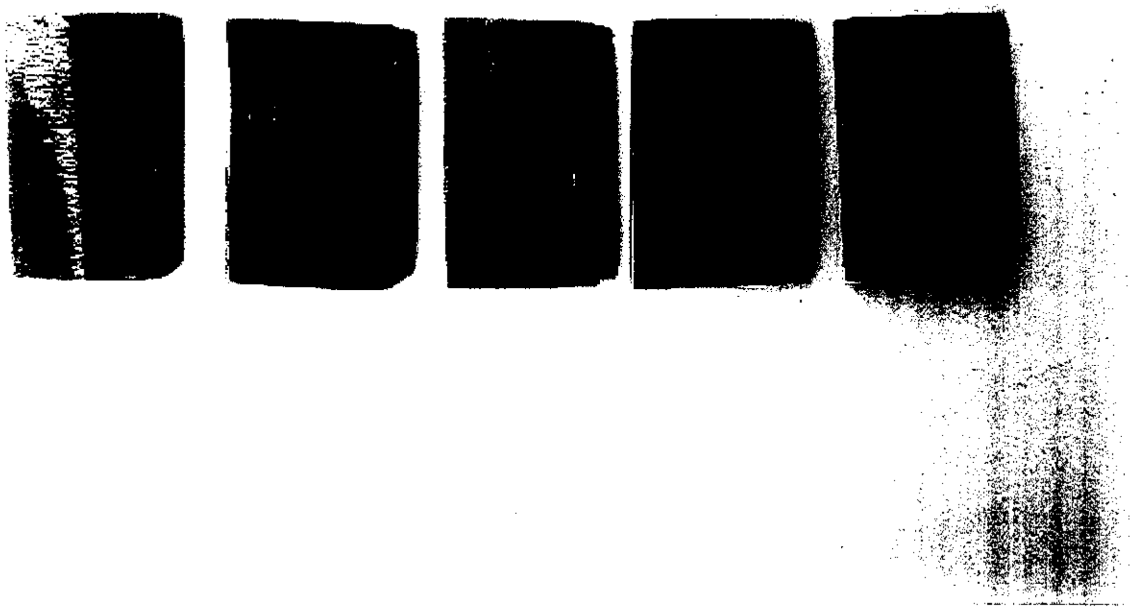


FIGURE 4.7 SPECIMENS WHICH ARE MACHINED FOR VICKERS HARDNESS TEST

4.6 MICROSTRUCTURE STUDIES:

The specimens who have to undergo the micro structure studies have to be prepared, the specimen should be surface finished and polished. First the specimens should be grinded in order to get a smooth surface by surface finish process.

Any classification of the numerous processes used to cut a section, then to prepare the cut surface suitably for metallographic examination, inevitably is arbitrary and arguable. One convenient system, however, is to classify the processes as machining, grinding and abrasion, or polishing. Machining involves the use of tools having cutting edges of controlled shape, as in conventional machine shop practice. Examples are sawing, lathe turning, milling, and filing. These processes normally are used only for the preliminary stages of preparation and do not require particular attention here.

Grinding and abrasion employ an array of fixed abrasive particles whose projecting points act as the cutting tools. In some of these processes, the particles are in effect cemented together into a block whose exposed surface is the working surface. This surface is "dressed" by fracturing the exposed abrasive particles to form an array of sharp points. Examples are abrasive cutoff wheels, grinding wheels, abrasive laps, and abrasive stones. In other processes, a layer of abrasive particles is cemented onto a cloth or paper backing, creating coated abrasive products such as papers, cloths, or belts. In still other processes, the abrasive particles are forced into a flat surface of a comparatively soft material where they are held as an array similar to that in a coated abrasive product. A range of surface speeds may be employed in any of these processes; it is convenient, therefore, to distinguish between grinding and abrasion. The term "grinding" denotes processes that employ high surface speeds with the possibility that significant heating of the surface layers of the specimen may occur. The term "abrasion" refers to processes that use low surface speeds and copious liquid coolant; significant heating of the specimen surface cannot occur.

Polishing uses abrasive particles that are not firmly fixed, but suspended in a liquid among the fibers of a cloth. The objective is to produce a bright mirror like, or secularly reflecting, surface, commonly referred to as a polished surface.

