AN EXPERIMENTAL INVESTIGATION ON WELD CHARACTERISTICS FOR A SHIELD METAL ARC WELDING WITH SS304&SS409

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ABSTRACT

Welding is a joining process of similar metals but nowadays it is also joined dissimilar metals by the application of heat. The different types of welding process are available in industry .Welding can be done with or without the application of pressure and filler materials In shielded metal arc welding (SMAW), an arc between a covered electrode and a weld pool is used to accomplish a weld. As the welder steadily feeds the covered electrode into the weld pool, the decomposition of the covering evolves into gases that shield the pool.Austenitic stainless steel and Martensitic chrome alloys is widely used materials in the current industrial area including higher and lower temperature applications such as storage tanks, pressure cups, furnace equipments etc. This paper concentrated to the investigate the dissimilar material joining by using shield metal arc welding and study the welding characteristics and do the mechanical tests. The aim of this study performance of steel and maximum hardness of welded material, microstructure of steel on next phase of project. The results will be used to character of dissimilar material performance.

Key words: joining dissimilar material, microstructure analysis, Hardness test.

INTRODUCTION

Welding is a joining process of similar metals but nowadays it is also joined dissimilar metals by the application of heat. Welding can be done with or without the application of pressure and filler materials. While welding the edges of metal pieces either melted or brought to plastic condition and it is used for permanent joints. In all fabrication companies welding is very essential. Since welding has been used in steel fabrication its uses has expanded in other industrial sectors like construction, mechanical and car manufacturing etc. It has been passed through the Bronze Age and the Iron Age and it has branched around the world. Ever since 17th century, after the industrial revolution, technology has made our lives comfortable. Man started using iron and steel and since then they play a crucial role in our day to day lives. There are simply surrounded by metals. Thus it has aided in almost all sectors of our lives. It in the most places, the things are doing or use to accomplish our work. One of the strongest methods of joining any metal is through fusion with the help of Arc welding. Many different energy sources can be used for welding, including gas flame, electric arc, laser, electron beam, friction, and ultrasound. This is related with soldering and brazing, which involve melting a lower melting point material between the work pieces to from a bond between them, without melting the work pieces. Welding is a most careful and precautions are

required to avoid burns, part damages, electric shocks, protect from poisonous gases and fumes, and exposure to ultraviolet radiation. Although in its present form it has been used beginning of 20th century but it fast replacing other joining process like riveting and bolting. Presently welding is used extensively for fabrication of different components in automobile bodies, bridges, aircraft frames, and chemical plants, nuclear reactors, structural's and earth moving equipments, railway wagons, pipe and tube fabrication, ship building, general repair works, etc.,. Almost all materials (metals, plastics, ceramics, and composites) can be welded but not by the same process, to achieve the universality a
Large number of welding and related process has been developed.

Most of industrial important processes are classified depending upon the nature of heat source and its movement resulting in spot, seam welds or on the low heat or high heat. Today developments continues to advance of robot welding is common place in industrial setting, and researchers continue to develop new welding methods and gain greater understanding of weld quality. The Most of welding work reviewed in aims at predicting or analyzing the structural response of the welded structure, focusing mainly on the residual.

1.1 Definition

Welding is a fabrication process whereby two or more parts are fused together by means of heat, pressure or both forming a join as the parts cool. Welding is usually used on metals and thermoplastics but can also be used on wood.

1.2.1 Welding processes

i. Cast weld processes.
ii. Fusion weld processes.
iii. Resistance weld processes.
iv. Solid state weld processes.

1.2.2 Allied welding processes.

i. Metal depositing processes.
ii. Soldering.
iii. Brazing.
iv. Adhesive bonding.
v. Weld surfacing.
vi. Metal spraying.

This approach of classifying the welding process is primarily based on the way
Metallic pieces are united together during welding such as

- Availability and solidification of molten weld metal between

Components being joined are similar to that of casting: Cast weld Process.

- Fusion of faying surfaces for developing a weld: Fusion weld process
- Heating of metal only to plasticize then applying pressure to forge Them together: Resistance weld process.
- Use pressure to produce a weld joint in solid state only: Solid state Weld process.

1.2.3 Cast welding process

Those welding processes in which either molten weld metal is supplied from External source or melted and solidified at very low rate during solidification like Castings. Following are two common welding processes that are grouped under Cast welding processes:

- Thermite welding
- Electro slag welding

In case of thermist welding, weld metal is melted externally using exothermic heat generated by chemical reactions and the melt is supplied between the Components to be joined while in electro slag welding weld metal is melted by Electrical resistance heating and then it is allowed to cool very slowly for Solidification similar to that of casting.

1.2.4 Fusion Weld Processes

Those welding processes in which faying surfaces of plates to be welded are Brought to the molten state by applying heat and cooling rate experienced by weld metal in these processes are much higher than that of casting. The heat required for melting can be produced using electric arc, plasma, laser and electron beam and combustion of fuel gases. Probably this is un-disputed way ofClassifying few welding processes. Common fusion welding processes are given below:

- Carbon arc welding.
- Shielded metal arc welding.
- Submerged arc welding.
- Gas metal arc welding.
- Gas tungsten arc welding.
- Plasma arc welding.
- Electro gas welding.
- Laser beam welding.

- Electron beam welding.
- Oxy-fuel gas welding.

1.2.5 Resistance Welding Processes

Welding processes in which heat required for softening or partial melting of base Metal is generated by electrical resistance heating followed by application of Pressure for developing a weld joint. However, flash butt welding begins withSparks between components during welding instead of heat generation by Resistance heating.

- Spot welding.
- Projection welding.
- Seam welding.
- High frequency resistance welding.
- High frequency induction welding.
- Resistance butt welding.
- Flash butt welding.
- Stud welding.

1.2.6 Solid State Welding Process

Welding processes in which weld joint is developed mainly by application of Pressure and heat through various mechanism such as mechanical interacting, Large scale interfacial plastic deformation and diffusion etc. Depending up on the Amount of heat generated during welding these are further categorized as under:

- Low heat input processes.
- Ultrasonic welding.
- Cold pressure welding.
- Explosion welding.
- High heat input processes.
- Friction welding.
- Forge welding.
- Diffusion welding.

There are many ways to classify the welding processes however, fusion welding And pressure welding criterion is the best and most accepted way to classify all The welding processes. The flow chart is showing classification of welding and Allied processes for better understanding of nature of a specific process.

