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OPTIMIZATION OF SHIELDED METAL ARC WELDING (SMAW) PROCESS

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Abstract

Shielded Metal Arc Welding (SMAW) or the conventional arc welding process is particularly dominant in structural joints, pressure vessels and in maintenance and repair work. This process is widely used in many industrial applications due to its versatility, simplicity and indoor and outdoor applicability. A certain level of operational skills is needed in performing the SMAW process in order to obtain a quality weldment. Further, input process parameters such as current, voltage, arc gap, welding speed, electrode orientation, etc. play a vital role in the quality of the weldment. This research especially addresses and simulates mild steel in arc welding, covering industrial applications including small scale industries. The study investigates the influence of different input process parameters on weld quality through mechanical tests and verified through microstructural examinations. Further, authors wish to identify the optimized process variables in obtaining quality weldment at minimum cost for real industrial applications. For the study, thirty-six number of welded samples of mild steel were selected based on a full factorial array, Taguchi's orthogonal array, welding standards, power source specifications and deviations based on a trial experiment. According to the planned experimental procedure, three types of mechanical tests (hardness, toughness and tensile) followed by the microstructural tests were carried out. Results of the investigation revealed that the 12th, 9th and 11th sample sets with corresponding input parameters had produced the best quality weldments. As their joint characteristics, tensile properties are better with poor impact toughness compared to the base metal.

Key words: Arc Welding, SMAW, Optimization, Mechanical tests, Microstructure.

1. Introduction

It is the objective of this study to identify the optimum welding parameters for the manual SMAW process in order to facilitate the industrial applications for better quality weldments. Especially this research addresses and simulates commonly mild steel in arc welding, covering industrial applications including small scale industries. An investigation was carried out to establish the concept by selecting welding current, voltage and groove angle as input welding parameters. As per SMAW process optimization, hardness, toughness/impact strength and tensile strength were determined and analysed experimentally in customizing industrial application with the intended purpose. Further, it is important and possible to improve process optimization continuously with different software developed with data acquisition systems (DAC for big data) in formulating optimized algorithms. The selection of an arc welding process is complex with respect to the work piece, application, simplicity, infrastructure, cost, expected quality, etc. Therefore, a particular welding application is performed with the interaction of many factors and attributes as shown in Figure 1. In this regard, the arrangement of Shielded Metal Arc Welding (SMAW) process is chosen due to its simplicity as few process-attributes such as work piece, welder, power source and electrode make the set up complete. It is an effective and low-cost process for producing quality products [8]. Application of SMAW or Manual Metal Arc Welding (MMAW) is gradually replaced in the global context with the introduction of new processes while it is very important for developing countries with low-cost infrastructure, simplicity and availability of human capital. The shielded metal arc welding is most widely used in small scale industries, because of its low cost, simplicity, flexibility and portability. Further, manual welding still occupies a leading position in domestic, maintenance, fabrication and offshore applications. Special advantages of Shielded Metal Arc Welding (SMAW) process are the improved microstructure at the welded joint by varying chemical coating formulation, availability of electrodes for almost all steels proper weld zone protection without additional equipment and possible to produce thin electrodes in diameter (up to 1mm) . SMAW is carried out best by human skill and practice and assessed by inspection and/or testing of the weld. Methods based on the measurement of input welding parameters (such as current, voltage, groove angle, electrode orientation, etc.) could be applied in assessing welding skill and weld quality. Further, the skill of a welder largely depends on the ability of the welder in maintaining a constant arc gap which, in turn, results in steady-state arc voltage. Highly skilled human welder’s responses are captured in developing models/simulations and also in developing automated welding systems. Hazards could occur during the SMAW process if proper safety precautions are not taken. To minimize the risk of electric shock, health hazards and environmental protection, welders should wear personal protective equipment (PPE) and process control devices during welding and allied processes. Welding process optimization through quantitative analysis is profound and far reaching significance in obtaining quality weldment at a low cost. Scientific analysis of the welding process could be useful and done through a multidisciplinary approach combining electromagnetic effects, heat transfer, fluid flow and solidification. Weld pool geometry is closely related to weld quality. Experimental research on SMAW is complex and it is required to establish a model of heat and mass transfer to investigate the effects of different factors on weld pool geometry. SMAW Process utilizes a constant current type of power sources and different electrodes with flux coatings having different arc characteristics.