Typical metallographic preparation procedures employ a sequence of machining or grinding stages of increasing fineness, then a sequence of abrasion processes of increasing fineness, followed by a sequence of polishing processes of increasing fineness until the desired surface finish has been achieved. Increasing fineness refers to the use of finer grades of abrasive to produce finer grooves or scratches in the surface. Therefore, metallographic preparation processes employ abrasive particles to remove material and to improve surface finish.

After the specimen is prepared using abrasive papers and polishing machine the specimens should be properly etched in order to get a required microstructures of the 316 SS specimens. The etchant used for the etching process is Marble's Reagent. The preparation of this reagent is stated below.

1. Copper Sulphate 10grams
2. Hydrochloric Acid 50 ml
3. Distilled Water 50 ml

First the copper sulpahte is weighed in weighing machine for accurate measure of 10 grams and taken in a beaker. Then the 50 ml HCL is taken in a separate beaker and then 50 ml distilled water is added to that beaker. Now the copper sulphate is added to the beaker which contains HCL and Distilled water and stirred well. Now the specimens are immersed or swab into the etchant solution, for 10 to 30 seconds. then a sequence of abrasion processes of increasing fineness, followed by a sequence of polishing processes of increasing fineness until the desired surface finish has been achieved. Increasing fineness refers to the use of finer grades of abrasive to produce finer grooves or scratches in the surface. Now the specimens are cleaned and dried and now the specimens can be used for the microstructure studies.

