EXPERIMENTAL STUDIES OF EFFECT OF HEAT INPUT AND FILLER COMPOSITION ON MECHANICAL PROPERTIES OF (GTAW) WELDED AISI-202 STAINLESS STEEL JOINTS

DISSERTATION-II

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By

(Arun Kapoor)

Under the Guidance of

Mr.AbhishekAbrol
UID-16929

LOVELY PROFESSIONAL UNIVERSITY

PHAGWARA (DISTT. KAPURTHALA), PUNJAB

(School of Mechanical and Manufacturing Engineering)
Lovely Professional University Punjab

CERTIFICATE

This is to certify that the Thesis "Experimental Studies of effect of heat input and filler composition on mechanical properties of (GTAW) Welded AISI 202 (SS) Joints" that is being submitted by "***Arunkapoor***" is in partial fulfillment of the requirements for the award of Master of Technology Degree , is a record of bonafide work done under my /our guidance. The contents of this Thesis, in full or in parts, have neither been taken from any other source nor have been submitted to any other Institute or University for award of any degree or diploma and the same is certified.

Supervisor

Mr. Abhishek Abrol

(Uid -16929)

(Lovely Professional University)

(Organization stamp)

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Student name -Arun Kapoor

Registration No. 11000354

ABSTRACT

Experimental investigations were carried out to study the influence of filler wire and heat input on mechanical properties of GTAW welding AISI 202 joints. We use butt weld 6mm thickness of the plate. The process was applied to different specimens in which we vary the heat input (ie low and high heat input)and we use 308L filler wire and 110 ampere current to fabricate a joint .similarly the another welded specimen is prepared by using 316L filler wire with 110ampere current. For high heat input we use 150 ampere current and two different fillers i.e. 308L and 316L. The groove angle that we use for our base plate is 60.Then four different welded specimens were under go to the mechanical testing and metallurgical studies. Mechanical testing includes tensile test and Charpy v-notch test and then co-relating with metallurgical studies .The results shows that all the welded specimens has greater tensile strength then base material. The specimen welded at low heat input with 316L filler wire possess maximum tensile strength and elongation also the maximum impact strength. The micro hardness results shows that specimens welded at low heat input has maximum hardness at weld zone and HAZ as compared to the high heat input .because of the faster cooling rate in the low heat input the micro structural study by optical microscope indicates that the specimen welded at high heat input has coarse grain structure and formation of dendrites but low heat specimens has fine structure and faster cooling rates therefore these specimens posses the better mechanical properties.

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CHAPTER 1

INTRODUCTION

Welding is the main process for the joining of similar and dissimilar materials. It is a permanent joining process..Welding process required heat and pressure for the joining of different materials. Welding is used for joining the large number of metals and alloys. Further, Welding is used for the joining of materials like thermoplastics. Heat is the most essential requirement in welding in order to join two or more work pieces. The welding processes can be classified into six classes on the basis of heat generation and applications [1]. Different major categories of welding are arc welding processes, resistance welding processes, solid-state welding processes, radiant energy welding processes , thermit welding processes and oxyfuel–fuel gas welding processes. The most common welding used in manufacturing industries is basically an arc welding process. The electric arc is generally produced between electrode and workpiece which aids the welding of metals. Occurrence of fusion takes place at the edges of the base metal during the welding of the metal with the help of arc welding process that's why it is known as fusion welding process .the weld is formed due to the fusion of base material so this process called as fusion welding process. The Fusion welding may or may not require the addition of filler metal to perform the welding operation and this welding process also does not require any pressure. The weld produced without adding any filler metal is known as autogenous weld. But mostly fusion welding is performed with the help of filler wire. There is a generation of an electric arc between base material and electrode which is a main source of heat to be produced to cause a fusion and to produce weld joint in an arc welding. The electric arc generated is the major as well as single source of welding heat .The temp of electric arc used is very much high and its is about 5000(°C) the properties of weld metal get changes as there is increase or decrease in heat provided to weld the base metal. Moreover metallurgical as well as mechanical properties depend on cooling rate allowed to the welded plates. The strength and toughness are most required weld metal properties. The welding performed at low heat and high heat must have a difference in its mechanical properties. Because low heat input produces a less chances of defects to occur as compare to high heat input. Generally it can be seen via microstructure that low heat causes a formation of fine grains structure and ultimately has higher mechanical properties like tensile strength. But in high heat input there is grain coarsening occurs and has slower cooling rates as compare to low heat therefore there is drastic decrease in mechanical properties. Mechanical properties will become better for the weld metal if the microstructure of a weld metal consist finer grains that lead to create large grain boundary that can restricts the movement of dislocations from its position. Ultimately the mechanical properties get enhanced and get improved.

The fine grain microstructure of weld joint produced offers the following advantages.-

1) It leads to decrease the occurrence of cracking of weld metal.
2) Mechanical properties like tensile strength and impact strength of welded joints get improved or enhanced with the production of fine grains in a microstructure that mainly depends on the heat input to be used.

Basically as welding performed on any base metal heat input plays an important role in the formation of fine grains. Because as a heat input increases more then it will cause the more melting of a base metal and difference in temperature between the electrode and work piece will create a thermal expansion and contraction of the welded plates and leads to create a defects like distortion , porosity and cracks. During high heat grain formation become coarse and time allows for cooling become much slower but during low heat input fine grains occurs in microstructure due to rapid cooling and also there is less chances of shrinkage and distortion to be occurred. As solidification takes place after a welding the nucleation get proceeds and lead to increase the further growth of a nucleus as its growth increases there is also much changes to occur in the microstructure. The nucleus growth is proportional to the occurrence of finer grains.

1.1 Solidification process during welding

The solidification process starts at the formation of the weld zone which is formed due to the melting of a base material with or without a filler wire. During the welding process there is change in temperature from the weld zone to the HAZ and most unaffected area is a base metal which does not get affected and remains the same but HAZ is most affected area and undergo the micro structural changes. Molten metal get solidifies as its temperature reaches near to the liquid temperature. Ultimately we can say that in high heat input the cooling rate is slower and it takes much time to reach the liquid temperature as compare to the low heat input. As solidification takes place after a welding the nucleation get proceeds and lead to increase the further growth of a nucleus as its growth increases there is also much changes to occur in the microstructure as the nucleus growth increases the size of the grains become smaller and smaller and in other words we can say grains become more fine.

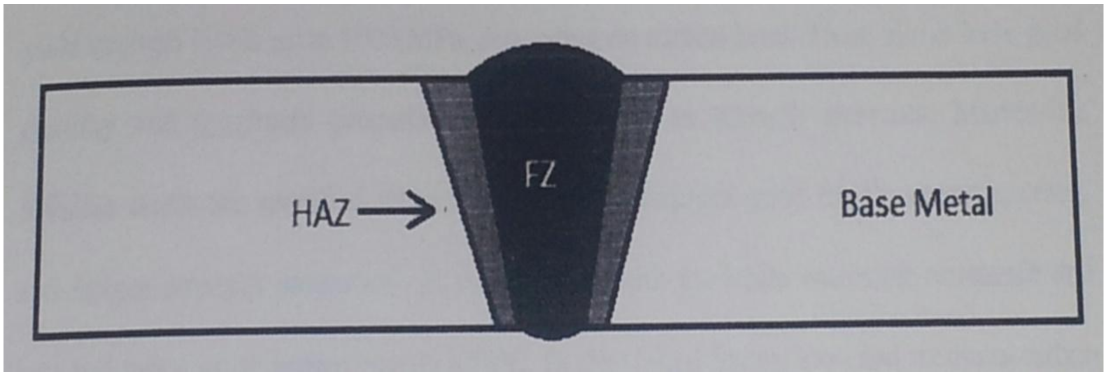


Fig 1.1 block diagram of the weld zone

1.2 Base material

AISI 202 Stainless steel isa austenitic standard, its common name is (chromium–manganese nickel steel). AISI 202(SS) has a similar mechanical properties as compare to AISI 304(SS) grade, but 202(SS) grade has the ability to resist to corrosion is less and compare with 304(SS) grade in chloride environment. This stainless steel is not so expensive and used in door application like indoor fabrication, automobile trim, other application where atmosphere is not considerable factor. In the AISI 202 (SS) has less percentage of nickel content as compare to 300 series of austenite stainless steels. The presence of nickel makes the material more expensive, so therefore lesser amount of nickel present in the AISI 202 (SS) makes it inexpensive as compare to other material but posses same mechanical properties comparable to other .The chemical composition of 202(SS) grade are 0.15 wt % C, 7.5-10.0 wt% Mn, 10 wt% Si, 17-19 wt% Cr, 4.0-6.0 wt% Ni , 0.06 wt% P, 0.03 wt% S, 0.25 wt% N. some of the features of 202 (SS) grades are non magnetic in nature . High carbon may cause stress corrosion cracking, especially after welding thicker material. They have corrosion resistance similar to 430 Grade but not good as 300 series.

Applications of AISI 202 (SS) are

1) Used for making furniture and cook wares.
2) Used for making window channel spacers and safety shoes.
3) Used for making hose clamps and trailer frames.
4) Used in industrial strapping and railway rolling stock.

The AISI 200 series steels are nitrogen strengthened and are commonly referred as nitronic steels. This grade contains high levels of carbon, manganese and nitrogen and is used in specialty applications such as where galling resistance is required.

They also have low nickel content than 300 series to balance high carbon and nitrogen levels. AISI202 grade stainless steel is formulated and thermo mechanically processed such that the microstructure is primarily austenite. Depending on the balance of ferrite promoting to austenite promoting elements the cast microstructure will be either fully austenite or a mixture of austenite and ferrite. The microstructure of fusion zone of 202 grade stainless steel is dependent both on the solidification behavior and subsequent solid state transformations after welding. During GTAW process, the formations of coarse grains and inter granular chromium rich carbides along the grain boundaries in the heat affected zone deteriorates the mechanical properties.

1.3 PROCESS USED

1.3.1 Gas tungsten arc welding process

GTAW welding process is widely used and very popular among manufacturing industries for welding of the stainless steel. In this process an electric arc plays a crucial role in melting as well as joining base material .Because an electric arc creates a heat that cause coalescence. The point of generation of an electric arc is between non consumable tungsten electrode and base material. In this arc welding process there is basically a torch which helps to hold or retain the electrode in its position which is non-consumable and also it is further connected to the shielding gas most commonly gas used is argon. This non-consumable electrode connected to torch is further connected to the power source. In this process basically the tungsten electrode always be in contact with the water cooled tube so to protect the electrode from occurrence of overheat because as current get flows continuously from electrode there is a large heat may generates, so we use a water cooled tube to protect overheating basically a one terminal of power source is connected to electrode into heat which a current passes that results into a formation of a heat. With the use of another cable wire the work piece is connected to the second terminal of power source. In GTAW welding there is shielding gas needed at time of welding in order to protect weld pool from the contact of the air. This shielding gas generates in a torch body and then it flows to nozzle which further supplies shielding gases to the welding portion. GTAW refers to be the best method in order to protect welding portion from the air contact. Commonly used gas includes argon and helium.

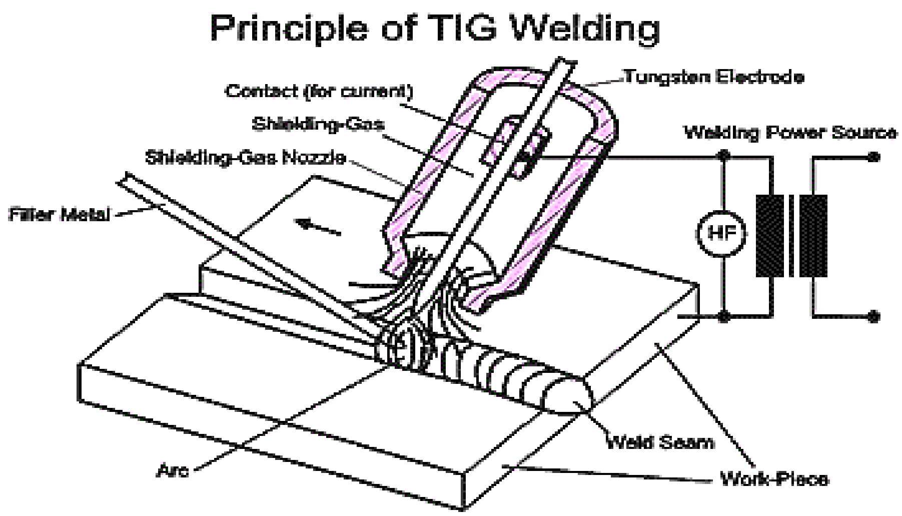


Fig 1.2 Schematic showing key components of the GTAW Process.[2]

1.3.2 Applications

GTAW process offers a wide range of application for welding several different materials like stainless steel, aluminum and magnesium etc. The industries which require essentially to join some alloy steel as well as carbon steel can use this welding technique and can get a satisfactory results. The requirements like pipe welding can be easily be possible via using this process.TIG welding is suitable and widely applied for welding of a materials where the thickness undergo the variation small, medium and large.

1.3.3 Advantages of GTAW

A) This process is free from spatter as compared with other welding processes

B) This process produces a high-quality and low distortion welds.