1.3 Shield Metal Arc Welding.

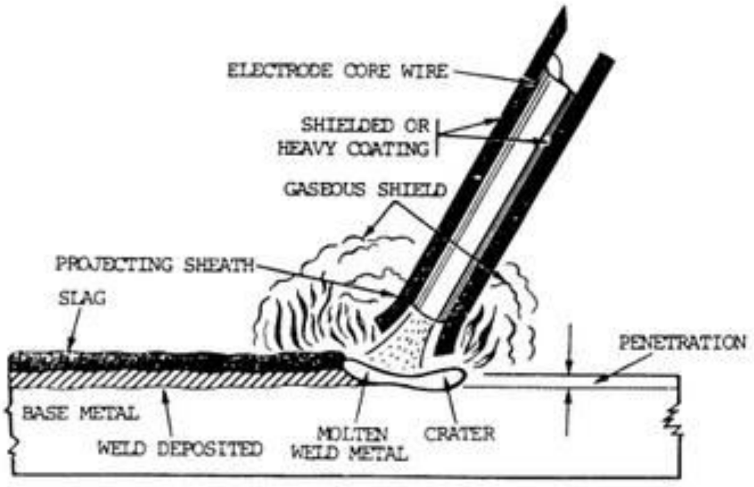


Figure 1.2 Shield Metal Arc Welding

Shielded metal arc welding (SMAW), also known as manual metal arc welding (MMA or MMAW), flux shielded arc welding or informally as stick welding, is a manual arc welding process that uses a consumable electrode covered with a flux to lay the weld. An electric current, in the form of either alternating current or direct current from a Welding power supply, is used to form an electric arc between the electrode and the metals to be joined. The work piece and the electrode melt forming a pool of molten metal (weld pool) that cools to form a joint. As the weld is laid, the flux coating of the electrode disintegrates, giving off vapors that serve as a shielding gas and providing a layer of slag, both of which protect the weld area from atmospheric contamination. Because of the versatility of the process and the simplicity of its equipment and operation, shielded metal arc welding is one of the world's first and most popular welding processes. It dominates other welding processes in the maintenance and repair industry, and though flux-cored arc welding is growing in popularity, SMAW continues to be used extensively in the construction of heavy steel structures and in industrial fabrication. The process is used primarily to weld iron and steels (including stainless steel) but aluminum, nickel and copper alloys can also be welded with this method.

LITERATURE REVIEW

Welding is an efficient and economical method for joining of metals. Welding has made significant impact on the large number of industries by raising their operational efficiency, productivity and service life of the plant and relevant equipment. Welding is one of the most common fabrication techniques which are extensively used to obtain good quality weld joints for various structural components four different industrial filler metals were selected for the joining of AISI 304 austenitic to AISI 409 ferritic stainless steel. These fillers were austenitic and duplex stainless steels and a nickel-based alloy. The micro hardness and longitudinal tensile tests were performed for evaluation of the mechanical properties. The micro structural analysis indicated that the dissimilar welding led to the formation of different ferrite-austenite solidification patterns in weld metals; also, no evidence of carbide/nitride phases was detected. Although three welds showed proper tensile strength values; the weld 316L presented the best mechanical properties from the cost saving point of view.

D.Simhachalam[1], M.S.S.Srinivasa Rao[2], B.Naga Raju[3] **Evaluation of Mechanical Properties of Stainless Steel (SS 304) by TIG Welding at Heat affected Zone (2015**) the welding parameters like welding current, Gas flow rate and filler rod diameter have varying degree of influence on the properties of the welded joint. Impact strength and hardness are determined at Heat affected Zone. Specimens of size 40x15x5 mm are taken for experimentation it is observed that the welding current has a significant effect on the welding parameters as compared to the filler rod diameter. The filler rod diameter also has similar effect on the welding current, but the welding current has a higher effect compared to the filler rod diameter. The present paper also involves prediction of hardness, impact strength and depth of penetration using MINITAB software. The residuals obtained from the analysis using software were found to be within limits which prove the correctness of the experimental values.

Alkahla, Ibrahim; Pervaiz, Salman **Sustainability assessment of shielded metal arc welding (SMAW) process(2017)** Shielded metal arc welding (SMAW) process is one of the most commonly employed material joining processes utilized in the various industrial sectors such as marine, ship-building, automotive, aerospace, construction and petrochemicals etc. The increasing pressure on manufacturing sector wants the welding process to be sustainable in nature. The SMAW process incorporates several types of inputs and output streams. The sustainability concerns associated with SMAW process are linked with the various input and output streams such as electrical energy requirement, input material consumptions, slag formation, fumes emission and hazardous working conditions associated with the human health and occupational safety. To enhance the environmental performance of the SMAW welding process, there is a need to characterize the sustainability for the SMAW process under the broad framework of sustainability. Most of the available literature focuses on the technical and economic aspects of the welding process; however the environmental and social aspects are rarely addressed. The study reviews SMAW process with respect to the triple bottom line (economic, environmental and social) sustainability approach. Finally, the study concluded recommendations towards achieving economical and sustainable SMAW welding process.

Mohammed, Raffi; Madhusudhan Reddy, G.; Srinivasa Rao, K **mechanical and corrosion properties of high nitrogen stainless steel shielded metal arc welds(2018)** The present work is aimed at studying the microstructure, mechanical and corrosion properties of high nitrogen stainless steel shielded metal arc (SMA) welds made with Cromang-N electrode. Basis for selecting this electrode is to increase the solubility of nitrogen in weld metal due to high chromium and manganese content. Microstructures of the welds were characterized using optical microscopy (OM), field emission scanning electron microscopy (FESEM) and electron back scattered diffraction (EBSD) mainly to determine the morphology, phase analysis, grain size and orientation image mapping. Hardness, tensile and ductility bend tests were carried out to determine mechanical properties. Potentio-dynamic polarization testing was carried out to study the pitting corrosion resistance using a GillAC basic electrochemical system. Constant load type testing was carried out to study stress corrosion cracking (SCC) behavior of welds. The investigation results shown that the selected type electrode resulted in favorable microstructure and completely solidified as single phase coarse austenite.

PROBLEM DEFINITION AND OBJECTIVES

3.1 Problem Definition

The following points are the general problems that are noticed.

- The different welding process is suitable for welding in similar materials so the dissimilar material welding process is comparatively very less.
- TIG AND MIG welding is high cost.
- Welding Characteristics is very poor performance compared to other dissimilar material.
- Similar material for welding is always let’s doing.

3.2 Objectives

- To analysis of welding characteristics of dissimilar materials.
- To evaluation of mechanical properties such as: Rockwell hardness test, Brinell hardness test and microstructure test.
- To study the dissimilar material performance.

RESULT AND DISCUSSION

7.1 Sensitization

Austenitic stainless steels are used in the nuclear, transportation, chemical, medical industry and pressure vessels due to their superior mechanical properties and corrosion resistance .And the used ss409 ferritic Stainless steel (Austenitic) are nickel chromium alloys with face centered cubic crystal structure having chromium content more than 12 wt. %. These steel exhibit good ductility, formability and better yield strength. Austenitic stainless steels are most commonly used due to its low temperature toughness and high corrosion resistance . Welding is the joining processes in the mechanical industry and the properties of the weldments are significantly different to the base metal. This may sometimes cause to the failure of the component. Sensitization of the weldments is one of the problems in the welding of ASS. Sensitization leads to degradation of mechanical properties and corrosion resistance of weldments.

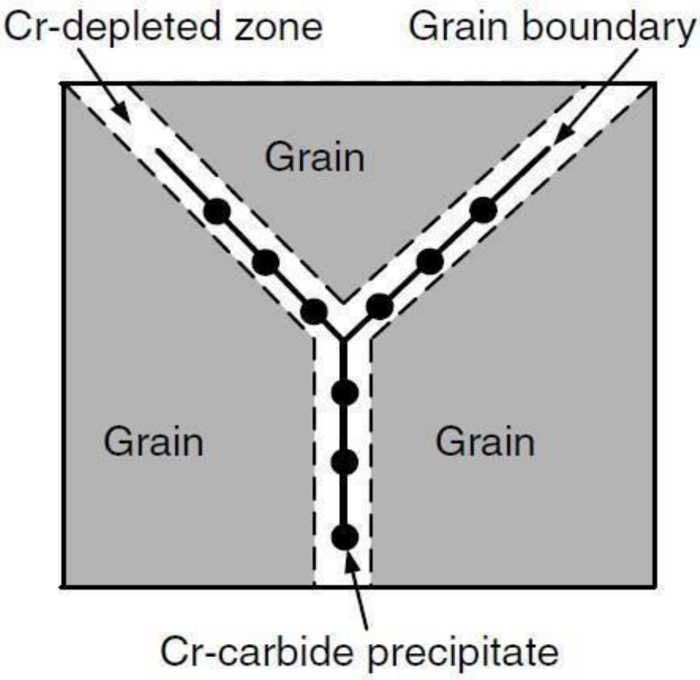


Figure 7.1 Grain boundary microstructure in sensitized austenitic stainless steel.