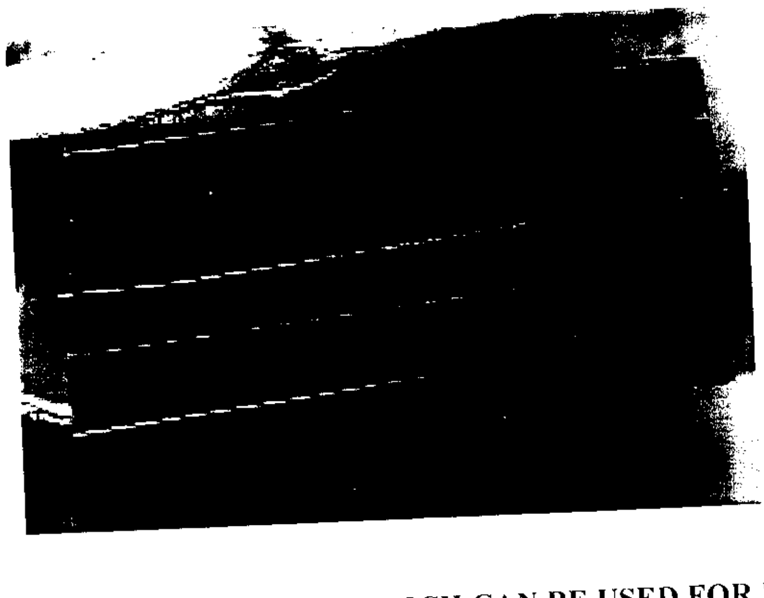


FIGURE 4.8 PREPARED SPECIMENS WHICH CAN BE USED FOR MICROSCOPIC STUDY

5. RESULT AND ANALYSIS:

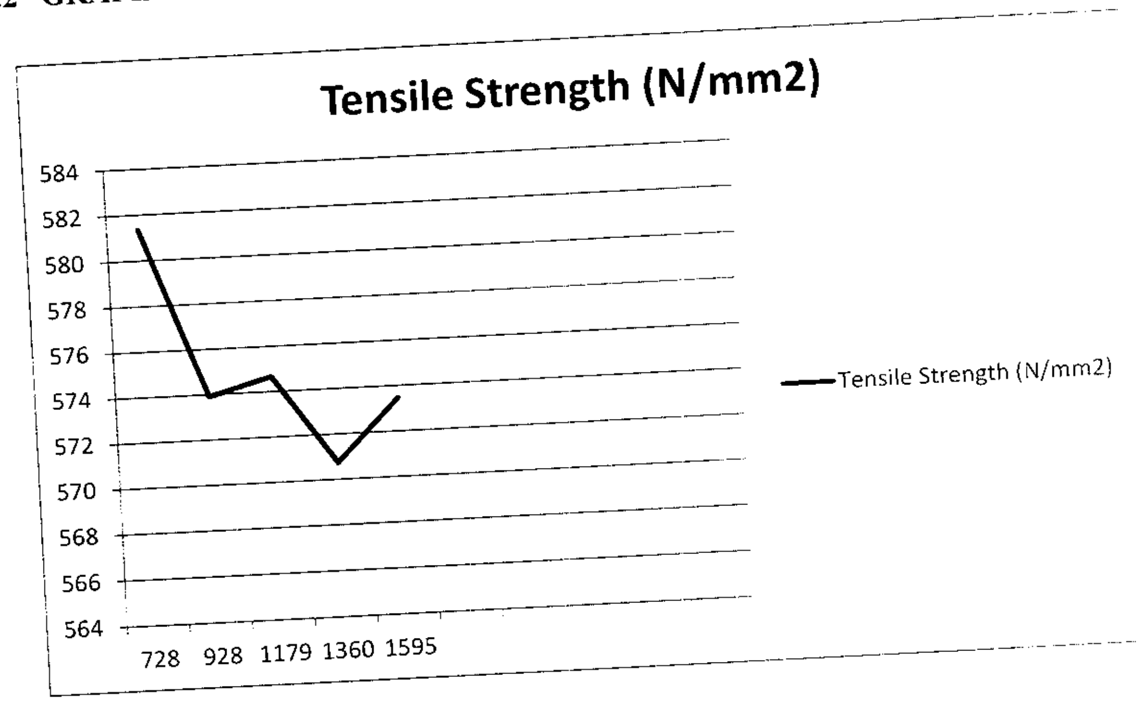
5.1 RESULT OF TENSILE TEST:

The specimens who have undergone the tensile test are illustrated below:

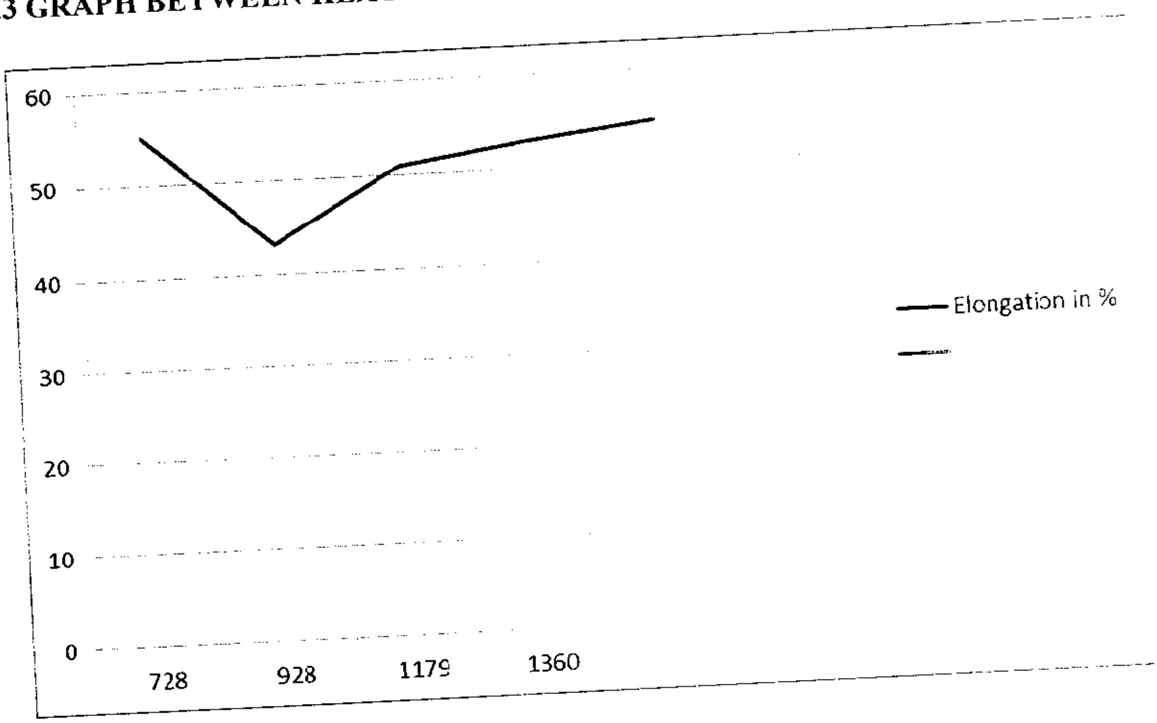
5.1.1 TABULATION:

SPECIMEN NO.	YIELD LOAD N	TENSILE LOAD N	ELONGATION IN LENGTH %	YIELD STRESS N/mm^2	TENSILE STRESS N/mm^2
1.	22400	36480	55.13	351.87	581.35
2.	22400	37120	43.17	346.32	573.90
3.	21760	35600	51.01	351.25	574.66
4.	22640	37040	53.01	348.84	570.72
5.	21920	36880	54.53	340.85	573.47

5.1.2 GRAPH DRAWN BETWEEN HEAT INPUT AND TENSILE STRENGTH



5.1.3 GRAPH BETWEEN HEAT INPUT AND ELONGATION



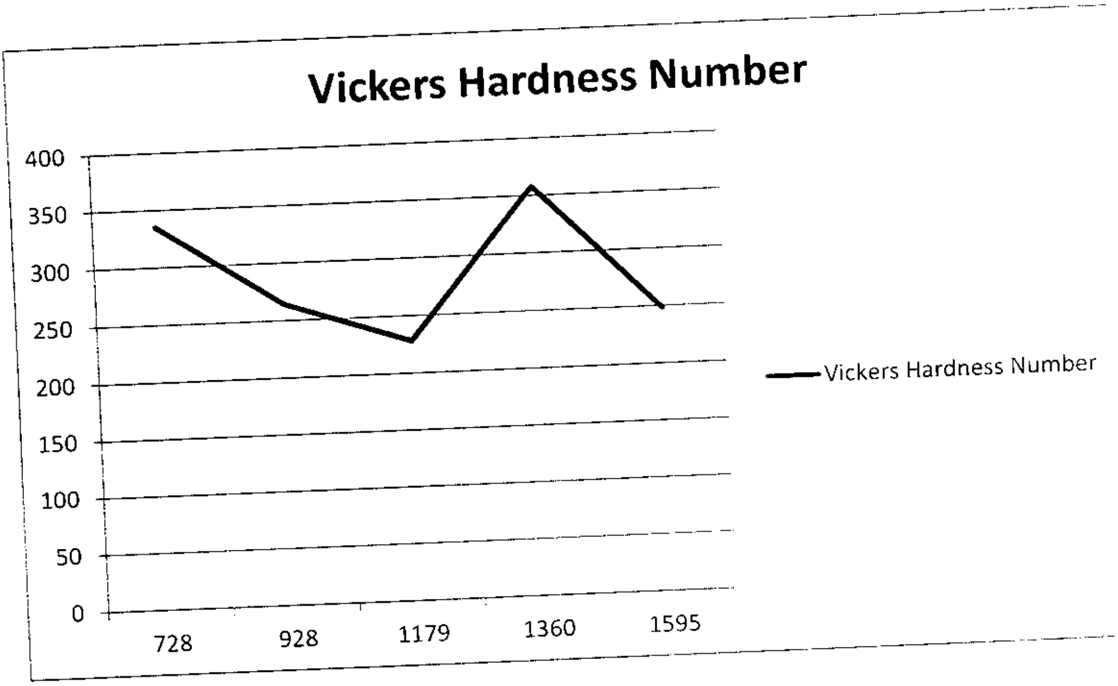
5.2 RESULT OF THE MICRO HARDNESS TEST:

The specimens who have undergone the MICRO HARDNESS test are illustrated below:

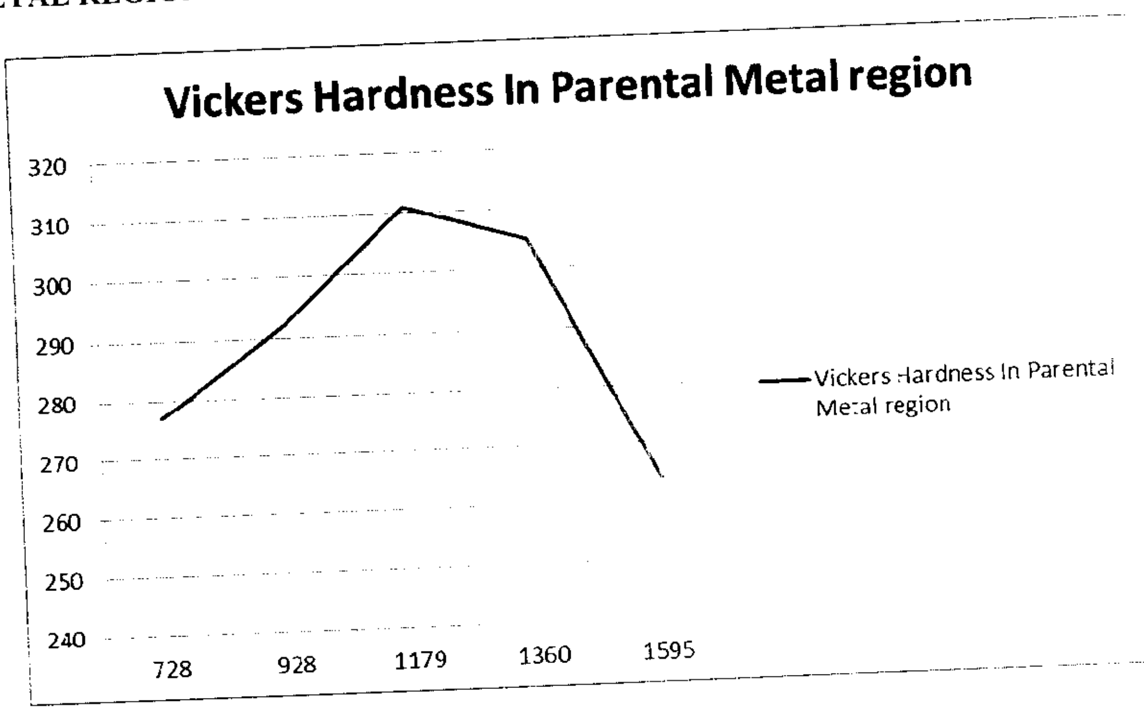
5.2.1 TABULATION:

SAMPLE NO	WELD METAL VHN	PARENTAL METAL VHN
1	335	277
2	264	292
3	228	311
4	358	305
5	248	264

5.2.2 GRAPH BETWEEN HEAT INPUT AND VICKERS HARDNESS IN WELD METAL REGION



5.2.3 GRAPH BETWEEN HEAT INPUT AND VICKERS HARDNESS IN PARENTAL METAL REGION

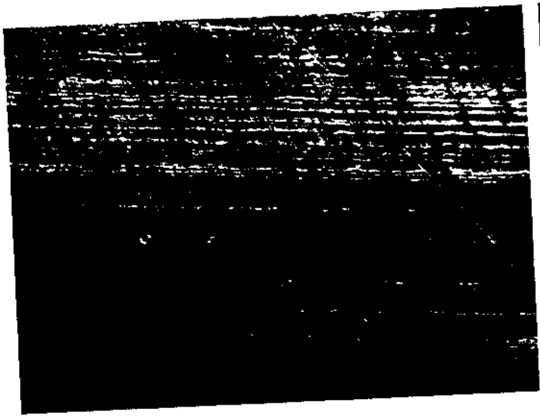


5.3 RESULTS OF THE MICROSTRUCTURE STUDY:

The specimens who have undergone the MICRO STRUCTURE are illustrated below:

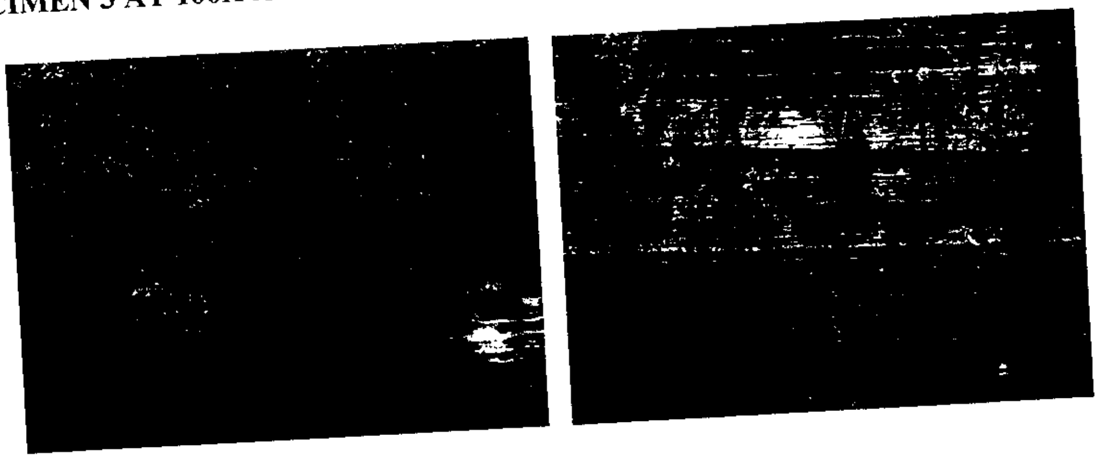
5.3.1 PARENTAL IMAGES OF THE SPECIMENS:

