International Journal of
Emerging Research in Management &Technology
ISSN: 2278-9359 (Volume-4, Issue-6)

Research Article

June 2015

Impact of SMAW on Ss-201

Vijayesh Rathi
Assistant Prof. (ME Dept.), GIMT,
Kanipla, India

Hunny
M.Tech Scholar (ME Dept.), GIMT,
Kanipla, India

Abstract---

Shielded-Metal Arc Welding (SMAW) is one of the oldest, simplest and most versatile arc welding processes. The arc is generated by touching the tip of a coated electrode to the work piece and withdrawing it quickly to an appropriate distance to maintain the arc. The heat generated melts a portion of the electrode tip, its coating and the base metal in the immediate area. The weld forms out of the alloy of these materials as they solidify in the weld area. The main objective is to study the effect of multipass welding on 16mm thick Plates of AISI 201 SS using SMAW process with an aim of achieving maximum strength and to establish correlation between the micro structural changes that are induced due to multipass welding and their mechanical properties.

Keywords---SMAW,tensile strength,welding,radiography.

I. INTRODUCTION

A weld is made when separate pieces of material to be joined combine and form one piece when heated to a temperature high enough to cause softening or melting. Filler material is typically added to strengthen the joint. Welding is a dependable, efficient and economic method for permanently joining similar metals. In other words,one can weld steel to steel or aluminum to aluminum, but cannot weld steel to aluminum using traditional welding processes.Welding is used extensively in all sectors or manufacturing, from earth moving equipment to the aerospace industry.

Welding Processes

The number of different welding processes has grown in recent years. These processes differ greatly in the manner in which heat and pressure (when used) are applied, and in the type of equipment used. There are currently over 50 different types of welding processes; we'll focus on 3 examples of **electric arc welding**, which is the most common form of welding.

The most popular processes are-
1) Shielded metal arc welding **(SMAW)**,
2)Gas metal arc welding **(GMAW)** and
3)Gas tungsten arc welding **(GTAW)**.

All of these methods employ an electric power supply to create an arc which melts the base metal(s) to form a molten pool. The filler wire is then either added automatically (GMAW) or manually (SMAW & GTAW) and the molten pool is allowed to cool.Finally, all of these methods use some type of flux or gas to create an inert environment in which the molten pool can solidify without oxidizing.

Shielded Metal Arc Welding (SMAW)

SMAW is a welding process that uses a flux covered metal electrode to carry an electrical current. The current forms an arc that jumps a gap from the end of the electrode to the work. The electric arc creates enough heat to melt both the electrode and the base material(s). Molten metal from the electrode travels across the arc to the molten pool of base metal where they mix together. As the arc moves away, the mixture of molten metals solidifies and becomes one piece. The molten pool of metal is surrounded and protected by a fume cloud and a covering of slag produced as the coating of the electrode burns or vaporizes. Due to the appearance of the electrodes, **SMAW is commonly known as 'stick' welding**.

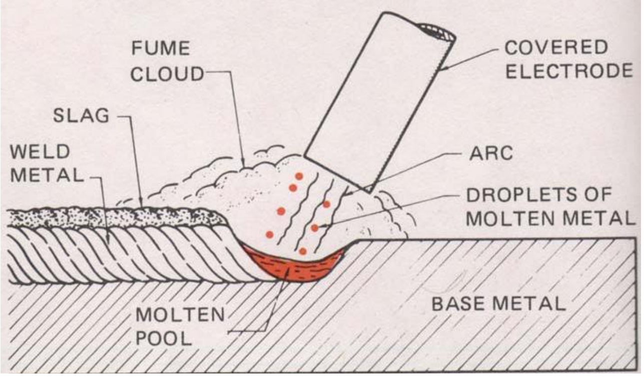


Figure 1: Shielded-Metal Arc Welding (SMAW)

SMAW is one of the oldest and most popular methods of joining metal. Moderate quality welds can be made at low speed with good uniformity. SMAW is used primarily because of its low cost, flexibility, portability and versatility. Both the equipment and electrodes are low in cost and very simple. SMAW is very flexible in terms of the material thicknesses that can be welded (materials from 1/16” thick to several inches thick can be welded with the same machine and different settings). It is a very portable process because all that’s required is a portable power supply (i.e. generator). Finally, it’s quite versatile because it can weld many different types of metals, including cast iron, steel, nickel & aluminum.