C) GTAW process has a precise control on welding heat.

D) Wide range of power supplies can be used by this process.

E) This process can be used with or without the addition of filler wire.

F) All metals including dissimilar ones can be welded by this process.

1.3.4 Limitations of GTAW

A) The major drawback is that it produces lower deposition rates than other consumable electrode arc welding process.

B) There is occurrence of some disturbance during to provide the shielding properly because of the effect of daftly environment.

C) With the increase in the thickness of base metal above 10mm this process become inefficient and cannot be economically preferred.

D) This process require slightly more concentration, high skill and welder coordination than other arc welding process.

1.3.5Additional problems with this process

A) This process has low tolerance level for contaminants on filler and base metals.

B) Formation of contamination or porosity caused by the coolant leakage from water- cooled torches.

C) Contamination of weld metal, if proper shielding of the filler metal by the gas stream is not maintained

D) Another problem of this process is Arc blow or arc deflection as compared with other processes.

E) If the electrode is allowed to contact the weld pool, then tungsten inclusion takes place

1.3.6 Torch construction

The tungsten electrode which is non consumable in nature is get hold by welding torch that transfer the current from the power source to the arc and also a mode of shielding provided to the welding portion so to protect it from the contact of air. The major components of a welding torch are describes as follows Fig 1.3

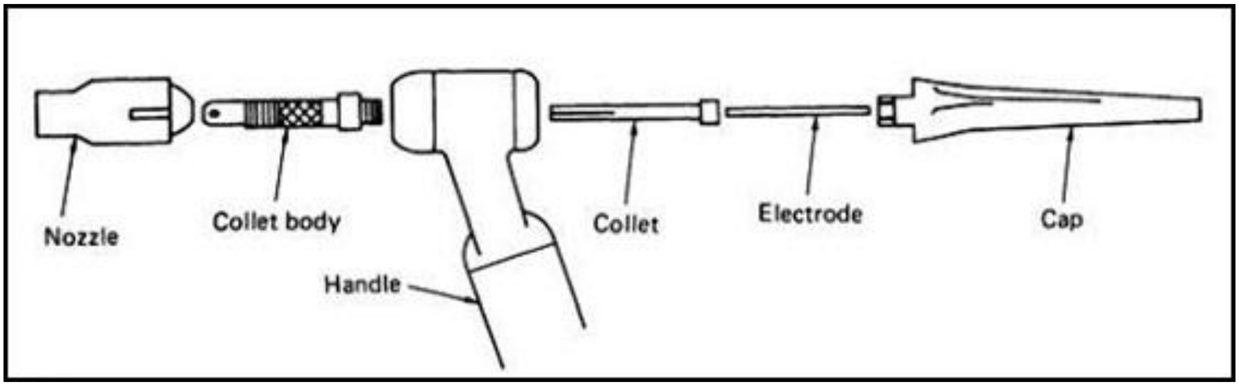


Fig 1.3: schematic showing exploded view of key components comprising a GTAW manual torch. [2]

Welding torches that are widely to be used are normally less than 200 Ampere are the gas cooled .The torches which are used for regular operation or the torches which suffers very high current are basically the water cooled and are used in automatic welding. There is tank which re-circulates the cooling water with the help of a radiator and direct it towards the direction of welding torch. The main purpose of doing is to reduce an excess of heat in the torch. The most commonly non consumable electrode that are preferred while doing GTAW process are tungsten . In GTAW process the highly used electrode used is somewhat consist of alloy i.e. made of 2.5% of Tho2-W alloy. The reason behind use of this alloy is that it shows stability very much higher. The electrodes should be handled with much care during sharpening process using thoria which is generally a Radiaoactive in nature .The different electrodes which consist of tungsten are namely the yttriated and Lanthaniated can be operated and starts at very low value of a voltage. As we compare different tungsten electrode on the basis of arc initiation as well as rate of melting ceriated tungsten performs better and posses slightly much greater arc initiation values as compare to the thoriated electrodes. AC welding can be performed by using only a pure tungsten electrode but in direct current welding it actually does not happen.

1.4 PROCESS PARAMETERS

1.4.1 Welding current

What is a current. It is one of a parameter in the welding process that may influence on other welding parameters .more the value of current used while doing welding operation it will cause to create more deep penetration and also has its adverse effects on the weld quality to be produced .in order to achieve required values of strength in mechanical properties and fine microstructure it must be controlled so generally in simple words current is major source during welding operation to create a heat that causes a base metal to melt and then solidifies. If we talk about the current it may be categorized into the following categories.

a) The first major category in which the current is divided is direct current electrode negative in which there is flow of current takes place from the electrode toward the work piece.
b) The second main category is that in which current flows in opposite direction from the previous case. ie from the work piece toward the electrode called as direct current electrode positive.
c) In Alternating current arc get extinguish itself as current reaches zero point before it reverses the direction because AC is combination of both DCEN and DCEP and performs the cleaning action as removal of oxide film. As fast there is occurrence of change of polarity it results into advantage and can be helpful for cathode in removing oxide layer specially welding of materials such as magnesium and aluminum. So we can say that AC is best suitable for magnesium and aluminum.. AC is combination of two polarities ie straight and reversed polarity. Simultaneously occurrence of two polarities there is arc get extinguished but during reverse direction there may be formation of high heat and it may reduces the efficiency of electrode to some extent. In GTAW process we commonly use and prefer a DC current in which we prefer a straight polarity which causes maximum melting and heat to base metal. The use of reverse polarity may be restricted due to some reason that it does not results into a proper melting of base metal because above 74% of heat get transferred to electrode

1.4.2 Voltage

It is also major welding parameter. Due to presence of voltage there is generation of force that results into flow of current takes place. It is measured in units called as volt. In General calculation of heat input during welding process. Heat input is equals to the product of voltage and current to the welding speed so as increase in voltage causes to increase current values and thereby increasing the heat input. so this parameter must be maintained in such a way that voltage, current and speed of welding supplied to the work piece or base metal may increase the mechanical strength of welded joints.

1.4.3 Travel speed

We can calculate the welding speed by dividing the distance or the length of the plate while welding to the time taken in seconds during the welding operation .In this way we can calculate that at which rate does the welding electrode proceeds. Welding speed can be measured in mm/min. we can understand the basic phenomenon of welding speed that if the welder takes much time for welding operation to be carried out then slower will be its welding speed and much greater is our heat input to be generated. It can be indicated by the symbol (S) which basically represents the welding speed.

1.4.4 Effect of heat input

From the above discussion it is understood that heat input occurred during arc welding process such as GTAW process is only cause to melt the work piece . Electric arc generated can produce an heat on the weld pool surface .Heat input is a combination of current voltage and speed when these parameters are measured during welding operation then we can calculate heat input by putting the values in a formula which is discussed as below. The welded specimen fabricated a very high input parameters would results into weaker mechanical properties .because it lead to create a shrinkage ,distortion and high residual stresses because of contraction and expansion between low temperature base metal and high temperature of a heat source

a) Distortion and warpage occurs due to high residual differential shrinkage stresses.
b) The reduction of ductility or a degree of hardening is a root cause for the occurrence of cracks

Heat input (KJ/mm) = voltage .current /speed

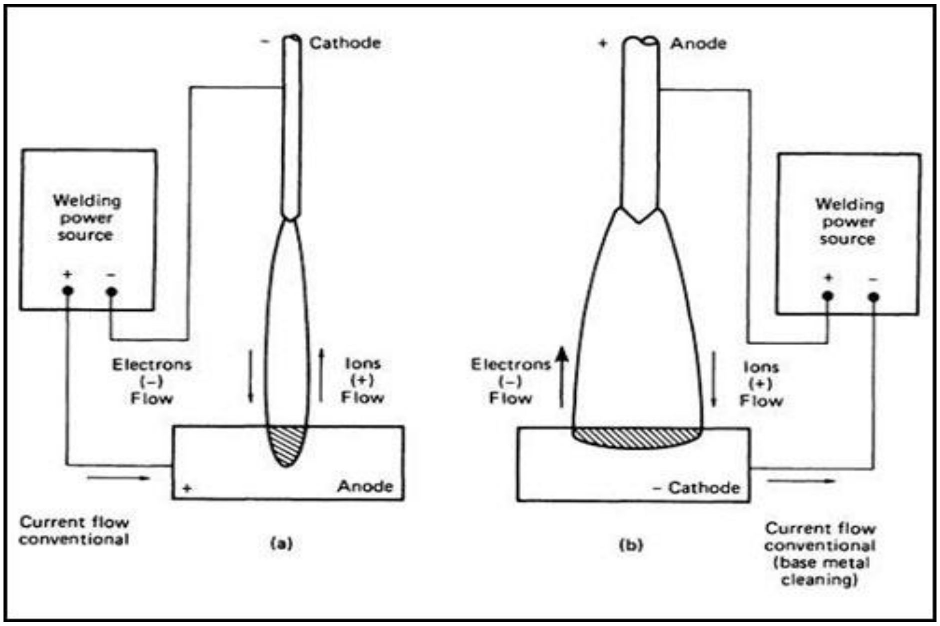


Fig 1.4: Depicts the effect of straight polarity and reverse polarity on the GTAW weld a) shows that during straight polarity causes deep penetration b) where as during reverse polarity causes shallow penetration [2]

After the study of this chapter it is concluded that AISI 202 SS is less expensive then 300 series of stainless steel but posses almost similar mechanical properties and can be used in Indoor application because of less tendency of corrosion resistance .Due to very small amount of nickel content present in the AISI 202 SS that makes it inexpensive. Also it is studied that GTAW welding is used in all manufacturing industries because it produces good quality of weld, with or without the filler wire ,no production of spatter and best for welding stainless steel. There are less chances of production of welding distortion in GTAW welding. GTAW welding is much better than MIG welding which produces low quality of weld with distortion and spatter. Welding parameters such as current, voltage and speed has direct impact on the welding base metal. Higher will be the current and voltage results into the maximum application of heat input to the workpiece and maximum melting of a workpiece. Welding speed is inversely proportional to the heat input. When GTAW Welding is used with direct current there are two polarities 1) DCEN 2) DCEP . In DCEN There is deep penetration and narrow melted area. But in DCEP there is shallow penetration and wide melted area.

CHAPTER 2

LITERATURE REVIEW

After deep study of the literature for the purpose of evaluating a research gap in a particular field provides the information that our work has yet not been performed and it is totally new and beneficial for the industrial view .This present work is not repeated and any wastage of money and my objectives of this work is totally beneficial and can be used for the manufacturing industries where such welding of these materials are carried out..

Vivekkumar Sharma and MunishKainth [3][2014] Investigated effect of auxiliary mechanical vibrations on the mechanical properties and metallurgical properties of AISI 202 SS. The study was done in such a way so that to investigate the effect of auxiliary vibratory set up on the mechanical properties of 8mm thick stainless steel (AISI 202) butt joint. Bad bead profile has a significant effect on the performance of weld. One pass of a multi-pass welding has a bad bead profile that can lead to incomplete fusion or slag inclusions, either the subsequent weld assess will partially re-melt the first pass. The auxiliary vibration setup produced the disturbance in weld pool during solidification. So After the completion of nucleation the solidification process will continue as the nucleus growth. The tensile strength of weld joint which was fabricated under vibratory condition was considerably very high. From this study it was concluded that Tensile strength of the material AISI 202 (SS) under the vibration welding is about 4.28% more as compared to the tensile strength of same material which do not undergo vibration during SMAW.

Sudhakaran .R Siva Sakthivel P. S Nagaraja S [4] [2014] Investigated the effect of welding speed on microstructure of chromium manganese stainless steel (AISI 202 SS)Gas tungsten arc welded plates This metallographic study focus only on the grain structure, presence of carbides and formation of ferrite, austenite and martensite that are present in the weldment. The obtained results from this study helps in selecting appropriate and real required process parameters to achieve the finest weld quality. From the above study it was concluded that when the welding speed is maintained at a lower level up to 170 mm/min coarse grain structure was observed in the heat affected zone and there is a significant transformation of austenite into tempered martensite with a very small portion of ferrite present in the microstructure in the weld metal zone .but if the welding speed is maintained at a higher level of 210 mm/min, fine grains are formed in the heat affected zone and therefore major proportions of austenite is retained along with equal proportion of martensite in the weld metal zone. We can also see some ferrite veins observed along the grain boundaries in the weld metal zone.

R.SUDHAKARAN et.al [5][2012] Studied on optimization of process parameters to reduce the angular distortion while welding the 202 grade stainless steel .Angular distortion is basically very serious problem and mostly occurs among different types of distortion in butt welded plates. So Therefore there is a need to control the process parameters that are chosen for the study are welding gun angle, welding speed, plate length, welding current and gas flow rate in such a manner to minimize the angular distortion to some extent. The experiments were performed with a five factor five level composite rotatable technique using design of experiments technique with full replication technique. An appropriate and suitable mathematical model was developed which correlates the process parameters with angular distortion. The results that are obtained from study tells about the optimized values for the process parameters that are capable of producing weld with minimum distortion. The maximum angular distortion obtained from experimental studies was 10°, when the process parameters such as gun angle, gas flow rate, welding current and plate length were maintained at 60°, 10 litre/min, 80 amps and 125 mm respectively and welding speed was maintained at 110 mm/min. From the above results It is clear that the process parameters will distort the plate more and therefore it must be avoided. The experimental results which shows the minimum angular distortion was about 0.4° at the same time the process parameters such as gun angle, gas flow rate, welding current and plate length were maintained at 70°, 15 lit/min, 90 amps and 150 mm respectively and welding speed was maintained at 100 mm/min. So therefore it is possible to obtain minimum angular distortion when our process parameters were settled to the optimum value. So these were the conclusions of our study in present work.