SPECIMEN 1 AT 100X AND 200X:

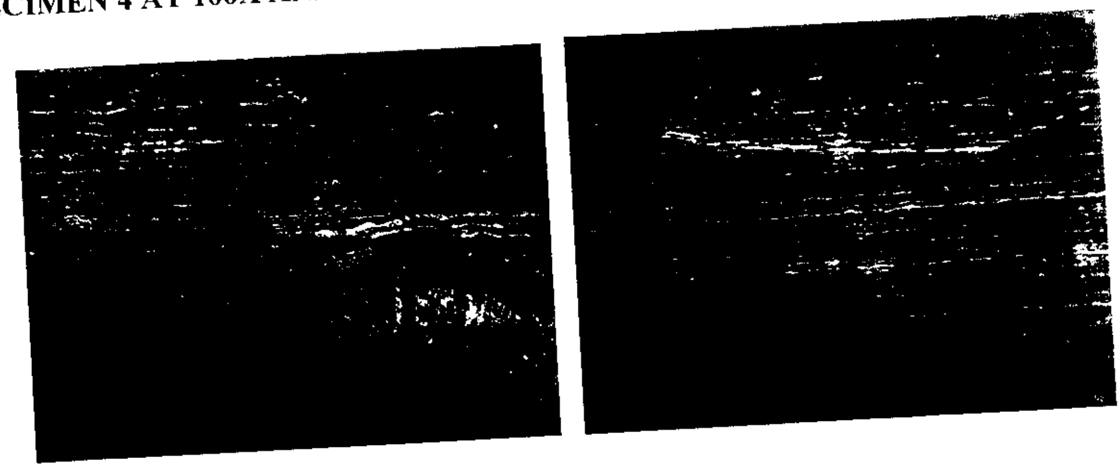


SPECIMEN 2 AT 100X AND 200X:

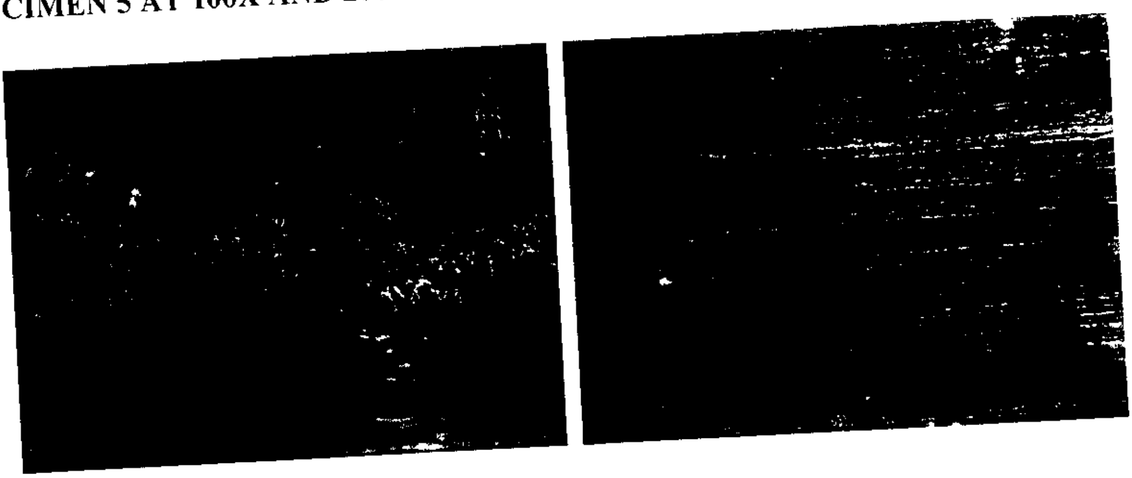
SPECIMEN 3 AT 100X AND 200X:



SPECIMEN 4 AT 100X AND 200X:

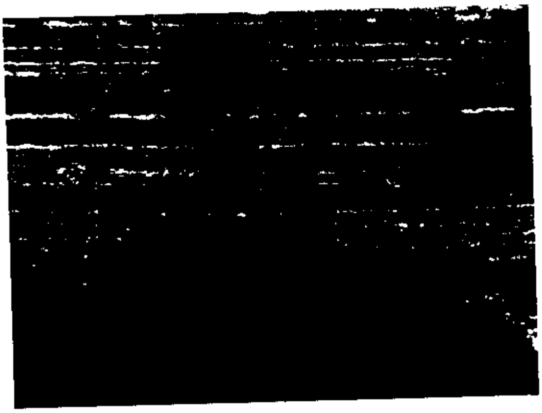


SPECIMEN 5 AT 100X AND 200X:



5.3.2WELD IMAGE OF THE SPECIMEN:

SPECIMEN 1 AT 100X AND 200X:



SPECIMEN 2 AT 100X AND 200X:

SPECIMEN 3 AT 100X AND 200X:

SPECIMEN 4 AT 100X AND 200X:

SPECIMEN 5 AT 100X AND 200X:

6. CONCLUSION AND FUTURE DEVELOPMENT

6.1 CONCLUSION:

6.1.1 TENSILE TEST:

The transverse tensile strength of all beads made using different heat input conditions has been evaluated. In each condition five specimens were tested and the corresponding percentage elongation thus obtained as mentioned. The tensile test result so obtained show that maximum tensile strength of 581.35 N/mm^2 is possessed by the specimen made using low heat input combination followed by tensile strength of 573.47 N/mm^2 is possessed by the specimen made using high heat input combinations. Inference obtained from the results is that in normal condition the tensile strength is found to be 515 N/mm^2 and in heat input condition the tensile strength is 581.35 N/mm^2.

6.1.2 VICKERS HARDNESS TEST:

The hardness strength of all beads made using different heat input conditions has been evaluated. In each condition five specimens were tested and the corresponding Vickers hardness number (VHN) is found. The tensile result so obtained is that minimum hardness is found as 256 VHN for metal which has the heat input of 1595 KJ/mm and the maximum hardness number of 311 VNH for metal which has the heat input of 1179 KJ/mm at the weld bead part. Inference obtained from the results is that in normal condition the Vickers hardness number is 225 VHN and in the heat input condition the Vickers hardness test is 311 VHN.

6.1.3 MICROSTRUCTURE OF 316 SS:

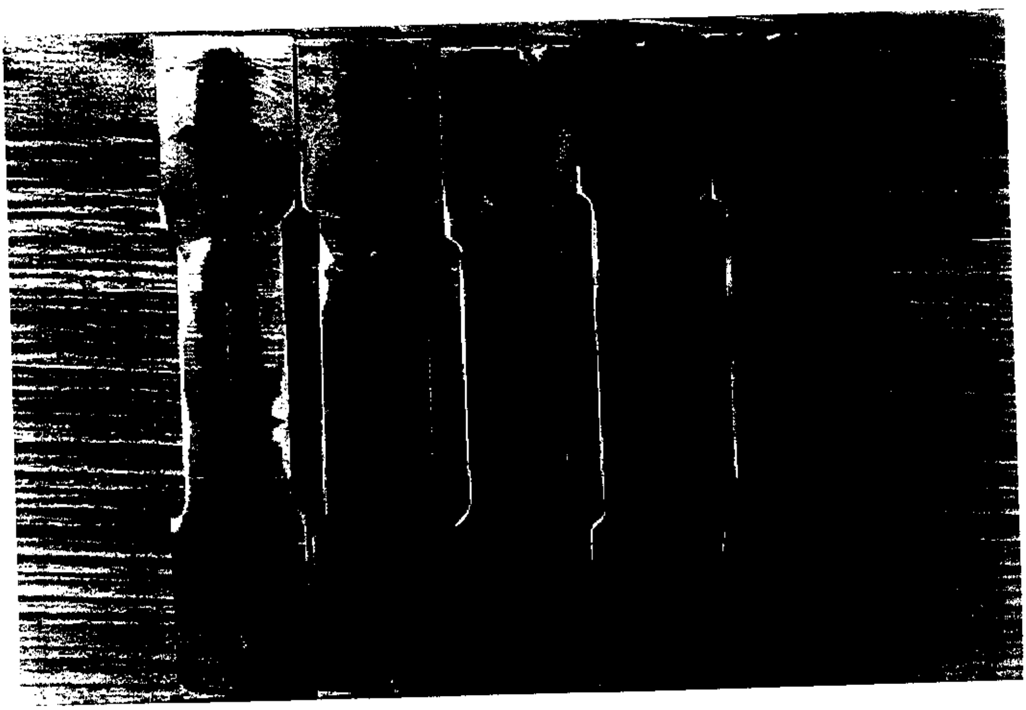
The microstructures of five specimens are taken in both 100 x and 200 x. These microstructure are studied and the results are analyzed. The inference from microstructure is Low heat input→ high cooling rat→ fine grain size→ good mechanical properties.