Working Principle

To strike the electric arc, the electrode is brought into contact with the work piece by a very light touch with the electrode to the base metal then is pulled back slightly. This initiates the arc and thus the melting of the work piece and the consumable electrode, and causes droplets of the electrode to be passed from the electrode to the weld pool. As the electrode melts, the flux covering disintegrates, giving off shielding gases that protect the weld area from oxygen and other atmospheric gases. In addition, the flux provides molten slag which covers the filler metal as it travels from the electrode to the weld pool. Once part of the weld pool, the slag floats to the surface and protects the weld from contamination as it solidifies. Once hardened, it must be chipped away to reveal the finished weld. As welding progresses and the electrode melts, the welder must periodically stop welding to remove the remaining electrode stub and insert a new electrode into the electrode holder. This activity, combined with chipping away the slag, reduce the amount of time that the welder can spend laying the weld, making SMAW one of the least efficient welding processes. In general, the operator factor, or the percentage of operator's time spent laying weld, is approximately 25%.

The actual welding technique utilized depends on the electrode, the composition of the work piece, and the position of the joint being welded. The choice of electrode and welding position also determine the welding speed. Flat welds require the least operator skill, and can be done with electrodes that melt quickly but solidify slowly. This permits higher welding speeds. Sloped, vertical or upside-down welding requires more operator skill, and often necessitates the use of an electrode that solidifies quickly to prevent the molten metal from flowing out of the weld pool. However, this generally means that the electrode melts less quickly, thus increasing the time required to lay the weld.

Equipment

Shielded metal arc welding equipment typically consists of a constant current welding power supply and an electrode, with an electrode holder, a ground clamp, and welding cables (also known as welding leads) connecting the two. Due to its simplicity and easy to use, it has many applications in the field of pipeline work, shipbuilding, maintenance and repair industries, offshore platforms, naval Industries and construction of steel structures (*Nadkarni, 1988*).

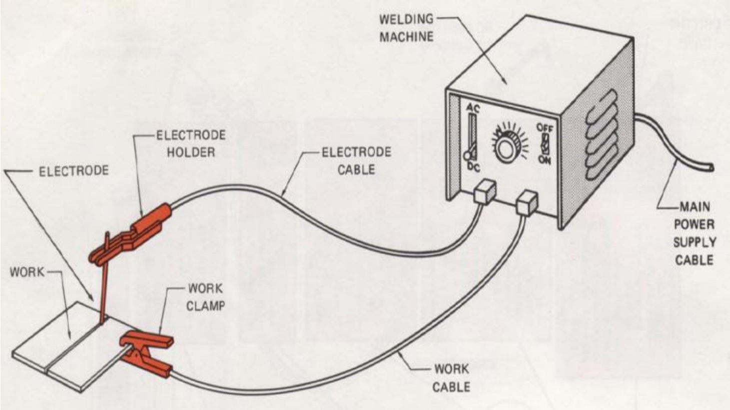


Figure 2:Shielded metal arc welded equipment

Advantages

(1)Versatility - readily applied to a variety of applications and a wide choice of electrodes
(2) Relative simplicity and portability of equipment
(3) Low cost
(4) Adaptable to confined spaces and remote locations
(5) Suitable for out-of-position welding

Disadvantages

(1)It produces a lot of smoke & sparks,
(2)There is a lot of post-weld cleanup needed if the welded areas are to look presentable,
(3)It is a fairly slow welding process and
(4)It requires a lot of operator skill to produce consistent quality welds.

II. RELATED STUDY

S. Murugan et al (1998) studied that the temperature distribution occurs during multipass welding of 6,8 and 12mm thick plates affects the material microstructure, hardness, mechanical properties and the residual stresses that will be present in the welded material. Experimental work was carried out to find out the temperature distribution during multipass welding of the above plates. From the multipass welding of plates the maximum temperature was estimated during different passes of weld and from the knowledge of maximum temperature, the likely changes in microstructure and degradation in mechanical properties are estimated. Average maximum temperature rise during each pass of welding is calculated and plotted against the distance from the weld pad centre line.