Weld decay does not occur immediately next to the fusion boundary, where the peak temperature is highest during welding. Instead, it occurs at a short distance away from it, where the peak temperature is much lower.

This phenomenon can be explained with the help of thermal cycles during welding, At position 1 near the fusion boundary, the material experiences the highest peak temperature and cooling rate. Consequently, the cooling rate through the precipitation range is too high to allow Cr carbide precipitation to occur. At position 2, which is farther away from the fusion line, the retention time of the material in the sensitization temperature range is long enough for precipitation to take place. At position 3, outside the HAZ, the peak temperature is too low to allow any precipitation.

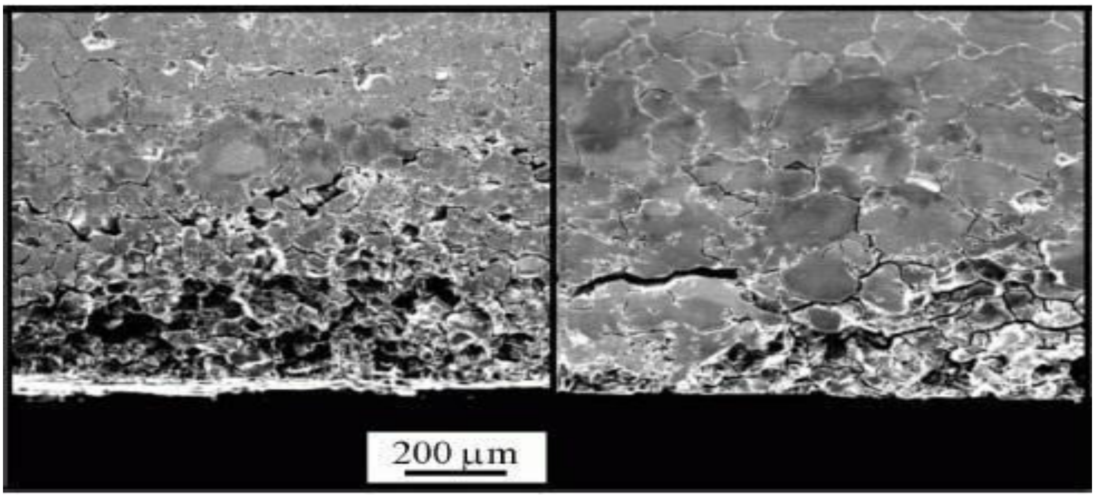


Figure 7.2. Micrographs showing grain dropping due to intergranular corrosion.

7.2 Remedies to Sensitization

Sensitization in austenitic stainless steels can be avoided as follows. [9]:

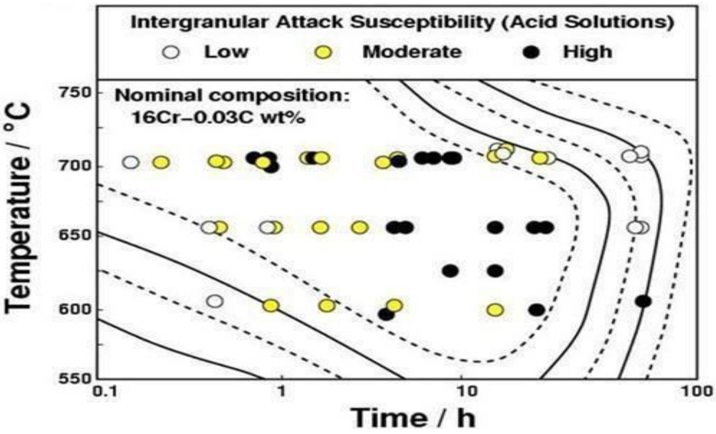


Figure 7.3. Time and temperature dependency of sensitization

1.Reducing the time during which the temperature of the steel is in the 450 to 850°C range. This is done by rapid cooling and minimizing heat input during welding and heat treatment.

2. Selecting the stainless steel (for welding) with lower carbon content because the lower the amount of carbon less is the effect.i.e. Of forming chromium carbide. The effect increases as the % of carbon increases. Steels with small % of carbon take much longer time to form carbides.

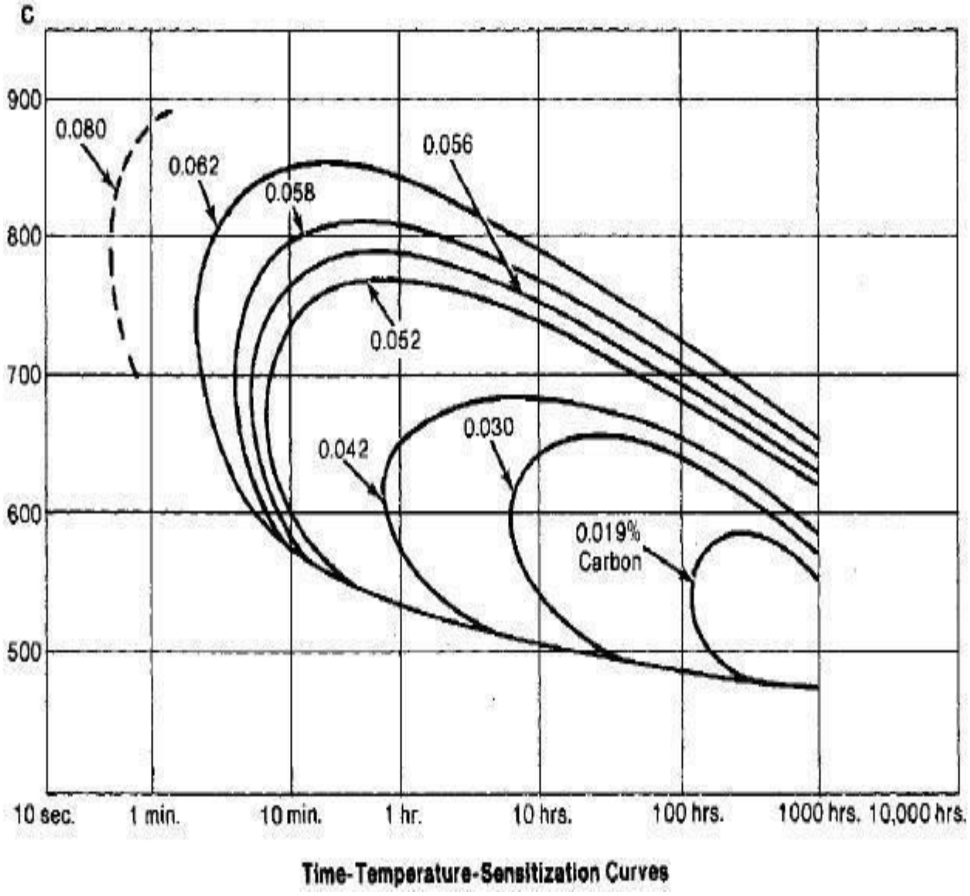


Figure 7.4. Effect of carbon contents in steel on the sensitization conditions.