M. S. Mohammed Musthaqet.al[6][2014] They predicted that optimal bead geometry is an important aspect in welding process and Therefore, there is a need to develop the mathematical models that will predict and control the bead geometry. This study focuses and aims to develop the simple and accuracy interaction model which is used for the prediction of bead geometry in Tungsten Inert Gas (TIG) welding process. The independently controllable parameters that are affecting weld pool geometry and also the quality of the weld pool V, I, F and G were selected and known as input control variables. The experiment was designed and constructed in such a way so that to control the linear movement of the torch along the weld pad center line. Weld pools were laid on the joint in such a manner that to join thin stainless steel plate with the experimental setup. In this present study the material to be selected is AISI type 202 stainless steel plates of 3mm thickness are going to be taken as work piece material. Only a single pass welding can be used to join the specimens. Therefore quality parameters are measured. The mathematical relationship which is going to be generated is appropriate. These processes will developed systematic approach can also be adopted for other type of arc welding processes. Direct effect of welding current on bead parameters, the direct effects of process parameters on bead geometry were determined and presented. Penetration increases with the increase in welding current (I), keeping the other variables constant. This is due to the fact that the increase in welding current resulting in enhanced heat input, causing large volume of the base metal to melt and hence deeper penetration. Bead width increases by increasing in welding current (I).Direct effect of welding speed on bead parameters. The penetration decreases with increase in welding speed. This is due to the fact more melting of base metal initially when speed is less. Also the interaction effect of welding current and welding speed on the penetration has been described. Interaction effect of welding current and gas flow rate on penetration has been described in a detail.

M. Chougule, M. Unhale, A. Walunj, S. Chavhan, S. Somase[7][2013] It is investigated from this study that there is a need to control welding process parameter so as to reduce the residual stresses and distortion. Residual stress distribution and distortion that occurs in welded plate are strongly affected by many parameters like deep penetration, current, voltage structural, material arc length and welding parameters. Such welding failure can only be minimized when we controls the weld heat input. The finite element methods were used for the temperature distribution in weld joint of AISI202 grade high strength steel was investigated by using ANSYS software and the experiment has been performed to verify the developed thermo-mechanical finite element model using Gas Metal Arc Welding (GMAW) process. In this study the residual stress were investigated only by the FEM model not by the experimental process because it is much expensive. The main aim or objective of this study was to analyze distribution of temperature and residual stresses in welding plate and to understand suitable parameters that should be selected so that to avoid the future failure in the material. No other zone or any location in surrounding area except the fusion zone has the higher residual stress gradient. Because of this high stress gradient, defects like cold crack at the fusion zone in high strength steel occur. The main purpose of this simulation was the determination of temperatures and stresses during and after the process. The Temperature distributions which define the heat affected zone where material properties are affected. The higher residual stress is distributed in weld bead and in Heat Affected Zone (HAZ) which are shown by the simulation process. Stress calculation is needed very much because high residual stresses may lead to fatigue, fractures and stress corrosion .The regions near the weld beads suffers from such a such undesirable failures.

T.A.Tabish et.al [8] Investigated that AISI 304 stainless steel plates were joined with the butt-welded through manual tungsten inert gas welding (TIG) process. During this study of welding process was applied to different specimens by varying amount of heat inputs (low, medium and high) to the stainless steel plates and welded by taking the different heat inputs. Therefore there is a change in micro-structural features and mechanical properties of the welded joints because of variation in the heat inputs as the welded specimen undergo change in current and voltage while doing the welding. The results showed that the tensile strength of welded specimens was greater than that of the base metal. Tensile strength is maximum for that specimen which is welded by using low heat input and vice versa. From the Micro-hardness measurement it is implied that hardness near to the upper surface of the weld is considerably high than that of the center of the weld because of the faster cooling which occurs at the exterior than the interior of the weld. It was observed that the Micro-hardness increased from 205 VHN to 230 VHN for low heat input, 194 VHN to 211 VHN for medium heat input, and 182 VHN to 195 VHN for high heat input welded specimens respectively. After the micro-structural studies it was investigated that the high heat input produces larger dendrites than those produced with medium and low heat input. The high heat input welded joints has not high mechanical properties as that of the low heat input welded joints.

SahilBharwal and Charit Vyas [9][2014] Studied the influence of AISI 202 SS (stainless steel) has similar mechanical property as compare to AISI 304 SS grade, but the ability of AISI 202 SS to resist corrosion is somewhat less as compare to AISI 304 SS grade in chloride environment. But (202) Grade is very inexpensive but we can use it in indoor applications like indoor fabrication, automobile trim and application where atmosphere is not a considerable factor. But there is very less research reported on welding of AISI 202 SS grade .In present work we use gas tungsten arc welding (GTAW) process to weld AISI 202 SS grade. GTAW process benefits the welded joint with maximum strength and better deposition rate. The results which are obtained after welding of AISI 202 are comparable to AISI 304 type satisfying the requirement of prescribed properties of welded joints. Hence 202 type SS can be used instead of 304type SS for the above mentioned applications, because AISI 202 SS are inexpensive and has almost similar mechanical properties as compare to AISI 304 SS because the less presence of nickel content in AISI 202 SS makes it inexpensive.

K.H. Tseng, C.P. Chou [10] [2003] Investigated that what is the effect of nitrogen added in argon shielding gas on the angular distortion of austenitic stainless steels. An autogenous gas tungsten arc welding was performed on austenitic stainless steels 304 and 310 to produce a bead-on-plate weld. The Ferritscope was for measuring the delta ferrite content .The mean vertical displacement method (MVDM) used to measure the angular distortion of weldments. The results obtained indicate that the retained ferrite content in Type 304 stainless steel weld metals was rapidly reduced as the nitrogen addition in argon shielding gas was increased. Also there is increase in angular distortion in the weld with the increase of the amount of nitrogen added in the shielding gas. This experimental result also found that the existence of retained ferrite microstructure within the austenitic matrix has a beneficial effect in reducing welding distortion tendency of austenitic stainless steel weldment.

Ravi Duhan&SurajChoudhary [11] [2014] Gas tungsten arc welding (GTAW) is a famous process used in industries for joining thin materials . GTAW welding results in achieving a high quality weld for stainless steels and non-ferrous alloys. TIG welding is basically used in those industries where there is a need to control the weld bead shape and its metallurgical characteristics. However, TIG welding results in shallow penetration as compare to the other arc welding process, so therefore it restricts its ability to weld thick structures in a single pass, and therefore productivity for this welding is relativity low. As we see from the industrial point of view stainless steel 304 is a very commonly used material because of its property of resistant to corrosion and better creep rupture strength. The activating flux effects the different properties of the joint produced by the welding. In this study, The activated flux such as Fe_2O_3, $MgCl_2$, MnO_2, and ZnO were used so that to investigate the effect of activated tungsten inert gas (activated TIG) process on microstructure as well as hardness of grade 304 stainless steels. The activated TIG welding showed non uniformly cooled unidirectional grains with varying size from fine to coarse in the weld zone in their microstructure characteristics. The results that are obtained from this study shows that no other flux lead to increase in hardness as MnO_2 flux led to increase in the hardness up to (306Hv) in weld zone.

Ahmed Khalid Hussain, Abdul Lateef, Mohd Javed, Pramesh.T[12][2010]In this paper studied the effect of welding speed on the tensile strength of the welded joint.Experimentation was performed on the specimens having single V-groove butt joints having different bevel angle and bevel heights. In this research work the base material used and selected for mechanical testing is Aluminium (AA6351) Alloy. The universal tensile testing was done on the welded joints of aluminium alloys and then strength of welded joints was evaluated.

Vedprakash Singh, vijay patel [13][2014] Tungsten arc welding is a most widely used welding process because of its higher accuracy and quality of weld. TIG welding requires that welding parameters that can control welding distortion and hence enhance the productivity. Experimental study was done on Austenitic stainless steel grade (304) plates welded by GTAW process having thickness of 5mm. In this research work Experiment was performed according to Full Factorial method and results are calculated. The parameters like Groove ,current and welding speed has a great influence on the welding distortion .if these parameters exceeds their limit they will definitely create welding distortion. The experiments was performed according to the full factorial technique then data is collected to obtain the results. In this Research work the welding characteristics of austenitic stainless steel 304 grade and then optimize the welding parameters by (ANOVA). After then comparsion is done between output of the multiple regression analysis and ANN ie. Artificial neural network output. It was concluded that ANN model is better than the multiple regression analysis in predicting the welding strength.

Parvinder Singh ,Vikram Singh [14][2014]In this experimental work it is studied that Taguchi approach is used and applied to design the experiments to determine the effect of process parameters like hardness and deposition rates on the weld bead geometry. Current, gas flow rate and no. of passes are the three input parameters that were selected to that to determine their effect on the hardness of the weld bead.. The results show that these three input parameters have significant influence on the hardness of weld bead. In this research work, the experimental work is done by using L-9 OA as standardized by Taguchi and the analysis is done by the standard procedure as well as S/N data. From the above study it is concluded that all the three selected parameters current, no. of passes and gas flow rate has the influence on both the mean value and the weld bead hardness

V.S.Vigneshvar and Dr.R.Sudhakaran [15][2014] In this research work it is investigated that AISI 202 stainless steel is prone to inter granular corrosion and stress corrosion after the welding .This material replaces the 304 grade stainless steel because of less cost due to the presence of nickel content in the 202 grade is less then 304SS Also 202 SS grade has similar mechanical properties as compare with 304 SS. Flux coating is most suitable method done in the weldment areas in improving the properties like inter granular corrosion and stress corrosion cracking to large extent.

V. SUBRAVEL, G. PADMANABAN, V. BALASUBRAMANIAN [16] [2013] This investigation was done in order to determine the effect of welding speed on tensile and micro structural characteristics of pulsed current gas tungsten arc welded (PCGTAW) AZ31B magnesium alloy joints. using the five different level of welding speeds i.e (105-145mm/min) Five different welded joints were prepared and then tensile properties of all welded specimens were observed after the tensile test the results shows that the joints prepared by using a welding speed of 135 mm/min posses higher tensile strength as compared to other joints. The reason is that at135mm/min welding speed there is formation of fine grains in the fusion zone therefore the joints prepared at this welding speed posses the higher strength.

G.Karthik, P.Karuppuswamyand V.Amarnath [17][2014]In this research work it is investigated that effect of different welding process (SMAW) and (TIG)welding process on the 304 Austenitic stainless steel. Experimentation is done by selecting a base material of 6mm thick plates and different welding is done on two different set of plates of 304SS. SMAW and TIG welding process was carried out on 6mm thick plate to study the difference that comes after different welding operation done on 304SS and its effect on mechanical properties. The size of single plate is of 200mmx150mmx6mm.This research work focuses on the hardness, toughness, tensile strength and microstructure of both welding process i.e. TIG and SMAW welding. Both of their weld joints fabricated by different welding were compared and results shows that out of these welding operation the TIG welding joints has better tensile properties as compared to SMAW welding joints of 304 SS

Arun Narayanan, Cijo Mathew, Vinod Yeldo Baby, Joby Joseph [18][2013] It is investigated during this research work that the Aluminum alloy 5083 welded by TIG welding and best welding parameters were observed using the two level full factorials various parameters were selected to conduct the experiments. Based on all parameters selected test were performed like tensile, micro hardness to analyze the best parameters that gives the good mechanical strength.

Apurv Choubey and Vijay Kumar S. Jatti [19][2014] Austenitic stainless steels are popular materials which has an excellent mechanical properties due to which these are prefer in manufacturing industries .These stainless steels contain 18% Cr–8% Ni.. It is investigated during this research work that welding heat input has influence on these parameters like bead height, bead width, and depth of penetration. After the experimentation they concluded the results that bead height and depth of penetration is greatly influenced by increasing the heat input. As heat input increases these parameters also gets increases .Increase in heat input increase in HAZ area and fusion zone Also causes formation of dendrites and dendrites size increases with increase in heat input.

Parvinder Singh and Rajinder Singh [20][2013] TIG welding is a very versatile process and it can weld similar or dissimilar metals . In this research work 304 SS is being used experiment was designed and planned in such a way to calculate the effect of three input welding parameters like No. of passes ,gas flow rate ,current on the hardness of weld bead and the metal deposition . Various experiments were performed by varying the input parameters to study the variation that comes during deposition rate and weld bead hardness.

Kundan Kumar, Somnath Chattopadhyaya, Avadhesh Yadav [21][2014] It is investigated during the research work that surface response methodology being used to study the effect of current ,voltage and travel speed (input variable) on the weld bead width and metal deposition rate (output responses). The input provided to model estimates the output values after the completion of the experiments.