S. Murugan et al (2001) investigates the temperature distribution and residual stresses due to multipass welding in type 304 stainless steel and low carbon steel weld pads .The literature work reports the effect of weld pad thickness on residual stress in which the author conclude that the peak tensile residual stresses in 6,8mm stainless steel weld pads are close to each other whereas in12 mm weld pad the value is slightly less and with the no. of passes ,the peak tensile residual stress gradually reduce in magnitude on the root side and gradually increase in magnitude on the top side of weld pads.

G. Magudeeswaran et al (2007) studied the effect of Welding Processes and Consumables on Tensile and Impact Properties of High Strength Quenched and Tempered Steel Joints. In this investigation, an attempt was made to determine a suitable consumable to replace expensive austenitic consumables. Two different consumables , namely, austenitic stainless steel and low hydrogen ferritic steel, were used to fabricate the joints by shielded metal arc welding (SMAW) and flux cored arc welding (FCAW) processes. The experimental work shows that the joints fabricated by using low hydrogen ferritic steel consumables showed superior transverse tensile properties, whereas joints fabricated by using austenitic stainless steel consumables exhibited better impact toughness, irrespective of the welding process used. The SMAW joints exhibited superior mechanical and impact properties, irrespective of the consumables used, than their FCAW counterparts.

Subodh Kumar et al (2011) studied the effect of heat input on the microstructure and mechanical properties of gas tungsten arc welded AISI 304 stainless steel joints in which the dendrite size in the fusion zone is smaller in low heat input joints than the dendrites in medium and high heat input joints, it is found that maximum tensile strength and ductility is possessed by the weld joints made using low heat input. Near to the fusion boundary the size of the grains in the HAZ of the joints is found to be relatively coarser at high heat input and finer at low heat input. The results of the investigation indicate that the joints made using low heat input exhibited higher ultimate tensile strength (UTS) than those welded with medium and high heat input by using GTAW process.

Andrés R et al (2011) predicted the Characterization of failure modes for different welding processes of AISI/SAE 304 stainless steels. In the study the weld joints manufactured with a welding electrode type 308L by three different arc welding processes shielded metal arc welding (SMAW), gas metal arc welding (GMAW) and flux cored arc welding (FCAW) in a AISI/SAE 304 were studied in order to compare the failure mechanisms associated with their mechanical and micro structural properties. Chemical compositions were analyzed by optical emission spectroscopy and the ferrite numbers (FN) of the welds were also identified. Relevant micro structural characteristics of the different processes were analyzed by microscopy techniques. Finally, fatigue tests were performed to study the variations in the mechanical properties of each process and to analyze their most probable failure modes by means of a fractographic study, in which the characteristic morphologies of each one (nucleation, propagation, final fracture) were identified by means of optical stereoscopy and scanning electron microscopy (SEM). The fatigue tests evidenced that the FCAW process has the best fatigue-life performance compared to the GMAW and SMAW processes. Furthermore, in the fractographic analysis three different fracture modes were found at the welding joints that showed correlations with micro structural changes produced during the welding process. The FCAW process was influenced mainly by the first failure mode, while the other two had a mixture of the three different failure modes.

Woei-Shyan Lee et al (2004) studied the deformation and failure response of 304L stainless steel SMAW joint under dynamic shear loading. The dynamic shear deformation behaviour and fracture characteristics of 304L stainless steel shielded metal arc welding (SMAW) joint are studied experimentally with regard to the relations between mechanical properties and strain rate. The results indicate that the strain rate has a significant influence on the mechanical properties and fracture response of the tested SMAW joints. It is found that the flow stress, total shear strain to failure, work hardening rate and strain rate sensitivity all increase with increasing strain rate, but that the activation volume decreases. It is found that the strain rate has a significant influence upon the dynamic shear properties and fracture response of 304L SS weldments. The flow stress, yield stress and total shear strain to failure all increase as the strain rate is increased.