1.Addition of strong carbide formers, suitable additions of Niobium and Titanium. These elements prevent the formation of chromium carbides by forming titanium or niobium carbides.

2.Heat-treatment (quenching from more than1000 °C) of the welded structure also removes the intergranular corrosion in steel. This type of annealing heat treatment is done where high corrosion s required.

7.3 Material Used

SS 304 and ss409 is selected for present stainless study steel family therefore attempt is made to describe stainless steels, austenitic stainless steels and SS 304 in this section of introduction.

7.4 Stainless Steel

A small amount of carbon alloyed with iron makes steel. Iron is allotropic in that it exists in at least two distinct crystalline forms, primarily dependent upon temperature. At high temperatures, the face centered cubic (FCC) crystal structure of iron is stable and the term used to describe this phase is austenite.

Stainless steels are classes usually contain from 12 to 27% Cr and 1 to 2% Mn by weight, with the addition of Ni in some grades. A small amount of carbon is also present, either deliberately added or as an unavoidable impurity. In general, they are alloyed with a number of other elements that make them resistant to a variety of different environments. These elements also modify the microstructure of alloy, which in turn has a distinct influence on their mechanical properties and weld ability.

Cr provides the basic corrosion resistance to stainless steel. A thin layer of Cr- oxide from on the surface of metal when it is exposed to oxygen of the air. The film act as a barrier to further oxidation, rust and corrosion. Stainless steels are extensively used in variety of applications where corrosion resistance is required in combination with good strength and toughness. Stainless steel can be classified into three major categories based on the structure: Ferritic, Martensitic and Austenitic.

7.5 Austenitic Stainless Steels

Among the various classes of stainless steels, the most easily welded are austenitic stainless steels. These steels contain typically 16-25% Cr, 7-20% Ni and less than 0.08% C. For improved corrosion resistance, 2-6% Mo, 0.1-0.2% N and niobium or titanium in the stabilized varieties are added. Austenitic stainless steels are usually the most corrosion resistant of all the stainless steels and generally have low yield strength and high ultimate tensile strength that is why are often very ductile and has excellent properties at cryogenics temperature.

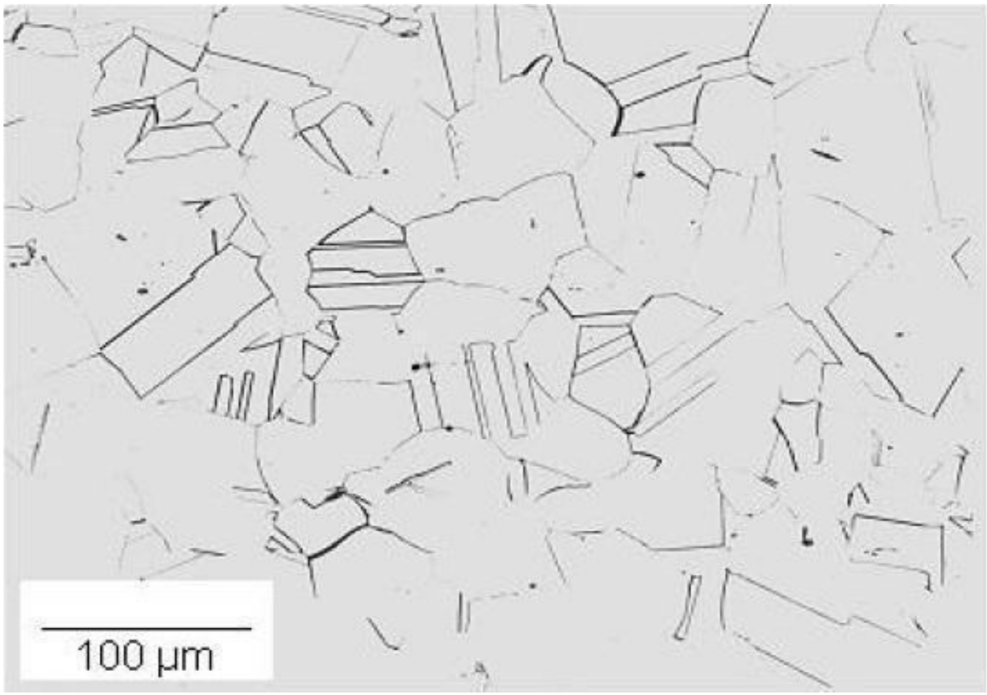


Figure 7.5 General microstructure of austenitic stainless steel.

Alloying additions can also alter the temperature ranges where fcc and bcc is stable. Nickel atoms are nominally the same size as iron atoms and arrange themselves in the FCC structure over a significant temperature range. Therefore, substitution of nickel atoms for iron atoms makes the austenite phase stable to very low temperatures. Chromium atoms are bcc therefore, a large substitutionl addition of chromium to the steel has the effect of stabilizing the ferrite phase. Thus, when approximately 8% nickel and 18% chromium are alloyed with iron, the austenite phase is stabilized down to very low temperatures and an austenitic stainless steel is produced. Carbon and nitrogen atoms are smaller than the iron, chromium, or nickel atoms and occupy interstitial sites between the primary atoms in a given crystal. The unit cell structure of the austenite phase accommodates these interstitial atoms more readily than the unit cell structure of the ferrite phase. Therefore, carbon and nitrogen are very strong austenite stabilizers at relatively small volume fraction additions. Sulphur and phosphorus are considered trace impurity elements, remnant from primary and secondary processing.

Table 1.1 Influence of physical properties on welding austenitic stainless steel compared to carbon steel.

Properties	Austenitic stainless steel	Carbon Steel	Remarks
Melting Point (Type 304)	1400 - 1450°C	1540°C	Type 304 requires less heat to produce fusion.
Magnetic response	Non-magnetic at all temperatures	Magnetic to over 750°C	Nickel stainless steels are not subjected to arc blow.
Rate of conductivity	(Type 304)		Type 304 conducts heat much more slowly than carbon steel.
100°C	28%	100%	
650°C	66%	100%	
Electrical resistance (Annealed)			lower current,as compared to Carbon steel.
At 20°C	72	12.5	
At 885°C	126	125	

7.6 316L WELDING ROD

316L electrodes are used for welding 18% Cr–12% Ni–2.5% Mo stainless steels where the corrosion-resistant qualities of AISI 316L are required. This electrode has a high deposition rate and produces a weld deposit with fine bead appearance and exceptional crack-resistance.

Tabl 7.2 Specification of welding Rod

Diameter	Standard
Length	350mm
Size	5mm
Operating Current	AC,DC
Material	Stainless Steel

Table7.3. Chemical composition of the base metal (0.19 wt. % C).

C%	Si%	Mn%	P%	S%	Al%	Mn%	Nb%	Ti%
0.19	0.25	0.4	0.025	0.015	0.09	0.009	0.05	0.03

Table 7.4. Chemical composition of electrode, wt %.