High heat input→ low cooling rate→ coarse grain size→poor mechanical properties.

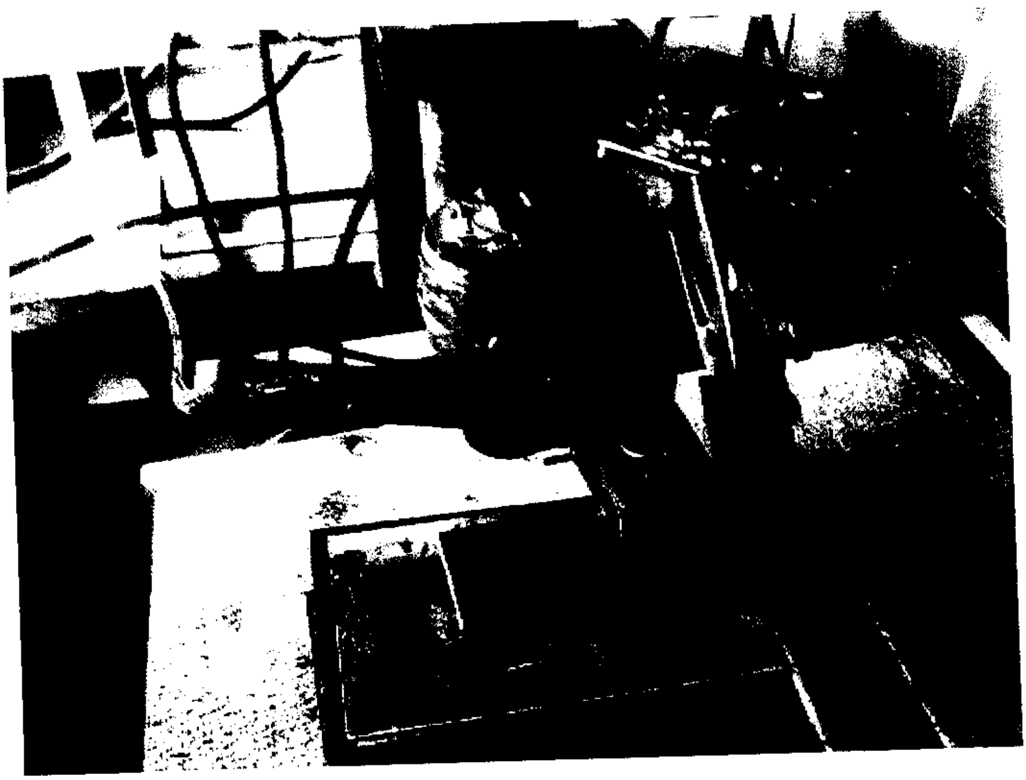
6.2 FUTURE DEVELOPMENT:

- This method can be used to reveal the fractographic images of the metal using Scanning Electron Microscopic.
- Moreover this method can be used the microstructure of the metal using SEM.
- Using this method we can also analysis the compression strength, ultimate strength, break point of the material when the metal is heated.
- Using this method we can also analysis the Rockwell hardness number, Brinell hardness number of the material when the heat input is given.

7. PHOTOGRAPHY:




INVERTEC V350 PRO
LINCOLN
ELECTRIC



8. REFERENCES

- Journal paper from the science direct entitled " **Effect of heat input on the microstructure and the mechanical properties of gas tungsten arc welded AISI 304 stainless steel joints**" author by 'Subodh Kumar, A.S. Shahi'

- Reference taken from book entitled "**Welding Technology**" author O.P.Khanna

- Metalloagraphic and Microstructure studies from the **"Metallographic and Microstructures 2004"** by ASM HAND BOOK.