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

Research Article

June 2015

Analyzing the Effect of Parameters on SMAW Process

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Abstract--

Shielded metal arc welding (SMAW) is an AW process that uses a consumable electrode consisting of a filler metal rod coated with chemicals that provide flux and shielding. This process provides a purer and cleaner high volume weldment that has a relatively a higher material deposition rate compared to the traditional welding welding methods. The effect of controllable process variables on the heat input and the microhardness of weld metal and heat affected zone (HAZ) are calculated and analysed.The main purpose of present work is to investigate and correlate the relationship between various parameters and microhardness. It is found that the microhardness of weld metal and heat affected zone increased when low heat input is employed.

Keywords---SMAW, HAZ, AW, MMA, microhardness.

I. INTRODUCTION

Welding is the most reliable, efficient and practical metal joining process which is widely used in industries such as nuclear, aerospace, automobile, transportation, and off-shore. In spite of the many advantages, there are some limitations affecting this process. Welding is often done by melting the work pieces and adding a filler material to form a pool of molten material (the weld pool) that cools to become a strong joint, with pressure sometimes used in conjunction with heat, or by itself, to produce the weld. This is in contrast with soldering and brazing, which involve melting a lower-melting-point material between the work pieces to form a bond between them, without melting the work pieces. [5]

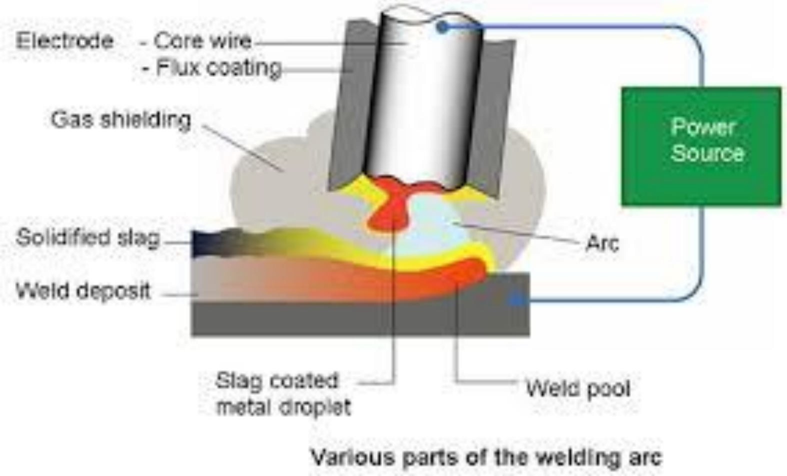

Figure 1:Various parts of welding arc.

1.1. Shielded metal arc welding process (SMAW)

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. Slag formed to protect the weld against forming oxides, nitrides, and inclusions. Welding can be carried out in all positions, both in shop and at site. Welded joints of sound quality and adequate mechanical properties can be obtained by using correctly designed electrodes and proper welding procedures. The process is intermittent, because welding has to be interrupted from time to time to discard the unused stub and to place afresh electrode into the holder and also to deslag the joint, i.e. to remove the layer of slag covering the weld. For higher productivity, semi-automatic or fully-automatic welding processes are preferred.

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**

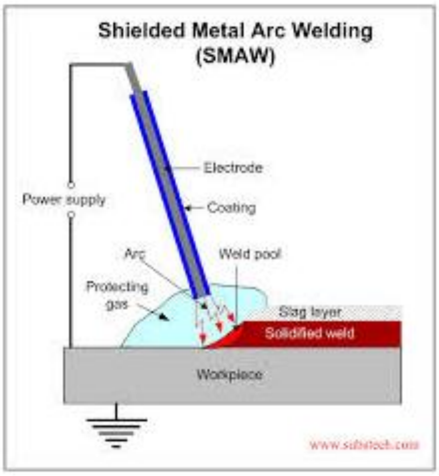

Figure 2:SMAW

Multipass welding is often employed with the submerged arc process. When plate thicknesses exceed the limitation of two pass techniques, or where inability to provide accurate joint fit-up prevents the use of high current - multiple pass submerged arc welding should be used. Where possible, a split pass procedure should be used to allow easy flux removal and to prevent weld cracking. Each weld pass should be slightly convex as shown to assist in slag removal and preventing weld cracking. Multipass welding procedures also enable a variety of weld joints and plate thicknesses to be welded with the same procedures and materials. In certain base materials, the multiple pass welding technique must be used to maintain adequate properties in the base HAZ.For pressure vessel circumferential welds such as head-to-shell and shell butts, this double bevel plate preparation with semiautomatic or automatic Mig used to handle varying fit-up in the root area is an excellent combination procedure. Fill passes are then welded with submerged arc to provide consistent quality low cost welds. The gas metal-arc welding process is the best choice for manual or automatic root or first pass procedures. The resulting weld metal is free from internal slag and external slag is minimal making the subsequent submerged arc welds free from defects. For welding plates above two inches thick, multipass procedures must be used. Welding flux and wire must be selected with multipass procedures in mind. Control of weld chemistry is especially important to insure crack free deposits.