C%	Si%	Mn%	P%	S%	Al%	Nn%	Nb%	Ti%
0.06-0.12	0.01	0.40-0.6	0.025	0.025	-	-	-	-

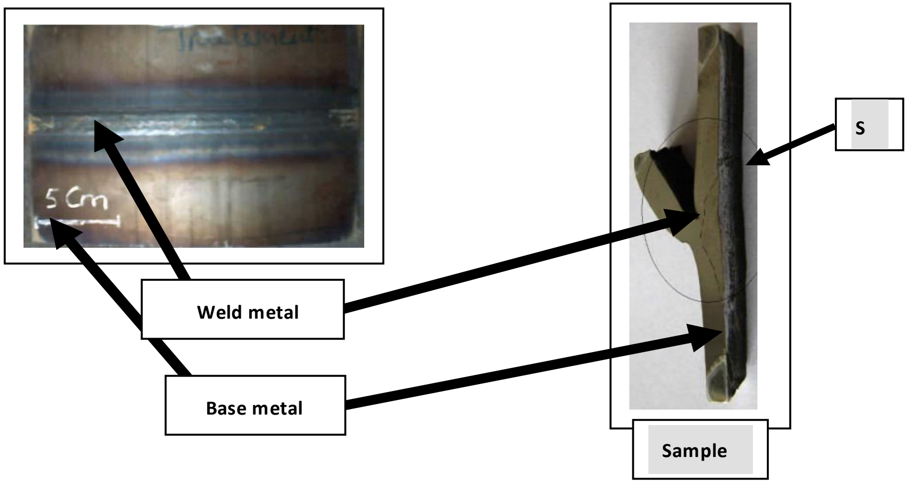


Figure 7.6. Part of welded sheets and sample used in the study. (S: Surface studied).

7.7 Stainless Steel 304

The carbon content is kept to 0.08% or less to avoid the formation of chromium rich carbides during processing and especially during welding. A loss of free chromium by the formation of chromium-rich carbides can drastically reduce the local corrosion resistance and lead to preferential intergranular attack. If the carbon content in the steel is high (>0.03 wt. %), chromium-rich carbides may precipitate on grain boundaries in the weld heat affected zone. Such precipitation reduces the free chromium content and makes the heat affected zone (HAZ) susceptible to intergranular corrosion. Such condition reducing the amount of carbon available for the reaction with chromium, the grades of stainless steel have an enhanced resistance to weld HAZ sensitization. [16] Chromium is, of course, the primary element for forming the passive film (i.e. high- temperature, corrosion-resistance chromium oxide). Other elements can influence the effectiveness of chromium in forming or maintaining the film, but no other element can, by itself, create the stainless steel. Nickel in sufficient quantities, is used to stabilize the austenitic phase and to produce austenitic stainless steel. A corrosion benefit is obtained as well, especially in reducing environments. Nickel is particularly useful in promoting increased resistance to mineral acids. When nickel is increased to about 8 to 10% this is a level required to ensure austenitic structures in a stainless steel that has about 18% chromium.] Table 1.2 and 1.3 shows the chemical composition range and mechanical properties of SS 304 respectively.

Table 7.5 Composition ranges for 304 grade of stainless steels.

	C	Mn	Si	P	S	Cr	Mo	Ni	N
Min.	-	-	-	-	-	18.0	2.00	10.0	-
Max.	.08	2.0	.75	.045	.03	20.0	3.00	14.0	.10

Table 7.6 Mechanical properties of 304 gradestainless steels at room temperature.

U.T.S (MPa) min	Y.S 0.2% Proof (MPa) min	% Elongation (%in 50 mm) Min	Hardness	
			Rockwell Max	Brinell Max
515	205	40	92	202

Generally, the Alloy 304 and 304L grades can be considered to perform equally well for a given environment. A notable exception is in environments sufficiently corrosive to cause intergranular corrosion of welds and heat affected zones on susceptible alloys. In such media, the Alloy 304 grade is preferred for the welded condition since low carbon levels enhance resistance to intergranular corrosion. For applications where heavy cross sections cannot be annealed after welding or where low temperature stress relieving treatments are desired, the low carbon Alloys 304 is available to avoid the hazard of intergranular corrosion

7.8 Welding Equipment

SMAW was used for experimentation. Welding machine used is shown in fig.

Having following specifications.

Manufacturer : Tech Pro, India

Supply voltage : 380/415/440 V

Welding current range : 5 A –350 A (DC)

Open circuit voltage : 80 V

Weight : 280 kg

Figure 7.7 Welding machine used.

7.9 Welding Consumables and Variables

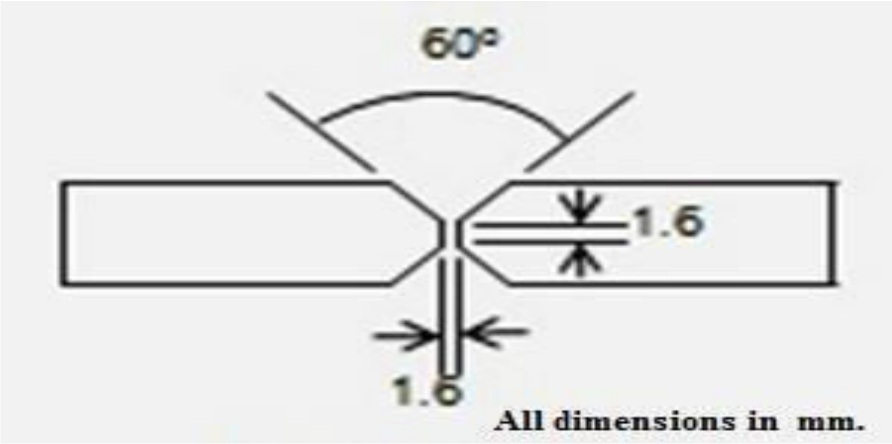


Figure 7.8 Joint design used, Double V.

- Material thickness : 5 mm
- Joint design : Double V
- Root face : 1.6 mm
- Root gap : 1.6 mm
- Joint type : Butt joint
- No. of Passes : 2
- Electrode dia : 2.0 mm
- Electrode type : EW-TH-2 (Thoriated tungsten)
- Filler rod dia : 1.6 mm
- Filler metal : SS 304
- Shielding gas : Industrial Argon
- Machine make : Tech Pro
- Polarity : Straight
- Welding torch used : Air cooled
- Voltage = 25 V
- Welding current = 130, 170 and 210 A

7.10 Working Procedure

Test coupons were prepared by butt welding 304 austenitic stainless steel specimens to each other by using a welding wire made from the same material. GTAW manual welding process was used. First of all, trial runs were conducted to find out the current range to be used and three set of TIG parametric combinations were decided for various heat inputs 130 A, 170 A and 210 A, because of well-established fact that among all the welding variables in arc welding processes welding current is the most influential variable since it affects the current density and thus the melting rate of the filler as well as the base material. The heat input from the welding process plays a major role in the heating and cooling cycles experienced by the weld and parent plate during welding. For a given plate thickness, a high heat input is likely to result in a slower cooling rate than a low heat input, and will therefore produce a softer microstructure in the HAZ that is less prone to hydrogen cracking. However, that does not mean that welding should always be carried out with a high heat input, because this brings with it other problems, such as loss of mechanical properties and an increased risk of solidification cracking. So it is necessary to select a heat input to give a sound weld with the desired mechanical properties.

Table 7.7 Heat input at different welding Conditions.