K. M. Deen et al (2010) predicted that to understand and predict the mechanical properties a weldment such as strength and toughness, it is important to know the microstructures and micro-hardness values of the weld metal and heat-affected zone regions. During welding thermal cycle heating and cooling rates of weld are much faster than those of steel base metal. Thus metallurgical transformations across the weld and heat affected zone vary, thereby their microstructures and morphologies become important. The microstructures that develop during welding thermal cycle are dependent on energy input, preheat, metal thickness (heat sink affect) and weld bead size. As a result of different chemical compositions and inclusions weld metal microstructures significantly differs from those of the HAZ and base metal.

Y.C. Lin et al (1995) studied a new technique for reducing the residual stress induced by welding in type 304 stainless steel .The experimental results showed that the maximum principal residual stress and parallel welding direction stress can be reduced by 21-32% when the conventional welding(CW) process is replaced by the parallel heat welding process and the effect of stress relief with lower heat input condition is more efficient then that with high heat input condition. Thus the increase of equilibrium temperature during welding process is a major mechanism of stress relief with PHW process.

Ravindra Kumar et al (2008) investigates the oxidation behaviour of base metal, weld metal and HAZ regions of SMAW weldment in ASTM SA210 GrA1 steel. Shielded metal arc welding (SMAW) was used to weld together ASTM

SA210 GrA1 steel. The oxidation studies were conducted on different regions of shielded metal arc weldment i.e., base metal, weld metal and heat affected zone (HAZ) specimens after exposure to air at 900 ◦C under cyclic conditions. The oxidation resistance was found to be maximum in case of HAZ due to the formation of densely inner oxide scale and it was least in case of base metal.

Zhibo Dong et al (2006) Predicted weld solidification cracks in multipass welds of SUS310 stainless steel. It is found that the driving force of first weld pass is larger than following weld passes. Furthermore, this paper predicts the weld solidification cracks of walled plates. The predicted results agree well with actual fabrication. The weld metal solidification cracks are controlled when the Chinese Daqing Oilfield adopts the welding procedure in this paper.

III. PROPOSED WORK

Problem Definition

Based upon the literature survey the research gaps identified were:

- Literature reports that many works are available where research attempts have been made on section thickness up to 12mm plates using various welding processes but only few works are reported for large section thicknesses. The main reason for this is that large sections often pose major challenges in terms of achieving sound quality and consistent mechanical properties.
- Since microstructure changes in the joint are found to affect the microstructure properties. Some papers are available on the study of effect of heat input or the microstructure properties. Changing heat input viz. varying no. of weld passes is known to affect the microstructure properties in favorable manner.

Objectives of the Present Work

- To study the effect of multipass welding on 16mm thick Plates of **J7 201** SS using SMAW process with an aim of achieving maximum tensile strength.
- To establish correlation between the micro structural changes that are induced due to multipass welding and their mechanical properties.
- To conduct X-ray radiography for any type of defects or discontinuities such as cracks, inclusions and porosity.

IV. RESULTS AND DISCUSSION

The objective of this chapter is to give the experimental results which are conducted for the present work. After conducting testing on the work samples, data was collected. Then data was analyzed and compared analytically and graphically.

1) X-ray radiography

To understand the any type of defects or discontinuities such as cracks, inclusions and porosity the radiography of the low and high heat input welded plates have been carried out which is shown in figure 3. and 4.