1.2 Problems associated with SMAW

The most common quality problems associated with SMAW include

1) weld spatter,
2) porosity,
3) poor fusion,
4) shallow penetration, and
5) cracking.

Weld spatter, while not affecting the integrity of the weld, damages its appearance and increases cleaning costs. It can be caused by excessively high current, a long arc, or arc blow, a condition associated with direct current characterized by the electric arc being deflected away from the weld pool by magnetic forces.

Porosity, Arc blow can also cause porosity in the weld, as can joint contamination, high welding speed, and a long welding arc, especially when low-hydrogen electrodes are used. Porosity, often not visible without the use of advanced non destructive testing methods, is a serious concern because it can potentially weaken the weld.

Poor Diffusion Another defect affecting the strength of the weld is poor fusion, though it is often easily visible. It is caused by low current, contaminated joint surfaces, or the use of an improper electrode.

Shallow penetration, another detriment to weld strength, can be addressed by decreasing welding speed, increasing the current or using a smaller electrode.

Cracking, Any of these weld-strength-related defects can make the weld prone to cracking, but other factors are involved as well. High carbon, alloy or sulphur content in the base material can lead to cracking, especially if low-hydrogen electrodes and preheating are not employed. Furthermore, the work pieces should not be excessively restrained, as this introduces residual stresses into the weld and can cause cracking as the weld cools and contracts.

1.3. Application and materials

Shielded metal arc welding is one of the world's most popular welding processes, accounting for over half of all welding in some countries. Because of its versatility and simplicity, it is particularly dominant in the maintenance and repair industry, and is heavily used in the construction of steel structures and in industrial fabrication. In recent years its use has declined as flux-cored arc welding has expanded in the construction industry and gas metal arc welding has become more popular in industrial environments. However, because of the low equipment cost and wide applicability, the process will likely remain popular, especially among amateurs and small businesses where specialized welding processes are uneconomical and unnecessary.

SMAW is often used to weld carbon steel, low and high alloy steel, stainless steel, cast iron, and ductile iron. While less popular for nonferrous materials, it can be used on nickel and copper and their alloys and, in rare cases, on aluminium. The thickness of the material being welded is bounded on the low end primarily by the skill of the welder, but rarely does it drop below 0.05 in (1.5 mm). No upper bound exists: with proper joint preparation and use of multiple passes, materials of virtually unlimited thicknesses can be joined. Furthermore, depending on the electrode used and the skill of the welder, SMAW can be used in any position.

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

1.)To study the effect of multipass welding on 16mm thick Plates of **J7 201** SS using SMAW process with an aim of achieving maximum hardness.
2.)To analyze the impact toughness of the base metal, weld metal zone (WM) and heat affected zone (HAZ) of low and high heat inputs.
3.)To study the effect of bend testing on welded samples.

IV. RESULTS AND DISCUSSION

The objective of this paper 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.

4.1 Micro hardness results

The samples were first polished on disc polishing machine and after that the micro hardness was checked. The micro hardness was checked for base metal, weld zone and heat affected zone of low and high heat input welded specimens. At every place readings were taken. All the readings are shown in Table 6.4. Average micro hardness of **base metal is 256 VHN.**

Table I. Micro hardness (VHN) results

Specimen name	Base metal	Weld zone	Heat affected zone
Low heat input	226-231	232-235	265-269
High heat input	226-231	215-218	245-249

Figure 3 and 4 represents the variation of micro hardness values obtained from the different sources such as base metal, as-welded condition. The hardness values of as-welded specimens are much greater than base metal. High hardness values were observed in the HAZ region of the both low and high heat input weldments.