Welding current (A)	Voltage (V)	Pass	Welding Speed mm/min	Heat input per unit length per pass (kJ/mm)	Total heat input per unit length of weld (kJ/mm)
130	25	1st	95	1.43	3.32
		2nd	72	1.89	
170	25	1st	105	1.7	3.8
		2nd	85	2.1	
210	25	1st	215	1.02	2.20
		2nd	187	1.18	

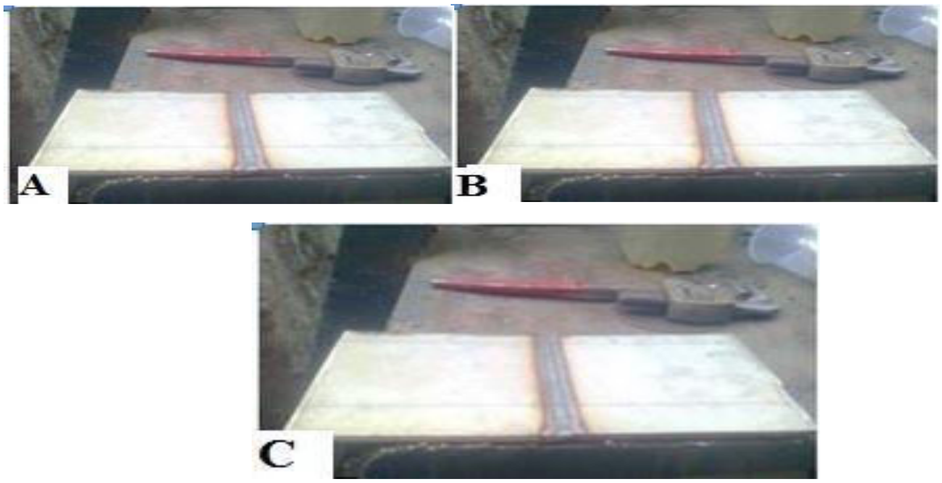


Figure 7.9 Welding Specimen

7.11Testing

Micro structural studies, tensile strength, micro hardness and impact strength tests were performed on as welded and sensitized specimens. Firstly, testing was done on as welded samples to find out the welding parameters for further work on sensitization studies and further testing was carried out on sensitized (heat treated) specimens welded at parameters decided after testing of as welded samples.

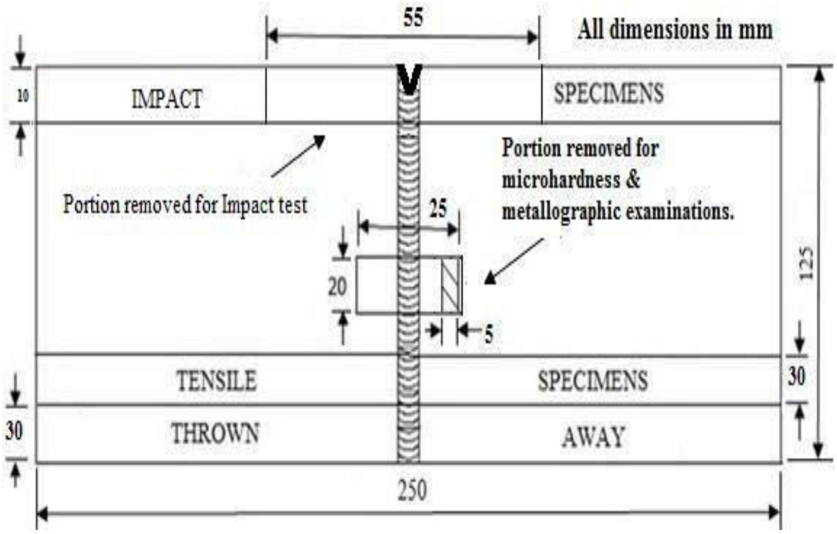
7.12 Specimen Sampling

In order to evaluate the mechanical and microstructural properties of the SS 304 weldments, the specimens for transverse tensile testing, impact strength, micro hardness testing and micro structural studies were machined out from welded pads.

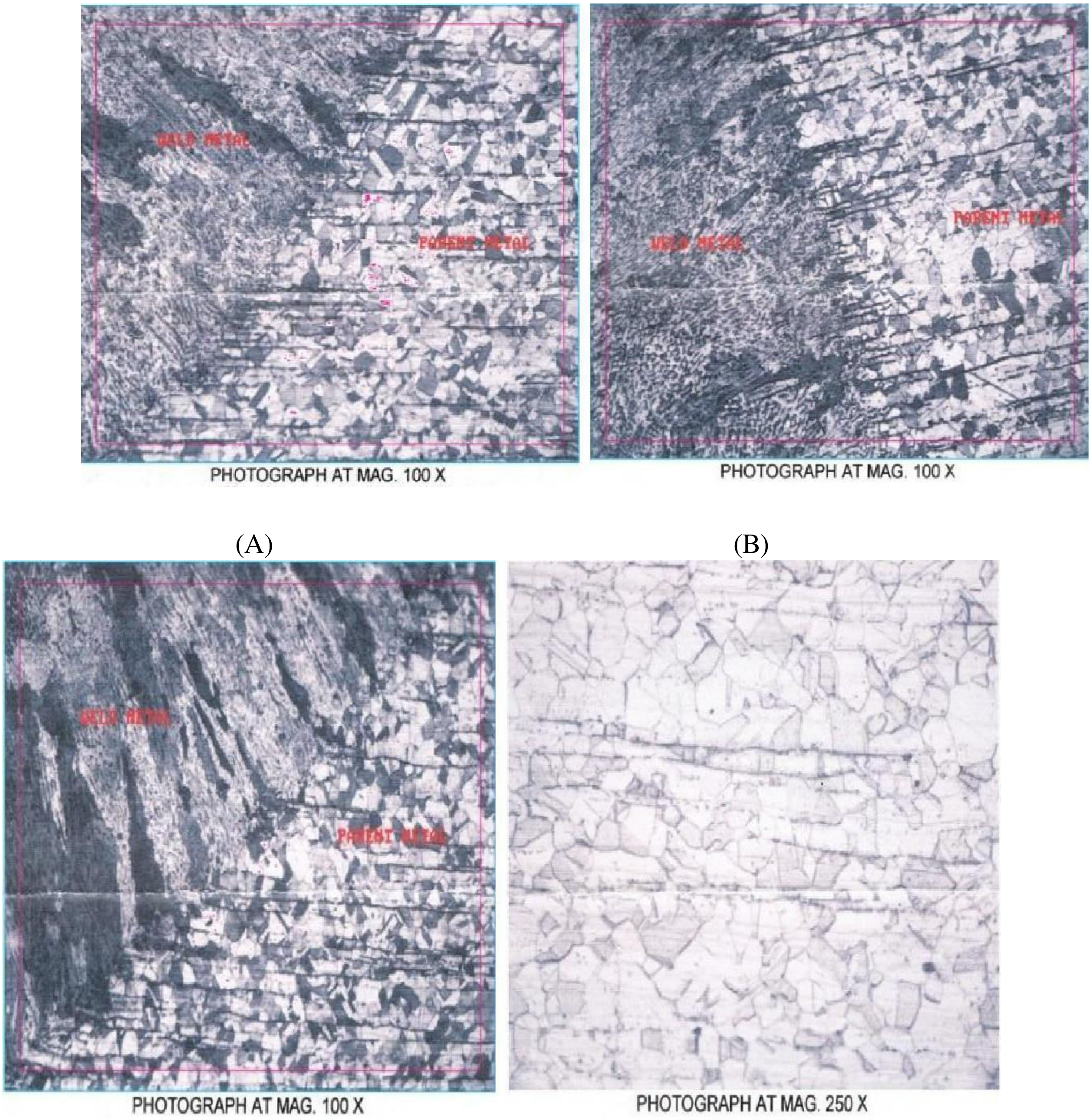
7.13 Microstructural Examination

In order to determine the microstructural changes taking place during welding under different heat input conditions and normalizing, microstructural examination was carried out on the cross section of the base metal, fusion boundary including both HAZ and weld metal and micrographs were captured with the help of optical microscope attached with a camera. Microstructural examinations were performed at LPU.