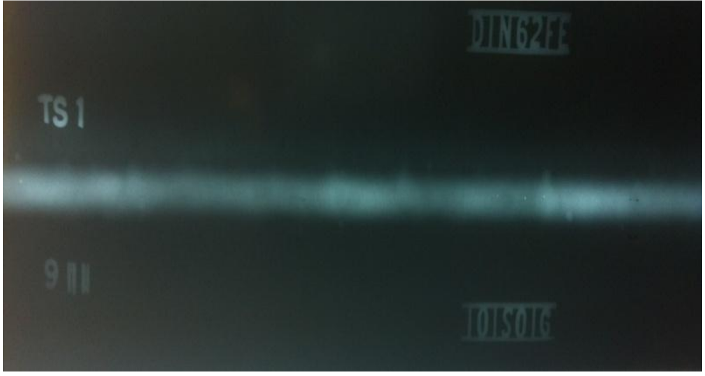


Figure 3: X-Ray Radiography of low heat input welded plates

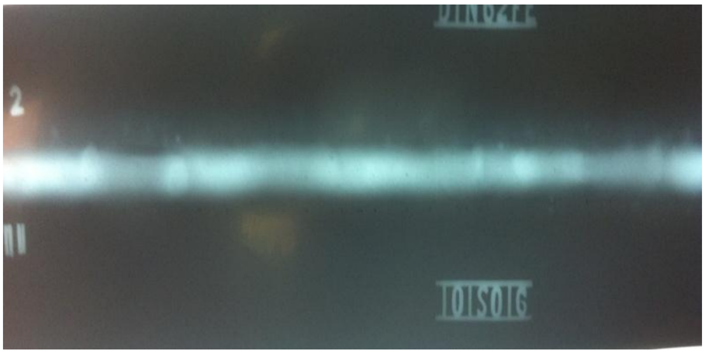


Figure 4: X-Ray Radiography of high heat input welded plates

Table I: X-ray Radiography results

Type of defects	Slag inclusion	Porosity	Internal shrinkage	Crack	Hot tear	Insert	Molting
Results obtained from plate 1	Level-1	Nil	Nil	Nil	Nil	Nil	Nil
Results obtained from plate 2	Nil	Level-1	Nil	Nil	Nil	Nil	Nil

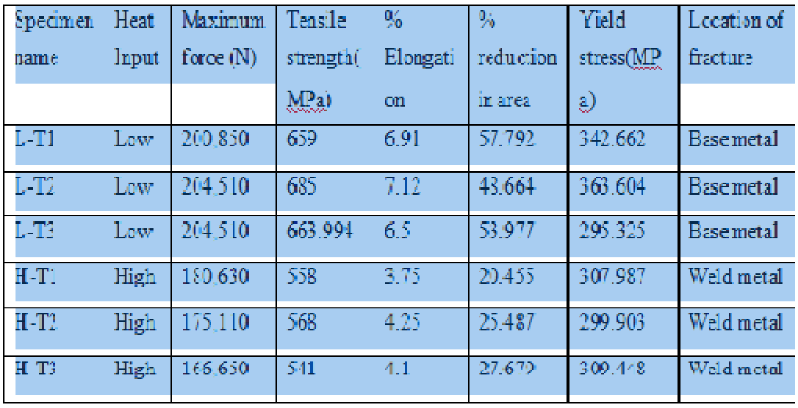
The Table I shows the result of Non-destructive testing on the welded joints of the 304stainless steel plates. Any types of internal flaws or discontinuities such as cracks, shrinkage, hot tear, insert and molting have not been observed in the weldment.

2) Tensile testing results

The transverse tensile strength of the joints made using different heat input conditions has been evaluated. In each condition three specimens were tested and the strength of the specimens per heat input and their corresponding percentage elongations, percentage reduction in area and yield stress thus obtained is mentioned in Table 2. Tensile results obtained from this study show that the average UTS value is 591.835MPa for base metal ,661.398MPa on low heat input combination and 565.357MPa on high heat input combination.

Microstructural details of the weld metal in terms of dendrite size and cell spacing indicates that high tensile strength and ductility is possessed by the joints at low heat input, which can be attributed to smaller dendrite sizes and lesser inter-dendritic spacing in the fusion zone. Relatively lower tensile strength and ductility is possessed by the joints with long dendrite sizes and large inter-dendritic spacing in the fusion zone of the joint welded using high heat input. Further it is found that all the low heat tensile specimens fractured in the base metal as shown in figure 4. which indicates that weld metal in all the joints possessed higher tensile strength than the base metal whereas all the high heat tensile specimens fractured in the weld zone as shown in Fig. 4. which indicates that base metal possessed higher tensile strength than the weld metal.

Table II- Results from transverse tensile test



Specimen name	Heat Input	Maximum force (N)	Tensile strength(MPa)	% Elongation	% reduction in area	Yield stress(MPa)	Location of fracture
L-T1	Low	200.850	659	6.91	57.792	342.662	Basemetal
L-T2	Low	204.510	685	7.12	43.664	363.604	Basemetal
L-T3	Low	204.510	663.994	6.5	53.977	295.325	Basemetal
H-T1	High	180.630	558	3.75	20.455	307.987	Weld metal
H-T2	High	175.110	568	4.25	25.487	299.903	Weld metal
H T3	High	166.650	541	4.1	27.672	309.418	Weld metal

Figure 5: Fracture features of transverse tensile tested specimens showing the location of fracture.