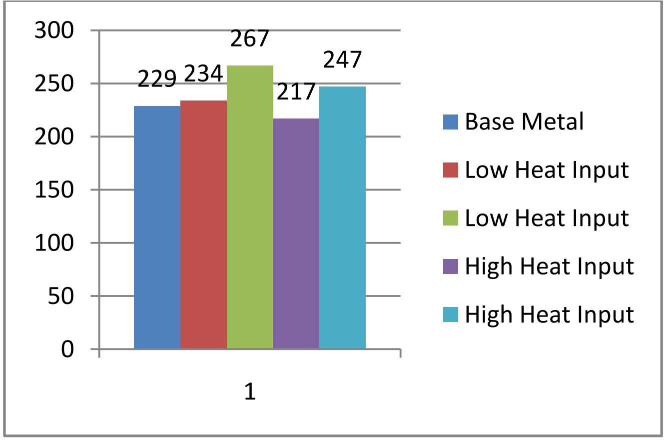

Figure 3: Comparison of micro hardness of base metal and as welded plates

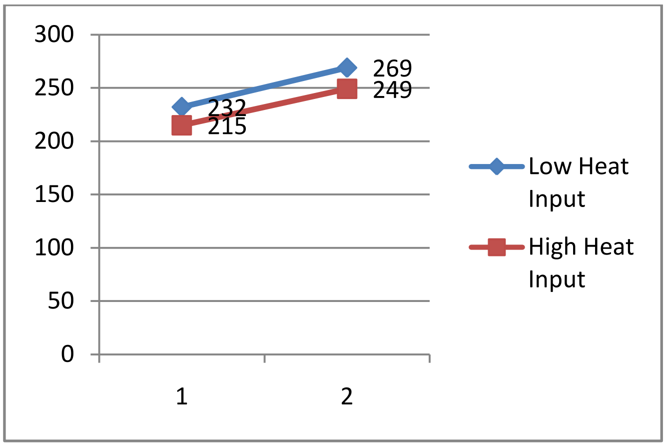

Figure 4:Line graph Comparison of micro hardness of base metal and as welded plates

From the above observation it can be easily concluded that at the low heat input welded joints the micro hardness is coming higher as compared to micro hardness values at high heat input welded joints. The main reason is that the cooling rate of low heat input welded specimens is very higher than at the high heat input and the micro hardness function is directly proportional to cooling at that point. Higher the cooling rate will produce higher micro hardness.

4.2 Impact toughness results

Table 2. shows the results of impact toughness observed from the base metal, weld metal zone (WM) and heat affected zone (HAZ) of low and high heat inputs.

Table II. Impact properties of welded joints With Low and High heat inputs

Specimen name	Impact value	Specimen name	Impact value	Specimen name	Impact value
B1 (BM)	276	L1 (WM)	206	H1 (WM)	78
B2 (BM)	290	L2 (WM)	130	H2 (WM)	212
B3 (BM)	199	L3 (WM)	150	H3 (WM)	195
B4 (BM)	198	L11 (HAZ)	177	H11 (HAZ)	200
B5 (BM)	190	L12 (HAZ)	192	H12 (HAZ)	202
B6 (BM)	218	L13 (HAZ)	172	H13 (HAZ)	228

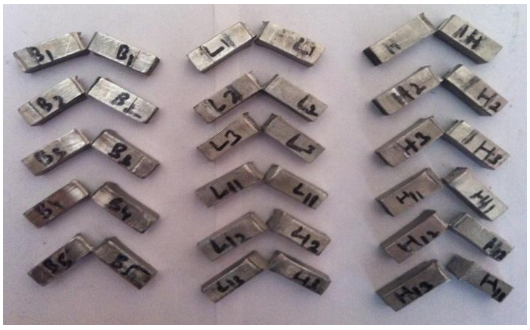

Figure 5: Fracture features of impact tested specimens showing the location of fracture.

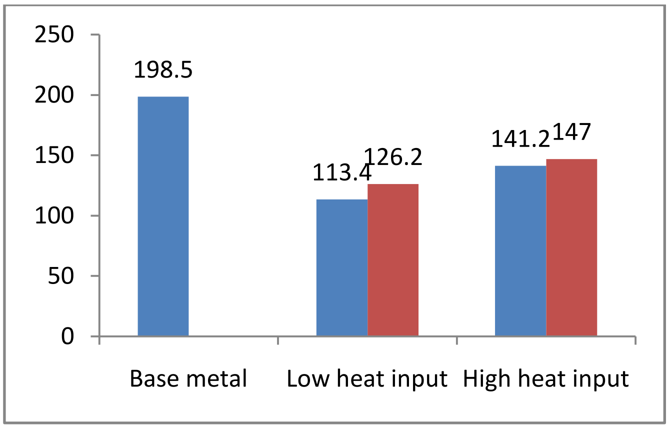

Figure 6:Comparison of impact values for base metal and as welded conditions

4.3 Bend test results

Bend test was conducted on universal testing machine. The load is applied to just start the fracture on the work samples. It was observed that low heat input welded samples have the higher ductility as compared to high heat input welded specimens. Fig.7 shows the fractured features of low and high heat input welded samples after the test.

Figure 7: Fracture features of Bend tested specimens showing the location of fracture On Low and High Heat input Welded Joints.

From above figure it can seen that the cracks were found on high heat input welded specimens where as there is no crack occurred in low heat input welded specimens. Hence it may be concluded that the multipass welding of low heat input welding shows the positive results for bend test.

V. CONCLUSION

In the multipass welding process parameters directly affect the number of passes and total heat input. The individual effect of current, voltage, speed on hardness of weld and HAZ is higher. It is observed that the hardness is higher in the HAZ than the weld metal. With increasing cooling rate, hardness increases in the weld metal and HAZ at higher cooling rate. 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 hardness,toughness and ductility to the material.Bend test also turns positive for low heat input.

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