Figure 7.10 Optical microstructure



The microstructure of weld metal shows delta ferrite in the matrix of austenite and of parent metal shows equiaxed grains of austenite. Dark streaks visible are stringers of ferrite and these are minimum in sample welded at minimum heat input of2.20 kJ/mm.



(A) (B)

(C) (D)

Figure 7.11 Photomicrographs of base metal and as welded specimens, welded under different heat conditions (A) 2.2kJ/mm, (B) 3.32kJ/mm, (C) 3.8 kJ/mm and (D) Base metal.

7.14 ROCKWELL HARDNESS TEST

7.14.1 Physical Properties of 304 Steel

Stainless steels get their names from the American Iron & Steel Institute (AISI) and the Society of Automotive Engineers (SAE), who have separately created their own naming systems for steel alloys based on alloying elements, uses, and other factors. Steel names can get confusing, as the same alloy can have different identifiers depending on which system is used; however, understand that the chemical composition of most alloy blends remains the same across classification systems. In the case of stainless steels, they are often composed of 10 to 30% chromium and are made to withstand varying degrees of corrosion exposure. To learn more about the differences among stainless steels, feel free to read our article on the steel. Type 304 steel is part of the 3xx stainless steels or those alloys which are blended with chromium and nickel. Below is a chemical breakdown of 304 steel:

- <=0.08% carbon
- 18-20% chromium
- 66.345-74% iron
- <= 2% manganese
- 8-10.5% nickel
- <=0.045% phosphorus
- <=0.03% sulfur
- <=1% silicon

The density of 304 steel is around 8 g/cm^3, or 0.289 lb/in^3. Type 304 steel also comes into three main varieties: 304, 304L, and 304H alloys, which chemically differ based on carbon content. 304L has the lowest carbon percentage (0.03%), 304H has the highest (0.04-0.1%), and balanced 304 splits the difference (0.08%). In general, 304L is reserved for large welding components that do not require post-welding annealing, as the low carbon percentages increase ductility. Conversely, 304H is most used in elevated temperatures where the increased carbon content helps preserve its strength while hot.

Type 304 steel is austenitic, which is simply a type of molecular structure made from the iron-chromium-nickel alloy blend. It makes 304 steel essentially non-magnetic, and gives it a lower weakness to corrosion between grains thanks to austenitic steels being generally low carbon. 304 steel welds well using most welding methods, both with and without fillers, and it easily draws, forms, and spins into shape.

Corrosion resistance & temperature effects

Type 304 steel, being the most popular stainless steel, is naturally chosen for its corrosion resistance. It can resist rusting in many different environments, only being majorly attacked by chlorides. It also experiences increased pitting in warm temperatures (above 60 degrees Celsius), though the higher carbon grades (304H) mitigate this effect considerably. This means that 304 steel mainly rusts not in high temperatures, but in aqueous solutions where continuous contact with corrosive materials can wear down the alloy. 304 steels are not readily hardened by thermal treatment, but can be annealed to increase workability and cold worked to increase strength. If corrosion resistance is of high priority to a project, 304L is the best choice as its decreased carbon content reduces intergranular corrosion.

Mechanical Properties

Table 7.8 Summary of mechanical properties for 304 steel.

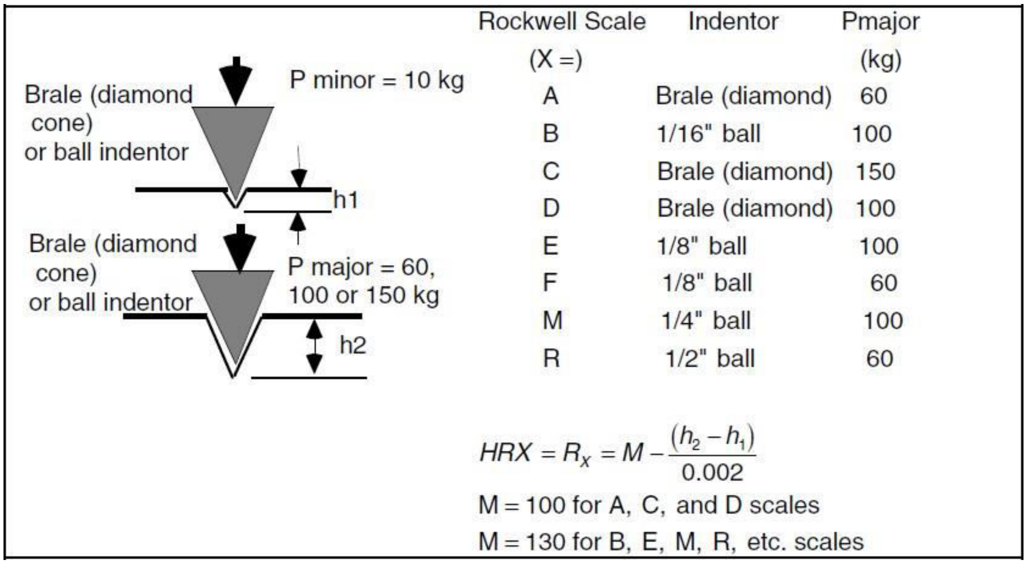
Mechanical Properties	Metric	English
Ultimate Tensile Strength	505 MPa	73200 psi
Tensile Yield Strength	215 MPa	31200 psi
Hardness (Rockwell B)	70	70
Modulus of Elasticity	193-200 GPa	28000-29000 ksi
Charpy Impact	325 J	240 ft-lb

Table 1 shows some basic mechanical properties of 304 steel. The following section will briefly detail each of these parameters, and show how they are pertinent to the working properties of 304 steel. The ultimate tensile and tensile yield strengths are a measure of a material's resilience to tensile (pulling) forces. The yield strength is lower than the ultimate strength, as the yield strength describes the maximum stress before the material will deform permanently, whereas the ultimate strength refers to the maximum stress before fracture. While not as strong as some other steels available, the decreased strengths allow this metal to be easily worked into shape and manipulated without much difficulty.

The Rockwell B hardness test is one of the various hardness tests used to describe a material’s response to surface deformation. A harder material will not scratch easily and is typically more brittle, while a softer material will deform under local surface stress and is generally more ductile. The higher the Rockwell hardness, the harder the material, but to what degree depends on how it compares to other metals on the same scale. 304 steel has a Rockwell B hardness of 70; for reference, the Rockwell B hardness of copper, a soft metal, is 51. Simply put, 304 steel is not as hard as some of its stainless steel brothers such as 440 steel (see our article on 440 steel for more information), but still holds its own as a tough general purpose steel.Type 304 steel has a range of elastic moduli, depending upon what type is used, but they all lie within 193-200 GPa. The modulus of elasticity is a good measures of a material's ability to retain shape under stress, and is a general indicator of strength. As with most steels, the elastic modulus of 304 steel is quite high, meaning it will not easily deform under stress; however, note that a lower elastic modulus makes it easier to machine, so 304 is often fabricated to have a lower elastic modulus to allow for easy machining.