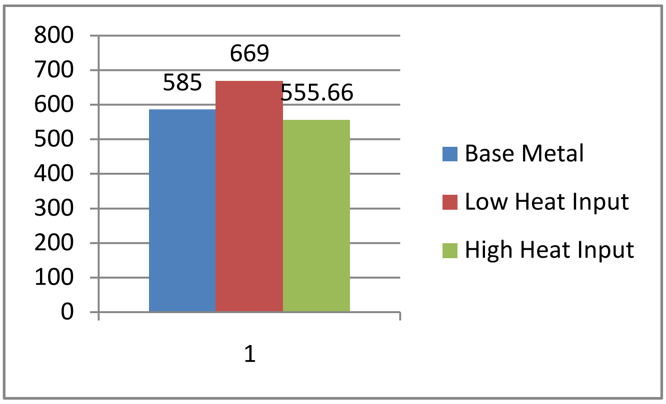


Figure 6:Comparison of tensile strength for base meat and as welded plates

3) Micro structural properties

Full penetration welds were obtained in both combinations of heat input .It is found that as heat input increases the fusion areas of the joints also increase proportionately. The same trend is followed for the HAZ area associated with each of these joints. Several Studies reported that the fusion zone and HAZ area increase with increase in heat input.

Optical micrographs showing the microstructures of base metal, weld zone and HAZ for different heat input combinations are presented from Figs. 7-9. It is observed from these optical micrographs that as heat input increases the dendrite size and inter-dendritic spacing in the weld metal also increase. This dendrite size variation can be attributed to the fact that at low heat input, cooling rate is relatively higher due to which steep thermal gradients are established in the weld metal, which in turn allow lesser time for the dendrites to grow, whereas at high heat input, cooling rate is slow which provides ample time for the dendrites to grow farther into the fusion zone.

Micro structural studies have shown that at low heat input, due to high cooling rate fine grain dendritic structure is obtained in weld metal and the base metal indicates self cooled non homogeneous structure where as at high heat input relatively coarse grain inter dendritic structure is observed.

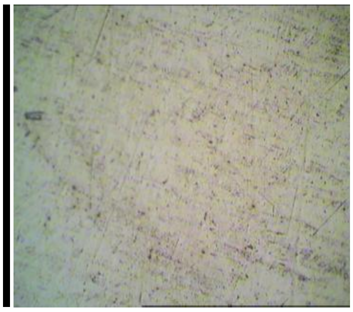


Figure 7: Optical micrograph showing the microstructure of base metal

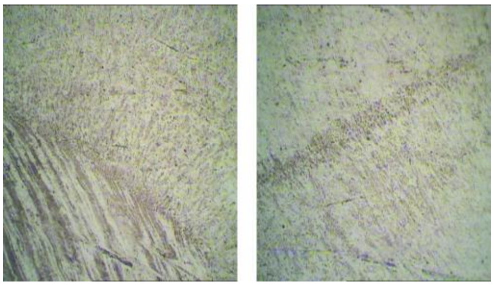


Figure 8: Optical micrograph showing the microstructure of (a) weld metal and HAZ (b)HAZ and base metal(low heat, at 100_).

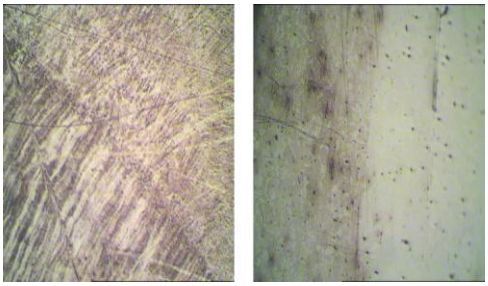


Figure 9: Optical micrograph showing the microstructure of (a) weld metal and HAZ (b)HAZ and base metal (high heat, at 100_).

V. CONCLUSION

Based upon the present study it is recommended that for the multipass welding of J7 201SS using SMAW process the low heat input should be preferred because of the reason that it gives good tensile strength,radiography and exhibit robustness in terms of microstructural properties.

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