Sreejith S Nair[22][2013]In this project it is investigated that we use a TIG welding of a Stainless steel to acquire the high tensile strength, harness and better surface finish. A high quality of product prepared by the welding is done only by the proper selection of a material. The experiments were conducted by the response surface methodology. The results were concluded that the welding parameter has the major influence on the penetration, hardness and tensile strength. The TIG welding used in this process uses various value of current and electrode diameter keeping voltage and welding speed constant. The weld joints prepared with TIG process have 6mm thick stainless steel plates .the tensile testing was performed to measure the mechanical properties of the joint

M. Zuber, V. Chaudhri, V. K. Suri, and S. B. Patil [23][2014] In this present work it is investigated that use of SiO_2 flux (oxide flux) on the 8mm thickness stainless steel plate 304L Grade and its effect on the welding distortion. It is concluded that with the use of oxide flux there is decrease on welding distortion. The flux used in this process is in form of powder mixed with the acetone and directly applied on the bead plate. The results show that using oxide flux there is increase in hardness as well as in ferrite number and also decrease in welding distortion. The major reason for increase in ferrite content is that increase in cooling rate.

Dinesh Kumar, Elangovan, Siva Shanmugam [24][2014]In this paper the study was carried out for stainless steel welded by TIG or Pulse TIG . Stainless steel basically has high toughness and superior mechanical properties therefore they used in pressure vessels. It is concluded that HAZ decreases the strength so therefore the use of pulse TIG lead to cause in reduction of HAZ. Here in this research work parameters like current voltage, speed, gas flow rate are optimized in such a way to improve the quality of the weld. The experiment was conducted using taguchi approach to get optimized parameters. The result shows that the parameters such as current, and welding speed are the important parameters that cause the variation in the mechanical properties (tensile strength and impact strength).

Biju S. Nair, G. Phanikumar, K. Prasad Rao and P. P. Sinha [25] It is observed during this work that the AA2219 alloy posses an excellent welding characteristics but during welding conditions this alloy suffers from the poor strength of fusion zone .in this experimental work it is observed that if we have to increase the mechanical properties of welded fusion zone, it is necessary to increase its cooling rates and the multi passes. In order to increase a cooling rate electron beam of high heat source may be used and DCEN i.e. DIRECT CURRENT ELECTRODE NEAGTIVE or STRAIGHT POLARITY is used to increase the multi pass GTAW welding. This helps to improve the hardness and the tensile properties to much better extent in the fusion zone.

Akash Sharma and Atul Raj [26][2015] TIG welding is one of the most popularly used welding technique due to its versatility and ease that makes it suitable in almost any kind of working condition. Stainless Steel (SS316) possessing high strength and toughness is usually known to create major challenges during its welding. TIG welding is suitable for Stainless Steel (SS316) with good weld ability and production economy. During this research work it is investigated that Taguchi's Design of Experiment approach is used to study the effect of welding process parameters on deposition rate of weld bead. In this work three input parameters Current, gas flow rate and no. of passes are selected to measure their effects on the deposition rate of weld bead. The three different levels of current, gas flow rate and number of passes have been chosen during this experiment. The parameters are analyzed and observed at three different levels. The different values of current that are taken 110 A, 130 A and 150 A. Gas flow rates are selected as 4(lit/m), 8 and 12 and number of passes as 1, 2 and 3. These parameters are selected according to achieve required objectives.

Chander Mohan, Dr.B. K. Roy [27] [2013] It is studied during this present work that a dissimilar weld joint comprising Stainless Steel (SS304) and Mild Steel (MS1144). Welds produced by shielded metal arc-welding with two different electrodes which are (Rutile & Cellulosic) were examined and observed to measure their tensile strength, hardness&

microstructure features. These welds that are formed by different electrodes were found to have overmatching mechanical properties.

Khairia Salman Hassan and Shatha Abdul hameed [28][2015] It is investigated that Corrosion of welded Aluminum Alloy 6061 T6 by potential state method in 3.5wt%. NaCl solution.at different velocities such as (1, 2, and 3) m/ min. In this experiment the Potentiodynamic and open circuit potential measurements were conducted. Many specimens prepared for Corrosion test by the dimensions of (15*15*3) mm according to ASTM G71-31 from butt welded joints which are fabricated by using Two different welding processes ie tungsten inert gas (TIG) and a solid state welding process known as friction stir welding, TIG welding process performed by using Rolled sheet of thickness 5 mm in order to get weld joint with dimensions of (100* 50* 5) mm using ER4030 DE (Al Si5) as filler metal and argon as shielding gas, while Friction stir welding process performed by using CNC milling machine with a tool of rotational speed 1000 rpm and welding speed of 80mm/min to obtain the same butt joint dimensions. Another butt weld joint processed in the same dimensions subjected to synergistic weld process TIG and FSW weld process at the same previous weld conditions. In metallurgical studies Optical Microscopy and micro hardness test were performed on the welded specimens. Corrosion results are obtained by using Tafel equation. After the experiment it was concluded that corrosion rate for TIG weld joint was higher than the others but synergistic weld process helps in improving its corrosion resistance by a percentage of 14.3%. Increase in media velocity also contributes in decreasing corrosion rate.

Degala Ventaka Kiran and Suck-Joo Na [29] 2014] The best application of any welding process depends on its various process parameters that has influence on the weld quality. The weld quality includes the weld bead dimensions, temperature distribution, metallurgical phases and the mechanical properties. It is investigated during this work An experimental and numerical approaches were used to understand the parametric influence of a single wire submerged arc welding (SAW) and multi-wire SAW processes on the final quality of the weld is described in two parts. The first part deals with the experimental approaches which explain how the parametric influence on the weld bead dimensions, metallurgical phases and the mechanical properties of the SAW weldment. Also This studies related to statistical modeling of the present welding process are also described. The second part deals with the numerical approaches which focus on the conduction based, and heat transfer and fluid flow analysis based studies in the present welding process. But this study describes only the first part.

P.Sathiya and S.Aravindan [30] 2013] Under this research work the bead-on -plate welds were carried out on AISI 904 L super austenitic stainless steel sheets using Gas Metal Arc Welding (GMAW) process. In this experimental work AISI 904 L solid wire having 1.2 mm diameter was used as an electrode with direct current electrode positive polarity. Argon was served for shielding purposes. The fusion zone is generally characterized by a few geometrical features namely bead width, bead height and depth of penetration. The shape of the fusion zone changes as gas flow rate, voltage, travel speed and wire feed rate such parameters changes. The experiment was performed by using taguchi technique. The bead profile parameters such as bead width, bead height and depth of penetration are measured. It is concluded from the results, that gray relational analysis is applied to optimize the input parameters simultaneously considering multiple output variables. Microstructural changes occurring in the weld zone is investigated with the help of optical microscopy. The hardness was measured across the fusion zone.

2.1 Research gap found on the basis of the literature review:-
Based on the literature review as discussed above the following research gap was found:-

1) No systematic study has been reported where the quantitative effect of variable heat input on mechanical properties of AISI 202 stainless steel welds has been carried out.
2) Micro structural and mechanical properties co-relation has not been extensively reported.
3) No paper is reported where effect of filler and heat inputs is investigated with an aim in improving mechanical properties of AISI 202 (SS) joints.

2.2 Industrial Relevance of this work:- The present work shall lead to generation of the data that can be directly used on shop floor of welding industries in AISI 202(SS) fabrication. It will help in designing welding procedure specification for this alloy which can act as priori information to higher section thickness of alloy.

2.3 Objective of the present work:-

1) To fabricate welded plates using two different levels of heat input and filler composition using GTAW process.

2) To study the effect of welding heat input (low and high) and filler composition on mechanical properties of AISI 202 (SS) joints.

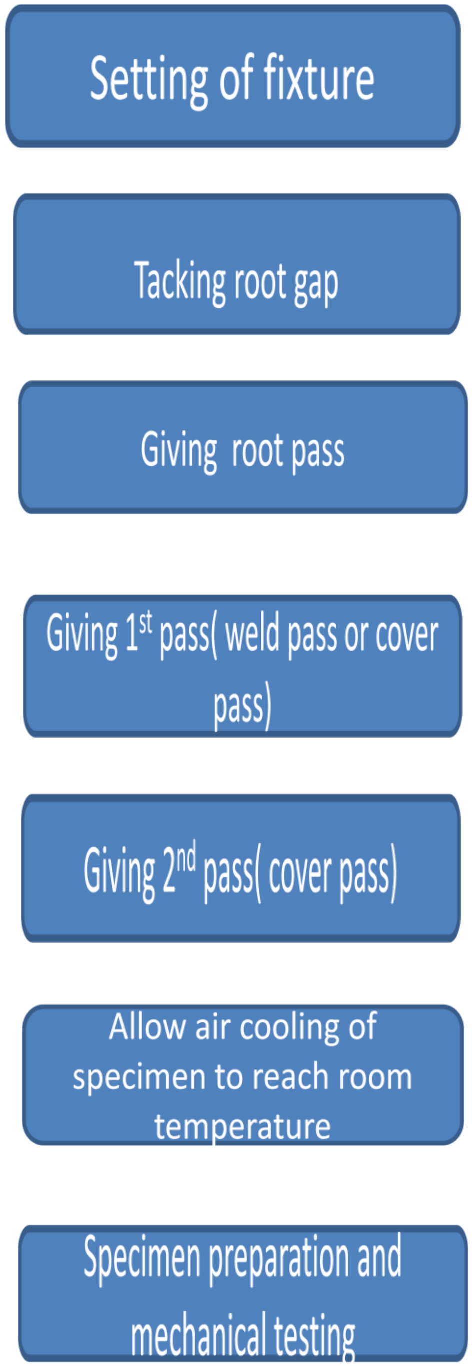
3) To carry out metallurgical studies on these joints and co-relate with mechanical properties.

Metallurgical studies include:-

a) Micro hardness along and across weld.
b) Micro structural studies - phases present along with their grain structure

4)To design the welding procedure for 6mm thick AISI 202 (SS) plates for achieving high mechanical strength by fabricating these using two welding heat inputs viz. low and high.

This chapter concludes that no systematic study has been reported where the quantitative effect of variable heat input on mechanical properties of AISI 202 stainless steel welds has been carried out. Micro structural and mechanical properties co-relation has not been extensively reported. The present work will be helpful in designing the welding procedure of this alloy that can be directly used on the shop floor.



The flow chart showing the sequence of investigations used in the present work

CHAPTER 3

EXPERIMENTATION

This chapter discusses about the procedural steps that are to used for carrying out the experimental investigations in a systematic and appropriate manner so that the required objective of this work could be achieved, thus leading to clear and meaningful conclusions. Details regarding heat input parameters used in the present work during the welding, filler combinations and methodology used for present work.

3.1 BASE METAL AND FILLER USED

3.1.1 Base metal

In our present work plates of austenitic steel grade AISI 202 SS will be cut to length from the flats and each plate will be cut to dimensions length 150mm, width 75mm and thickness 6mm.

3.1.2 Filler used

During welding of the base plates two types of solid filler wires viz.. AISI 308L SS, AISI 316L SS are used to fill the groove volume.

3.1.2.1AISI 308L SS

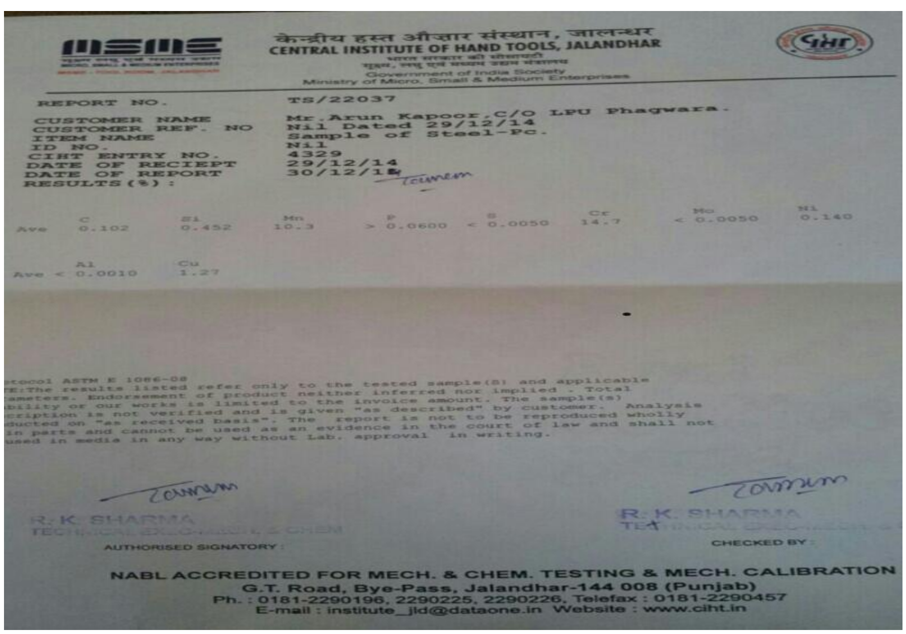
AISI 308L is the low carbon austenite steel grade (0.03percent max). The use of308L filler wire reduces the possibility of inter granular carbide precipitation. Low percentage of carbon lead to increase in the resistance to inter-granular corrosion without the use of stabilizers such as columbium or titanium .Strength of this low-carbon alloy is not greatly high at an elevated temperature as that of the columbium (niobium)-stabilized alloys. Joint made by this filler metal have a good ductility and good corrosion resistance. The basic use of filler is to strengthen the joint and fill the volume of the groove.