A relatively obscure, but nevertheless important measure of a material is how much energy is absorbed when it is stuck by a large force, which will show how it fractures under stress. It is vital to know how a material will break, as some applications will desire a more ductile failure scenario over a more brittle fracture. The Charpy impact test uses a large pendulum that swings into a notched specimen of steel to simulate these conditions, where a gauge will show how much energy is transferred from the pendulum into the metal. A low Charpy impact score means that the material is generally harder, where its rigid crystal structure would rather simply fracture under the high energy pendulum force. 304 steel has a high Charpy impact score, meaning it is generally more malleable and will bend before it breaks, absorbing some of the impact. This value is yet more proof that 304 steel is easily worked and manipulated, where fracture is less likely under stressful conditions.

The Rockwell hardness test method consists of indenting the test material with a diamond cone or hardened steel ball indenter. The indenter is forced into the test material under a preliminary minor load $\square_0$ (Fig. 1A) usually 10 kgf. When equilibrium has been reached, an indicating device, which follows the movements of the indenter and so responds to changes in depth of penetration of the indenter is set to a datum position. While the preliminary minor load is still applied an additional major load is applied with resulting increase in penetration (Fig. 1B). When equilibrium has again been reach, the additional major load is removed but the preliminary minor load is still maintained. Removal of the additional major load allows a partial recovery, so reducing the depth of penetration (Fig. 1C). The permanent increase in depth of penetration, resulting from the application and removal of the additional major load is used to calculate the Rockwell hardness number.



Rockwell Scale (X =)	Indentor	Pmajor (kg)
A	Brale (diamond)	60
B	1/16" ball	100
C	Brale (diamond)	150
D	Brale (diamond)	100
E	1/8" ball	100
F	1/8" ball	60
M	1/4" ball	100
R	1/2" ball	60

$$HRX = R_X = M - \frac{(h_2 - h_1)}{0.002}$$

M = 100 for A, C, and D scales

M = 130 for B, E, M, R, etc. scales

Figure 7.12. Rockwell Principle

There are several considerations for Rockwell hardness test

- Require clean and well positioned indenter and anvil
- The test sample should be clean, dry, smooth and oxide-free surface
- The surface should be flat and perpendicular to the indenter
- Low reading of hardness value might be expected in cylindrical surfaces
- Specimen thickness should be 10 times higher than the depth of the indenter
- The spacing between the indentations should be 3 to 5 times of the indentation diameter
- Loading speed should be standardized.

7.15Test Result

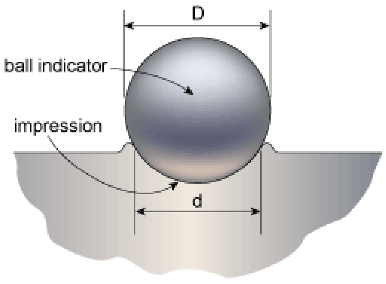
Table 7.9 Test Result

SL NO	Specimen	Type of indentor	RHN	Average RHN
1	SS304&409	Ball(1/6'')	**93**	**93**

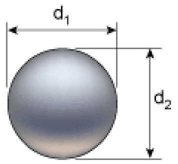
7.16 BRINELL HARDNESS TEST

The Brinell hardness test method consists of indenting the test material with a 10 mm diameter hardened steel or carbide ball subjected to a load of 3000 kg. For softer materials the load can be reduced to 1500 kg or 500 kg to avoid excessive indentation. The full load is normally applied for 10 to 15 seconds in the case of iron and steel and for at least 30 seconds in the case of other metals. The diameter of the indentation left in the test material is measured with a low powered microscope. The Brinell harness number is calculated by dividing the load applied by the surface area of the indentation. When the indentor is retracted two diameters of the impression, d_1 and d_2 , are measured using a microscope with a calibrated graticule and then averaged as shown in *Fig.2(b).*

$$BHN = \frac{P}{\frac{\pi D}{2}\left[D - \sqrt{D^2 - d^2}\right]}$$



(a) Brinell indentation



(b) measurement of impression diameter

The diameter of the impression is the average of two readings at right angles and the use of a Brinell hardness number table can simplify the determination of the Brinell hardness. A well structured Brinell hardness number reveals the test conditions, and looks like this, "75 HB 10/500/30" which means that a Brinell Hardness of 75 was obtained using a 10mm diameter hardened steel with a 500 kilogram load applied for a period of 30 seconds. On tests of extremely hard metals a tungsten carbide ball is substituted for the steel ball. Compared to the other hardness test methods, the Brinell ball makes the deepest and widest indentation, so the test averages the hardness over a wider amount of material, which will more accurately account for multiple grain structures and any irregularities in the uniformity of the material. This method is the best for achieving the bulk or macro-hardness of a material, particularly those materials with heterogeneous structures.

7.16.1 Hardness testing in estimating other material properties:

Hardness testing has always appeared attractive as a means of estimating other mechanical properties of metals. There is an empirical relation between those properties for most steels as follows:

$UTS = 0.35*BHN$ (in kg/mm2)

This equation is used to predict tensile strength of steels by means of hardness measurement. A

$$UTS = \frac{VHN}{3}\left[1-(n-2)\right]\left\{\frac{12.5(n-2)}{1-(n-2)}\right\}^{(n-2)}$$

reasonable prediction of ultimate tensile strength may also be obtained using the relation:

Where VHN is the Vickers Hardness number and n is the Meyer's index.

The 0.2 percent offset yield strength can be determined with good precision from Vickers hardness number according to the relation: *(Hint: For steels, the yield strength can generally* be taken as 80% of the UTS as an approximation)

7.17 Test Result

Table 7.10 Test Result

SL NO	Specimen	Total Load(P) Kg-F	Indentor Diameter(mm)	BHN
1	**Stainless Steel 304&409**	**250**	**2.5**	**205**

CONCLUSION

The properties of material and welding characteristics of were studied. The various mechanical tests such as Rockwell hardness test, Brinell hardness test and microstructure are completed and result will be possible to using dissimilarmaterial joining to future.So, from here after performing different tests on the welded regions of SS 409 and SS 304 and concluded that after performing SMAW welding, this dissimilar material with property of high corrosion resistant and thus this ferritic material provides better facility of corrosion resistant which gives the opportunity of using it on different fields which are highly prone to corrosion areas and so it can use on different fields like on chemical industries, to make machines, engines etc. As the SS 409 and SS 304 has high corrosion resistant property but the difference is SS 304 has better corrosion resistance than SS 409 and also the cost is high than the SS 409. So now the result have succeeded in welding both the materials by performing different test this combination can use it now indifferent fields by the combination of both the material with the help of SMAW welding. It is concluded that the heat produced during the welding is about 3000ich is shown by the red colour on the photograph. It is observed that the heat is travelling throughout the plate. Whereas this temperature will not affect the metal to change its form but it shows that its thermal conductivity is quite higher. From the simulation for heat flux it is observed that the heat flux generated over the bevelled region during welding is about 8.2102e5 W/m^2 which is given by the red colour on the photograph. It travelled over the whole plate from the weld pool and is least at the corners of the plate which is given by blue colour and is about 9906.7 W/m^2.whether there is any defect or not. During microscopic examination or microstructure analysis, the structure of a material is studied under magnification.

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