3.1.2.2 AISI 316L SS

AISI 316L is also the low carbon austenite steel grade (0.03percent max). The use of 316L reduces the possibility of inter granular carbide precipitation. Low percentage of carbon lead to increase in the resistance to inter granular corrosion without the use of stabilizers such as columbium or titanium .Strength of this low-carbon alloy may not be great at elevated temperature as that of the columbium (niobium)-stabilized alloys. Joint made by this filler metal have a good ductility and good corrosion resistance. The basic use of filler to strengthen the joint and to fill the volume of the groove

ELEMENTS	C	Mn	Si	Cr	Ni	P	S	N	Mo
Base metal AISI 202SS	0.102	10.3.	0.452	14.7	0.140	0.06	0.005	0.25	0.005
AISI308LSS	0.03	1.00-2.50	0.30-0.65	19.50-22.00	9.00-11.00	0.03	0.03	-	0.75
AISI316LSS	0.03	1.00-2.50	0.30-0.65	18.00-20.00	11.00-14.00	0.03	0.03	-	2.00-3.00

Table 3.1 chemical composition of base metal and filler wires


केन्द्रीय हस्त औज़ार संस्थान, जालन्धर
CENTRAL INSTITUTE OF HAND TOOLS, JALANDHAR
Government of India Society
Ministry of Micro, Small & Medium Enterprises

REPORT NO. TS/22037
CUSTOMER NAME Mr.Arun Kapoor,C/O LPU Phagwara.
CUSTOMER REF. NO Nil Dated 29/12/14
ITEM NAME Sample of Steel-Pc.
ID NO. Nil
CIHT ENTRY NO. 4329
DATE OF RECIEPT 29/12/14
DATE OF REPORT 30/12/14
RESULTS(%) :

	C	Si	Mn	P	S	Cr	Mo	Ni
Ave	0.102	0.452	10.3	> 0.0600	< 0.0050	14.7	< 0.0050	0.140

	Al	Cu
Ave	< 0.0010	1.27

tocol ASTM E 1086-08
E:The results listed refer only to the tested sample(S) and applicable
ameters. Endorsement of product neither inferred nor implied . Total
bility or our works is limited to the invoice amount. The sample(s)
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Figure 3.1 Certificate of base metal composition

3.2 WELDING PROCEDURE USED

3.2.1 Precleaning: Before starting welding procedure it is necessary to clean the surface of base metal and groove edges, So as to remove the oil, dust ,rust and other unwanted particles can be removed properly otherwise these particles may lead to some types of defects in weld metal. The precleaning of the base metal will be done with help of wire brush and surface grinder so that proper fusion at groove edges can be obtained.

3.2.2 Joint design and edge preparation: The joint design used in this work is a single V groove which is selected according to the thickness of the base material. The groove angle will be approx 60°, root gap of 2mm and root face of 1.5mm is going to be used. Other relevant information is shown in figure 3.2. The edge preparation done with help of hand grinding operation. V groove weld should be designed carefully. Single V groove are used to join medium to thicker metals and pipe welding. They provide excellent weld quality. The groove angle for a groove weld should be such that the torch can fit into groove. Groove angle depends upon metal thickness, desired extension, and torch nozzle size. There is a need of proper penetration and fusion of root pass to avoid welding defects.

Double V-Groove weld can be made on thicker material. Groove weld size relates how deep weld fuses into the joint. Groove completely filled is beneficial but excess fill called weld reinforcement should be minimum. The extra reinforcement decreases the strength of the joint by large stresses at weld toes. By reducing the bevel angle and groove angle the amount of weld metal require to fill groove is reduced, the cost of a filler metal add to fill joint can be reduced by selecting the small groove angle, thus reducing labour cost and therefore also amount of heat input is reduced which reduces distortion that lead to cause crack in a weld.

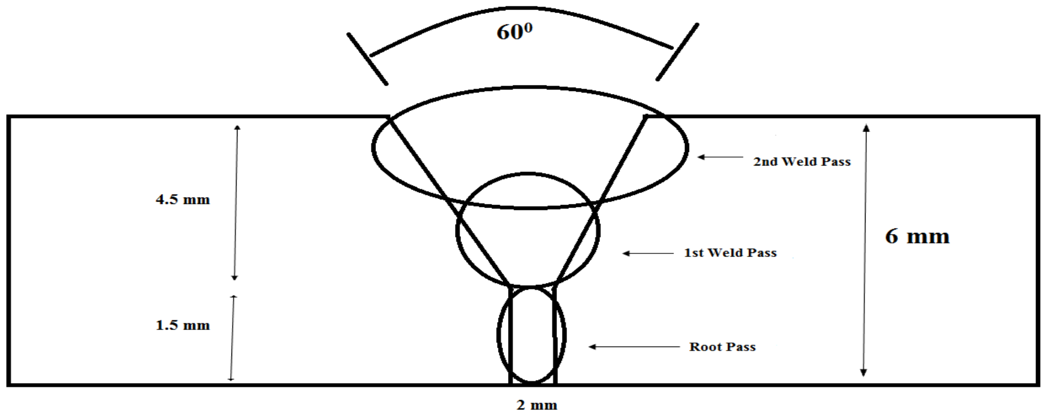

Fig3.2: Schematic diagram of joint design and sequence of weld passes during welding

3.2.3 Use of fixtures: During welding, there may be the possibility of distortion due to non uniform distribution of the heat, so therefore to prevent the joints from the effect of distortion, fixtures are going to be used.

3.2.5 Welding of base plates

3.2.5.1 Root pass In each plate the root pass is made with help of same solid filler wire .The welding parameters used for each plate during root pass are as follows

Filler	Current (A)	Voltage (V)	Speed (S)	HeatInput (KJ/mm)
308L	110	10	125	0.528
316L	110	10	150	0.44
308L	150	14	83.3	1.51
316L	150	14	93.75	1.344

Table 3.2: Welding parameters given for root pass

3.2.5.2 Weld passes

After achieving the root pass two main weld passes are made with every filler i.e AISI 308L and AISI 316L to fill the groove volume . By using single filler wire two base plates are welded at different heat input combinations by changing welding parameters. So with this procedure total four plates are going to be welded i.e. corresponding to each filler wire two plates are welded using low heat and high heat input combinations of parameter.

Table 3.3 Total Heat input is a combination of weld and root pass for welding base metal

Filler used	Weld pass	Current (I)	Voltage (V)	Welding speed (S)	Heat input per unit length of weld(KJ/mm)	Total heat input per unit length of weld(KJ/mm)
AISI308L (Low heat input)	first pass	110	10V	60.48	1.091KJ/mm	2.956KJ/mm
	second pass	110	10V	49.34	1.337KJ/mm	
AISI 308L(High heat input)	first pass	150	14V	75.00	1.680KJ/mm	4.45KJ/mm
	second pass	150	14V	100	1.26KJ/mm	
AISI 316L(Low heat input)	first pass	110	10V	50.00	1.32KJ/mm	2.802KJ/mm
	second pass	110	10V	63.29	1.042KJ/mm	
AISI 316L(High heat input)	first pass	150	14V	98.6842	1.27KJ/mm	3.904KJ/mm
	second pass	150	14V	97.40	1.29KJ/mm	

Figure 3.3 and 3.4 Actual photograph of different current used for welding base metal

CHAPTER 4

MECAHANICAL TESTING AND METALLURGICAL STUDIES

This chapter discusses the procedural details of the methods used for mechanical testing (viz. tensile testing and impact testing) and metallurgical studies (viz. micro-hardness and micro-structural studies) as welded specimens will be subjected with an aim of generating data for further analysis.

4.1 MECHANICAL TESTING OF THE WELDED JOINTS.

Mechanical testing will be carried out on the welded specimens fabricated using different conditions as mentioned earlier in chapter 3. Now we are going to discuss about details of mechanical testing of different welded samples in this chapter. The two types of tests are use viz. tensile testing and impact testing. The top view of welded plates from which samples for different studies will be taken out.

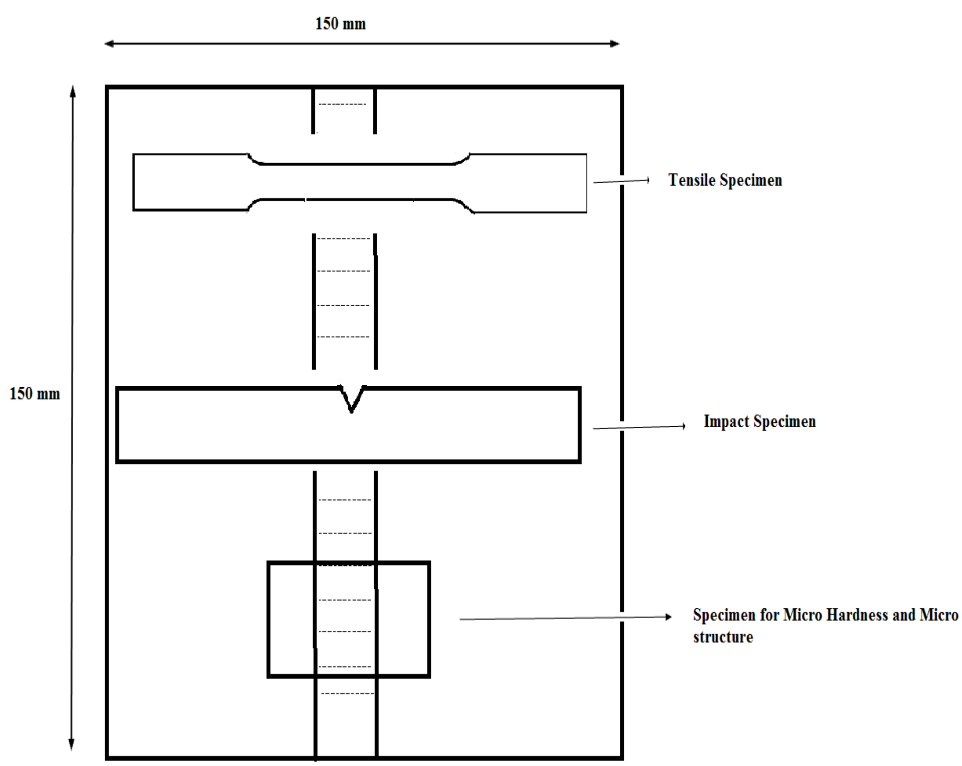

Figure 4.1: Schematic diagram of top view of welded plates from which samples for different studies are going to take out

4.1.1 Transverse tensile test of the specimens

Total four tensile specimens are machined out from each welded plates and can be used for mechanical testing. These specimens will be made according to ASTME-08 which is used for tension testing. Observation recorded after carrying out tensile test are ultimate tensile strength (UTS), percentage elongation and location of fracture

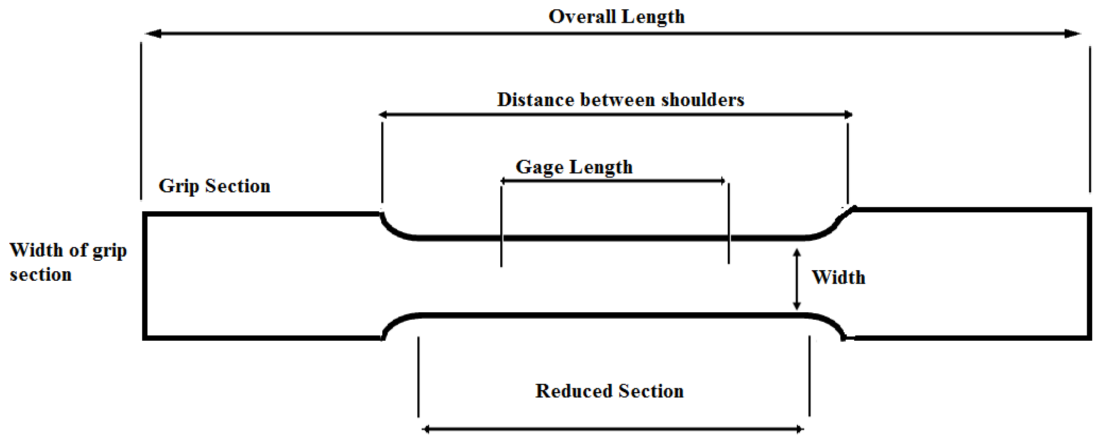

Figure 4.2: Schematic diagram showing tensile specimens as per ASTM E-08

Overall length= (150) mm

Distance between shoulders= (80) mm

Gauge length= (50) mm

Reduced section= (60) mm

Width of grip section = (20+-0.25) mm

Width of reduced section = (12+-0.25) mm

Sample no 1 represents TIG weld joint with the use of 308L filler with 110 ampere current.

Sample no 2 represents TIG weld joint with the use of 316L filler with 110 ampere current.

Sample no3 represents TIG weld joint with the use the use of 308L filler with 150 ampere current.

Sample no 4 represents TIG weld joint with the use the use of 316L filler with 150 ampere current.

Sample no 5 represents the transverse tensile test of base material AISI 202

Figure 4.3 Actual photograph of universal tensile testing machine

Figure4.4: Actual photo of transverse tensile tested specimens showing the location of fracture (filler used AISI 308L, 316L SS)

4.1.2 Impact test

The impact specimen will be taken out from each welded plates and prepared in accordance with ASTM E-23 standards which is Charpy V-notch testing of metallic materials. V notch will be prepared in a weld metal so as to make assess of weld metal toughness. Since the area affected by using different heat input parameters and different filler wires is weld metal, so it will be important to study weld metal toughness changed due to change in the condition during welding of joints. The impact energy absorption by each of the welded specimen is indication of Charpy V-notch.

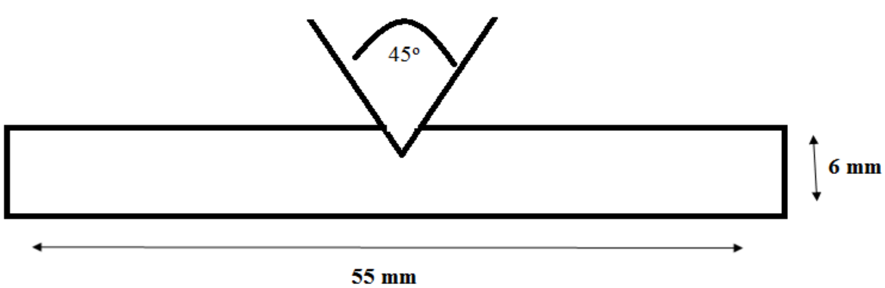

Figure 4.5 and 4.6: **Impact testing machine and Charpy V- Notch Specimen (ASTM E-23)**

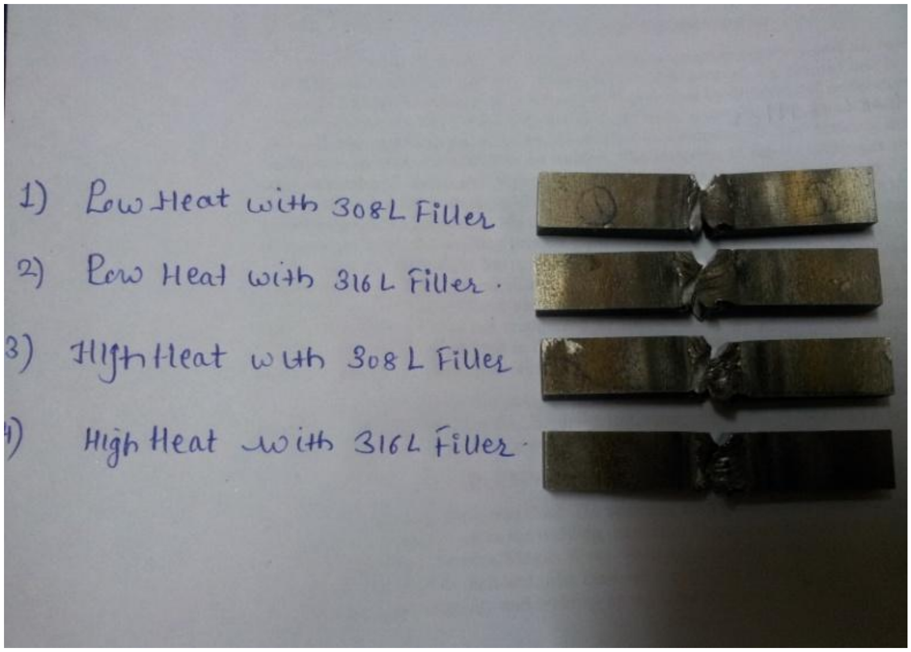

Figure4.7 Schematic diagram showing Impact test specimen showing location of fracture.

4.2 METALLURGICAL STUDIES

In order to find out and analyze the micro -structural changes that occurred in the different zones of weldments for different conditions we use optical microscopy to study and analyze different micro-structures. This is further supplemented with micro hardness of different zones.

4.2.1 Micro-hardness studies

For micro-hardness testing the specimens will be prepared by using standard procedure like polishing using successively fine grades of emery upto 2500 grit size. This will be helpful in removing coarse and fine oxide layer as well as scratches on the surface that are to be metal graphically analyzed. Micro-hardness can be measured with the help of micro-hardness tester at various zones of interest in different weldments. Micro-hardness testing will be carried out on each weldment surface in the longitudinal as well as transverse direction. Micro-hardness plot can be generated from this part of the study, which will be presented in next chapter on result and discussion.

Figure 4.8 Actual Photograph of Vicker hardness tester on (L.H.S)

4.2.2 Micro-structural studies: In order to study the effect of heat input and filler wire on the weld zone and HAZ (heat affected zone), micro-structural studies are to be carried out on different welded samples. The specimens used for micro-hardness measurements will be used for micro-structural studies .The surfaces of the specimens will be electrolytically etched. Different micrographs of different zones of the weldments will be viewed and captured using image analysis software

In this part of study we have done mechanical testing and metallurgical studies on the TIG welded AISI 202 SS joints. First of all tensile test specimens were prepared from the wire cut EDM machine and codification is done to recognize the all welded specimens of different parameters. Then transverse tensile test is performed on all welded specimen. Similarly Charpy V-notch impact test specimens were prepared from wire cut EDM and then impact test was performed .Similarly in metallurgical studies we have done micro hardness and observe the microstructure of the welded specimens. The values of different test were recorded and different results are obtained

CHAPTER 5

RESULTS AND DISCUSSION

5.1 Mechanical testing of welded joints

.Mechanical testing like transverse tensile test and charpy impact test was carried out on different specimens following the standard procedure.

5.1.1 Transverse tensile testing results

The results of transverse testing of different welded specimens are mentioned in table 5.1. The values are recorded for different tensile specimens for different heat input and filler wire combination.

5.1.2 Analysis of transverse tensile testing results

As seen from the results it is observed that location fracture for tensile specimens were HAZ zone. The transverse tensile strength of all the joints made using different heat input has been evaluated. The welded joint made using a low heat input posses high tensile strength and elongation as compare to the specimen which were prepared at high heat input. All the welded joints either using low or high heat input posses higher tensile strength. Basically tensile strength is greatly affected with the variation in heat input. Different Filler wire used during welding operation may increase or decrease tensile strength properties. Because the welded specimen prepared by low heat input with 316L filler wire posses maximum UTS and % elongation than the specimen prepared by the low heat combination using 308L filler wire. Similarly the welded joint using high heat combination with 316L filler wire posses higher UTS than the 308L wire However the maximum ultimate tensile strength obtained was 666MPa which was recorded using the low heat input with 316L Filler wire from all the five different welded specimens

Nomenclature of sample	Area (mm^2)	Heat input	Filler used	Tensile strength (MPa)	% EL
Sample-1,dumble (8.99)(5.86)mm	52.68	Low (110Amp)	308L	618	22.87
Sample-2,dumble (8.98)(5.73)mm	51.45	Low (110Amp)	316L	666	25.75
Sample-3,Dumble (8.98)(5.85)mm	52.53	High (150Amp)	308L	571	10.67
Sample-4,Dumble(8.96)(5.89)mm	52.77	High (150Amp)	316L	597	12.89
Base material,dumble (9.01)(5.93)mm	53.42	_	_	564	10.26

Table 5.1 Transverse tensile testing results of welded specimens using different heat input and filler wire combination.

5.1.3 Analysis of Charpy impact testing results

The Charpy impact test was performed on different welded specimens by varying heat input and filler wire and results obtained are summarized in table 5.2 . the result shows that specimen which is welded at low heat input posses maximum impact strength about 110 joules by using 316L filler wire. Similarly using low heat input with 308L filler gives the impact strength which is less than the previous case. The impact strength values of welded specimens reduce as use high heat input to weld the base metal. The impact values for 308L high heat input is 70 joules and for 316L filler with high heat input is 82 joules.

Specimen name	As welded (joules)
308L filler with low heat input	88
316L filler with low heat input	110
308Lfiller with high heat input	70
316Lfiller with high heat input	82

Table 5.2: Charpy results of welded joints

5.2 MICRO HARDNESS TESTING

Extensive micro hardness survey of different weldments was carried out and results obtained are mentioned and discussed below:

It was observed that micro hardness results of different weldments was that specimens welded using low heat input possessed relatively higher micro hardness value as compared to the weldments using higher heat inputs. It was observed that as the indentor moves outward from the centre toward the HAZ, micro hardness increases. In general the trend for the micro hardness is that it increases as indentor moves away from weld zone toward the heat affected zone and base material. In the high heat input welded joints (HAZ) posses lesser hardness as compare to the low heat input (HAZ). It was observed that extent of grain coarsening increases in HAZ as the increase in the heat input. The HAZ area for the low heat input posses fine grained microstructure and therefore posses high micro hardness. The reason is that low heat results in the high cooling rates lead to fine grain microstructure and consequently higher micro hardness but high heat results in slower cooling rates due to which coarse grain microstructure is obtained in HAZ and posses the lesser hardness. In longitudinal direction as indentor moves from top of the weld zone to the centre of weld zone and then reaches at bottom the micro hardness gradually decreases. Because the cooling rate is relatively higher at the top of the weld bead surface than at the centre of the weld metal.

Nomenclature of sample	HAZ(left side) HV	On weld HV	HAZ(right side) HV	Longitudinal HV
Sample-1 (low heat with 308L Filler)	271.5	265.5	271.5	236.5
Sample-2(low heat with 316L Filler)	274	260.5	273	231.5
Sample-3(high heat with 308Lfiller)	265.5	251.5	266.5	229.5
Sample-4(high heat with 316L filler	236.5	219	255	212
Base material	Average	318		

Table 5.3 Showing the variation in hardness at (weld zone and HAZ) at the different heat input and filler wire

The above table describes the Micro hardness both in the transverse direction and longitudinal direction for both low and high heat input parameters. In the Transverse direction hardness follows an increasing order for all the various parameters. The hardness values increases as indentor moves from weld zone to the (HAZ) and become maximum at base metal. In the weld zone and (HAZ) the micro-hardness values are high in low heat input as compare to the high heat input. The hardness values obtained at the high heat input parameters ie in weld zone and HAZ are less as compare to low heat input.

In longitudinal direction micro-hardness follows the decreasing trend for all the various parameters. In low heat input there is small decrease in hardness from top to the bottom of the weld zone. Whereas in high heat input there is large decrease in hardness from top to the bottom of the weld zone.

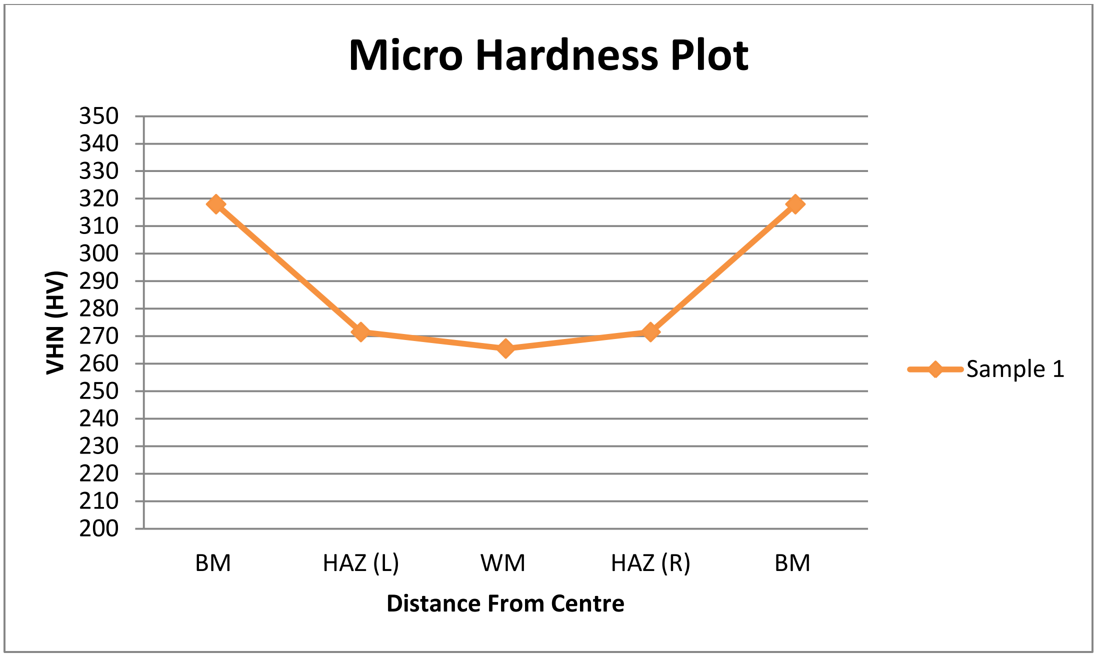

Figure 5.1: Micro hardness plot showing variation in transverse direction of 308L filler at low heat input (This plot shows the higher micro hardness in weld zone and HAZ as compare to high heat input)

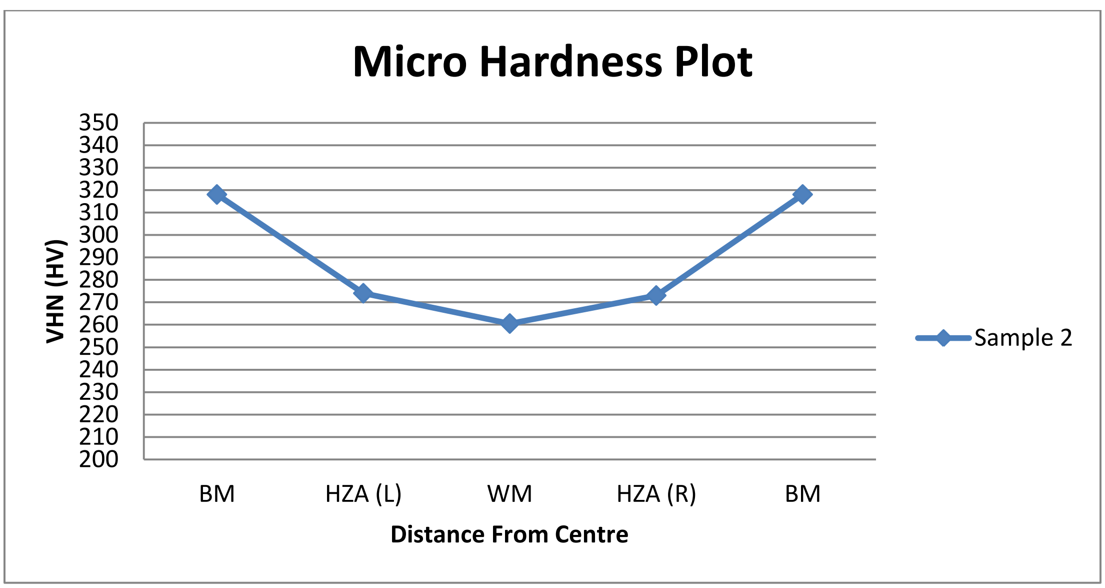

Figure5.2 Micro hardness plot showing the variation in transverse direction of 316L Filler at low heat input (Also has higher micro hardness values in weld zone and HAZ then high heat input)

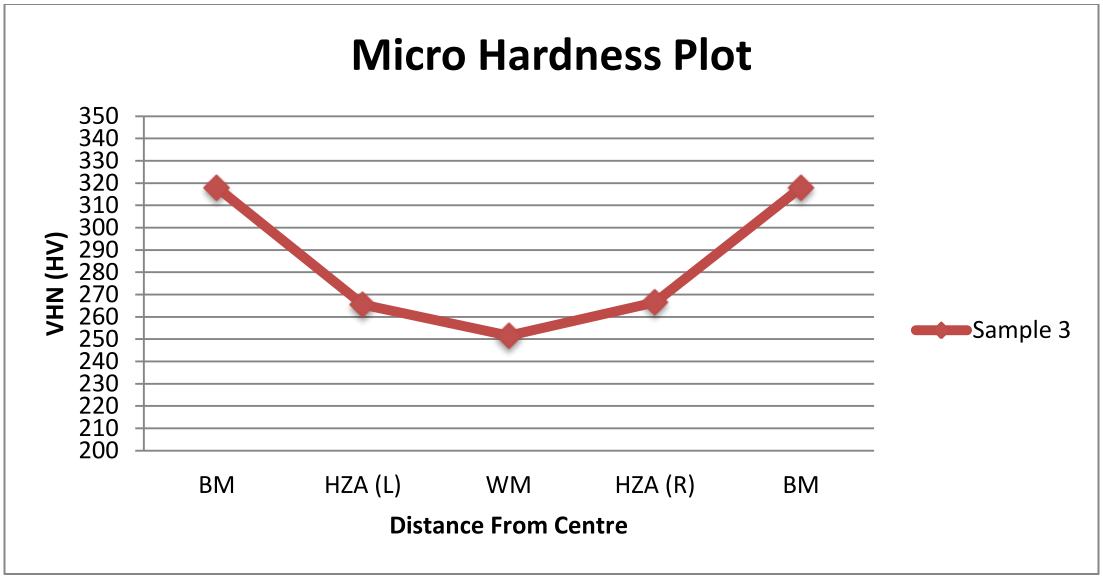

Figure5.3: Micohardness plot showing the variation in transverse direction of 308L filler at high heat input.(Lesser micro hardness values occur in weld zone and HAZ due to high heat input)

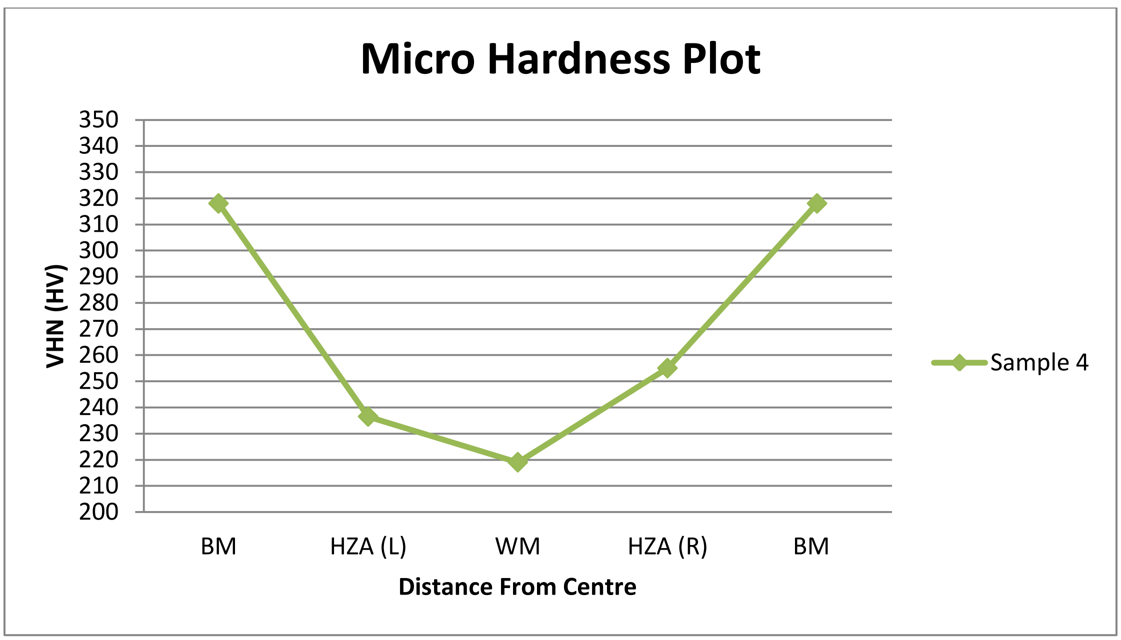

Figure5.4: Micro hardness plot showing the variation in transverse direction of 316L filler at high heat input.(Much lesser values of micro hardness in weld zone and HAZ due to high heat input)

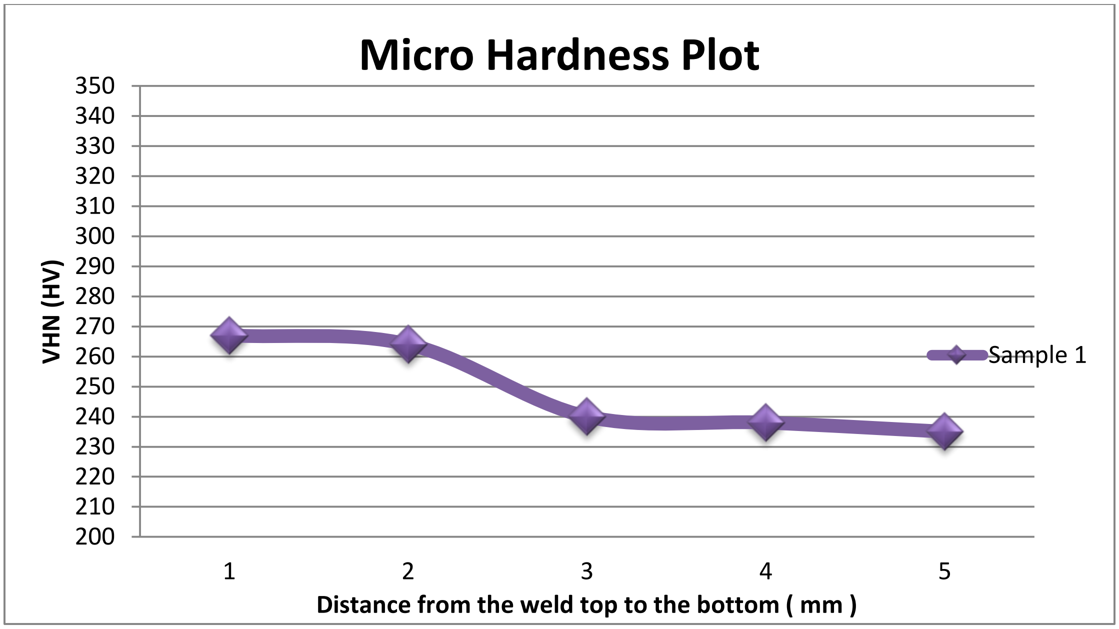

Figure5.5: Microhardness plot showing the variation in longitudinal direction of 308L filler at low heat input (There is small decrease in micro hardness as indentor moves from top to bottom)

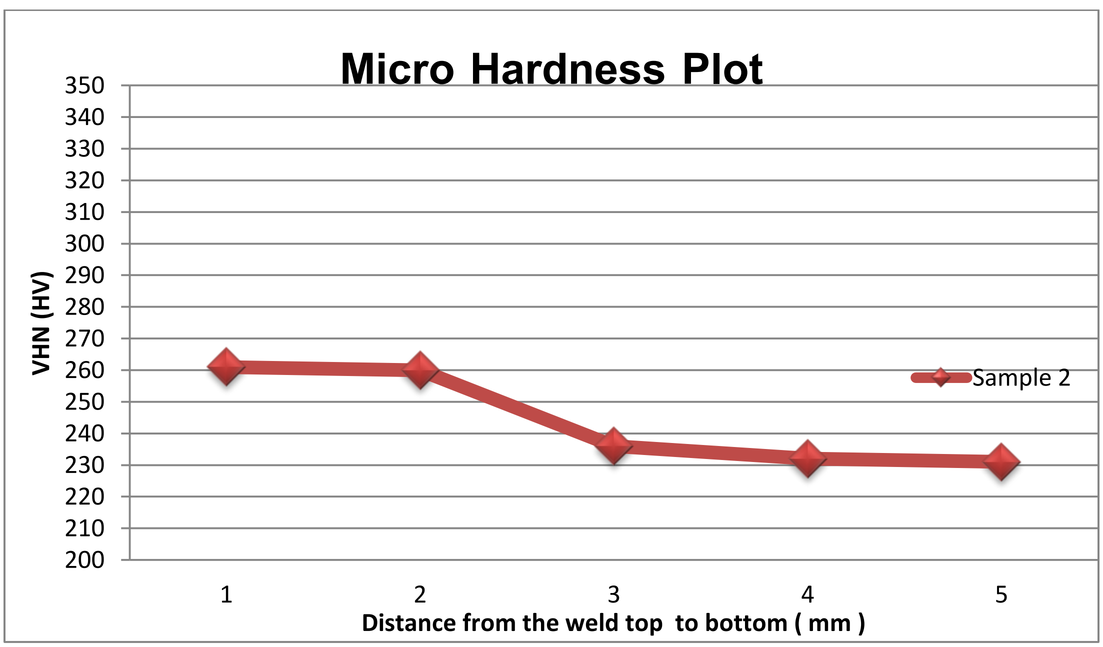

Figure5.6: Micro-hardness plot showing the variation in the longitudinal direction of 316L filler at low heat input. (There is lesser decrease in micro hardness values from top to bottom as compare to high heat input)

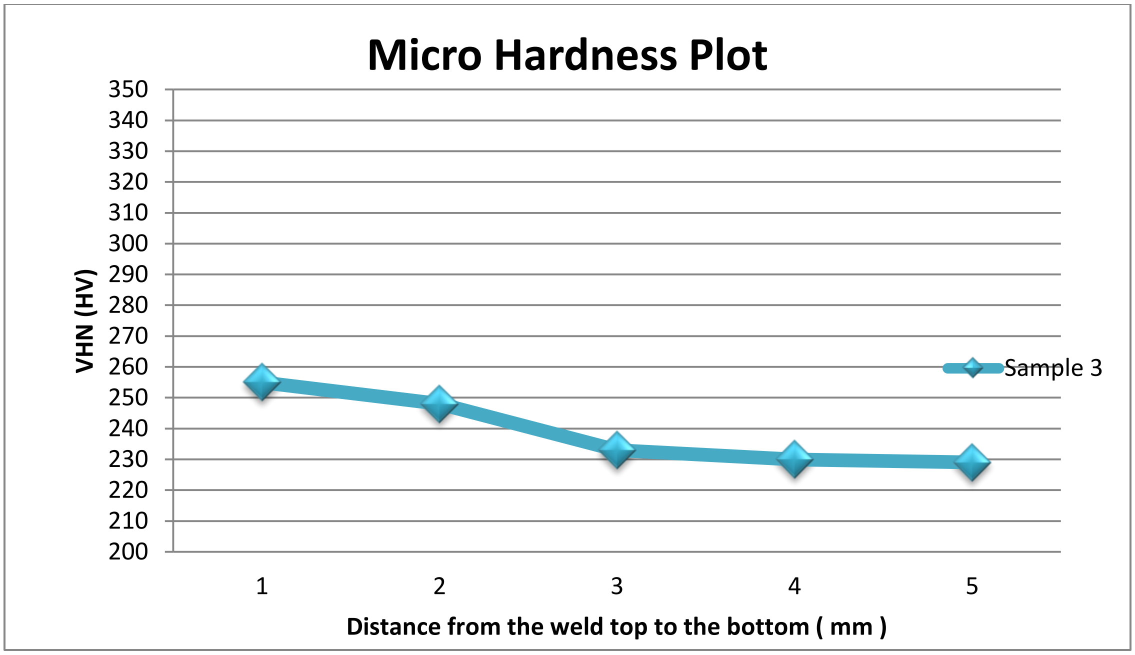

Figure5.7 Micro hardness plot showing the variation in longitudinal direction of 308L filler at high heat input. (Large decrease in micro hardness values as indentor moves from top to bottom due to high heat input)

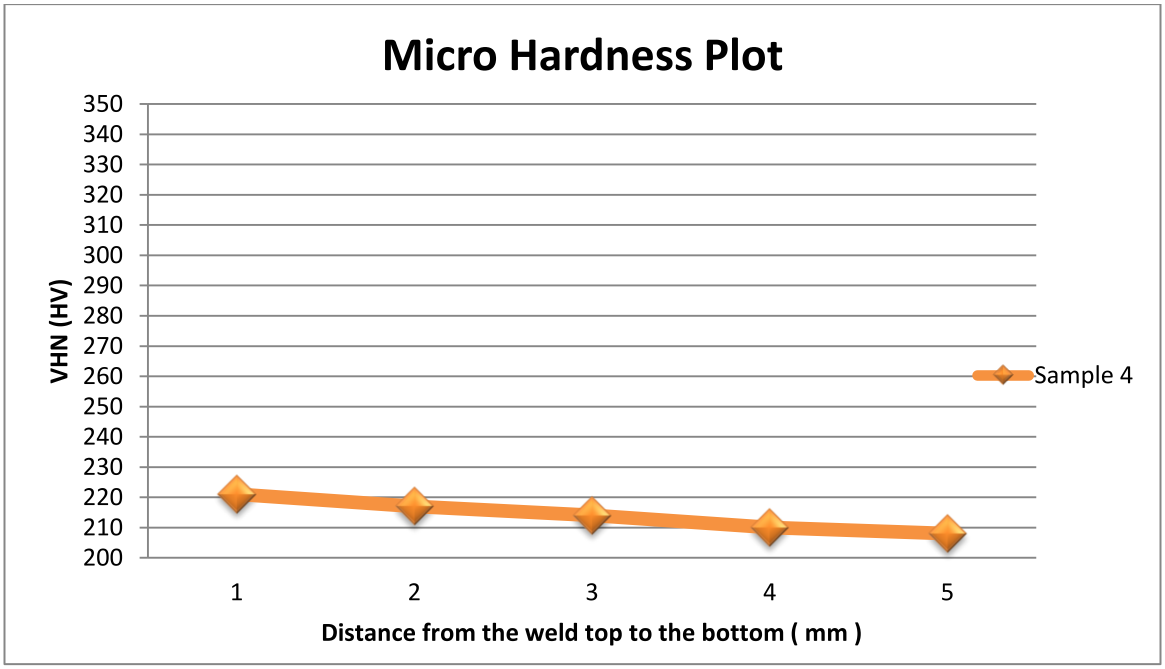

Figure5.8: Micro hardness plot showing variation in longitudinal direction of 316L filler at high heat input (Large decrease in micro hardness due to high heat input as indentor moves from top to bottom)

5.3 MICROSTRUCTURAL STUDIES

In order to study the effect of heat input and filler wire on the weld zone and HAZ (heat affected zone), micro-structural studies are to be carried out on different welded samples. The specimens used for micro-hardness measurements will be used for micro-structural studies .The surfaces of the specimens will be electrolytically etched. Different micrographs of different zones of the weldments will be viewed and captured using image analysis software. The observation which is obtained from these micrographs that at low heat input microstructure is relatively finer this is due to the reason that low heat input has faster cooling rates which lead generates a finer microstructure. Therefore the micro hardness is comparatively higher in weld metal and HAZ which is welded at low heat input due to fine microstructure. Further it is observed that the joints which are welded at high heat input consequently results into coarse microstructure also high heat input lead to generate thermal gradients that are not actually found in low heat input. The cooling rate for high heat input welded joints are slow which lead to generates coarse microstructure.

Figure 5.9: Photo micrograph of AISI 308L SS at low heat Input showing the weld zone, HAZ and base metal consisting of fine grains (In this photograph it can be seen that there is

formation of fine grains and small dendrites and thus microstructure is relatively finer due to rapid cooling rates)

Figure 5.10: Photo micrograph of AISI 316L SS at low heat input showing the weld zone and HAZ consisting of fine grains. (Formation of fine grains occurs at low heat input in weld zone and HAZ due to rapid cooling rate)

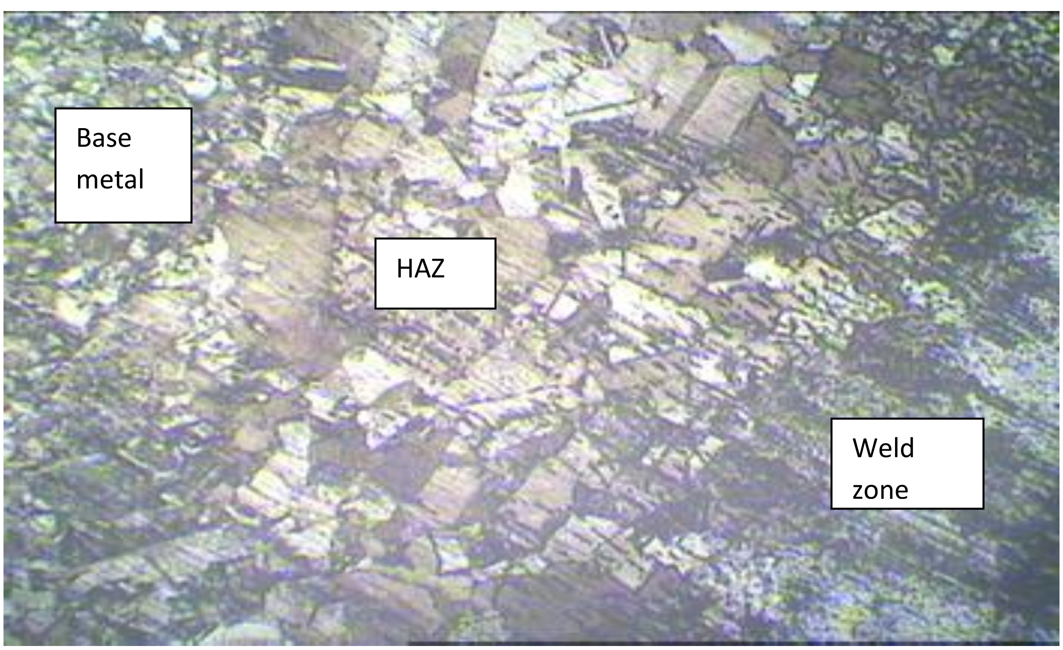

Figure 5.11: Photo micrograph of AISI 308L SS at high heat input showing weld zone, HAZ, base metal consisting of coarse grains (In this photograph there is formation of coarse

grains due to high heat input in weld zone and formation of dendrites because its cooling rate is slower

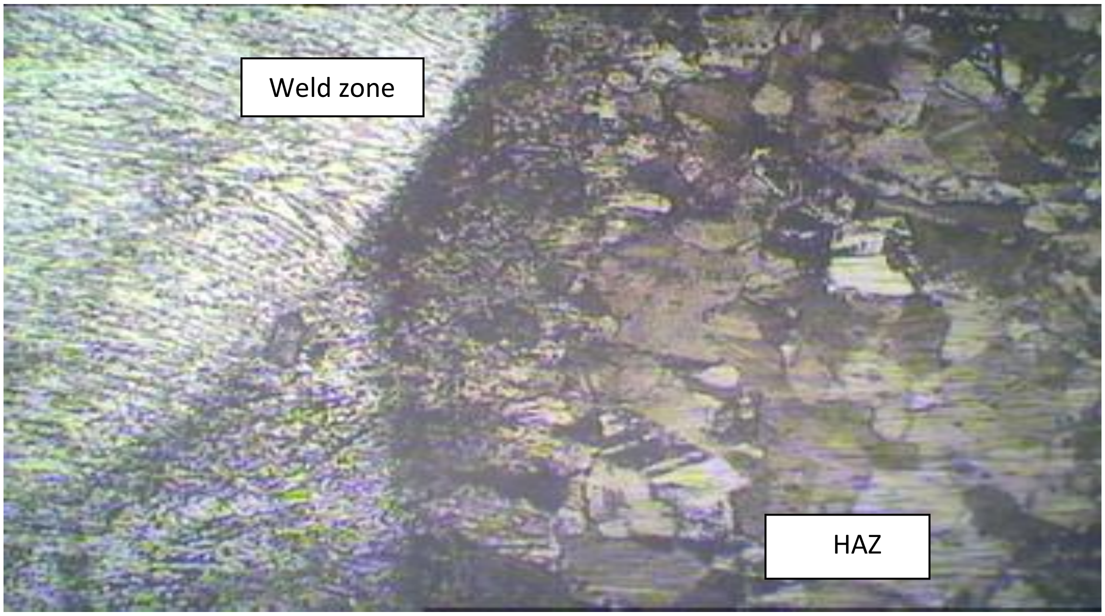

Figure 5.12: Photo micrographs of AISI 316L at high heat input showing weld zone and HAZ consisting of coarse grains (The high heat input causes grain coarsening to occur due to slower cooling rate)

CHAPTER 6

CONCLUSIONS

From this experimental work a few conclusions could be drawn. These conclusion shows that which heat input parameter and filler wire results into better mechanical properties and co-relating with the mechanical properties.

1) Among all the joints it is investigated that maximum tensile strength is 666Mpa and elongation i.e. 25.75 % obtained using low heat input with 316L filler wire. As we use filler 308L there is slightly decrease in tensile strength and elongation as compared with previous case using same heat input because filler wire 316L contain more nickel content than 308L wire. The increase in nickel content lead to increase in the tensile strength and elongation.

2) Charpy impact test was performed among all the welded joints and investigated that maximum impact strength value of 110 joules was possessed by the 316L SS filler which is welded at low heat input. As heat input increases the impact strength values goes on decreasing. So Specimens welded at low heat input has better toughness values then the high heat input.

3) As we use low input parameters to weld AISI 202 SS, there is high mechanical properties to occur as compared to the high heat input parameters because all the mechanical properties decreases with increase in heat input due to the reason that low heat input has faster cooling rates and finer microstructure whereas high heat input possesses the slower cooling and formation of dendrites which lead to generate the coarse microstructure and decreases hardness in HAZ , weld zone and all the mechanical properties.

4) The present work shall lead to generation of the data that can be directly used on shop floor of welding industries in AISI 202(SS) fabrication. It will help in designing welding procedure specification for this alloy which can act as priori information to higher section thickness of alloy.

Scope of future work

1) Effect of different filler and heat input on the corrosion resistance properties of GTAW welded AISI 202 SS can be studied.
2) Fatigue properties of these welded joints fabricated using different condition can be studied.
3) Scanning electron microscope (SEM), transmission electron microscope (TEM), and X-ray diffraction (XRD) techniques can be performed on this welded specimen to enhance the material characterization.

APPENDIX

Name of Machine	Specifications
Universal tensile testing machine	Load capacity is 100 ton or 1000 KN
Vicker hardness tester	Diamond indenter in pyramid form and 5 kgf capacity.

Table 6.1 Show the no. of machines to be used for testing

Name of filler to be used	Specifications
308L	Venus company ,brand name – Hiver ,diameter – 2.4mm
316L	Venus company ,brand name–Hiver ,diameter – 2.4mm

Table 6.2 Show the different fillers used during welding operation

TIG welding setup	Specifications
Name of machine	GTAW fronius setup imported from USA
Electrode and polarity to be used	Tungsten electrode , Straight polarity used

Table 6.3 show the information about welding setup

Elements	C	Mn	Si	Cr	Ni	P	S	N	Mo
Base metal AISI 202SS	0.102	10.3.	0.452	14.7	0.140	0.06	0.005	0.25	0.005
AISI308LSS	0.03	1.00-2.50	0.30-0.65	19.50-22.00	9.00-11.00	0.03	0.03	-	0.75
AISI316LSS	0.03	1.00-2.50	0.30-0.65	18.00-20.00	11.00-14.00	0.03	0.03	-	2.00-3.00

Table 6.4 show the chemical composition of base metal and filler used

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