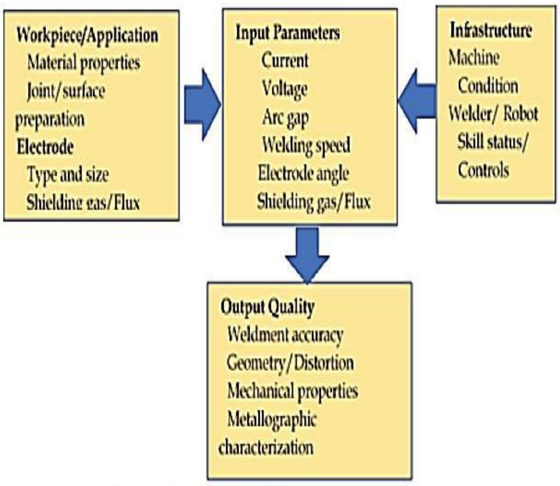

Figure 1. Attributes of arc base welding processes

Hardness properties

Average Rockwell hardness values obtained under selected combinations of weld parameters are plotted in Figure 2 using experimental results. Higher hardness is observed in the weld-zone in all three clusters for all specimens. This can be ascribed possibly to the microstructure resulting from the higher cooling rates experienced by the weld-zone

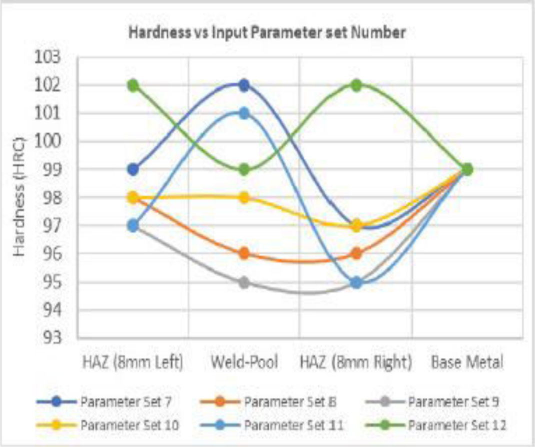

Figure 2 **Hardness of weldments**

Toughness properties

Toughness or impact resistance of the weldments of SMAW is comparatively low compared to those generally obtained using Gas Metal Arc Welding (GMAW), Gas Tungsten Arc Welding (GTAW) and Submerged Arc Welding (SAW), and Friction Stir Welding (FSW). Toughness results are shown in Table 2 and plotted in Figure 3. The experiment revealed that the highest toughness is 41 J (12thspecimen in cluster No 4) whereas the toughness of the base metal is 117J. Accordingly, the highest toughness or impact strength is 35% that of the base metal during SMAW process. Furthermore, impact toughness severely decreased with the decreased groove angle (specimen set 11th& 10th and specimen set 8th & 7th). Low values of toughness could be due to the formation of fine grain structure and/or martensite. Presence of grain boundary ferrite which provides crack propagation paths and cracks enhance by high cooling rates. Determination of the fracture mechanisms responsible for impact failure, however, is beyond the scope of this work.

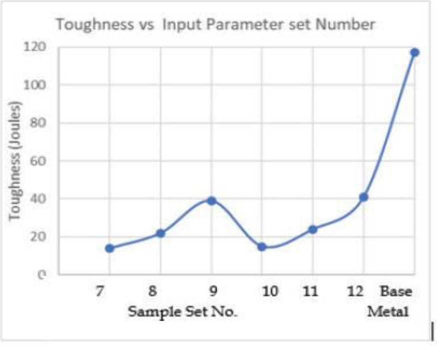

Figure 3 **Toughness of weldments**

Tensile properties

Tensile properties of welded samples of SMAW are better compared with impact strength. The experiment result shows ultimate tensile strength is 355 MPa for welded joint of 12th specimen set and 513 MPa for base metal which shows 70% of UTS recovered after arc welding compared with the base metal. Tensile properties of welded samples are plotted in Figure 4 which are based on the experimental results shown in Table 3. The best values of ultimate tensile strength in the weld zone are obtained in the 12th&11th sets of cluster No.4 and 9th & 8th sets of cluster No.3 of specimens (Table 3). Further, higher the groove angle (600) in 12th & 9th sets of cluster No.4 gives the higher tensile strength (Figure4). Therefore, tensile strength is influenced by the groove angle ("V" groove) of joint Preparation. This can be due to the result of better bonding with higher heat input, mass transfer and faster cooling.

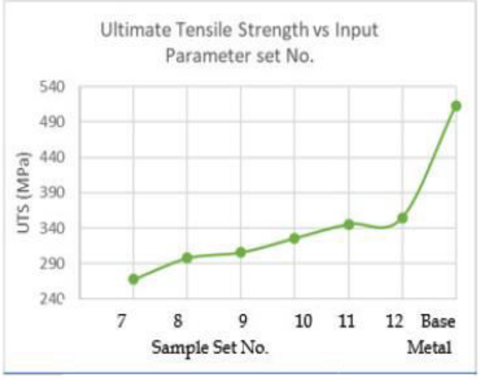

Figure 4 **UTS of weldments**

Microstructure and Metallographic Characterization

The metallographic phase structures of samples were compared against those predicted by the Iron-Carbon diagram. Phase structures obtained for selected specimens are shown in Table 3, which reveals that the microstructures (Figure 5) are almost identical. The weld-zone microstructure is mainly dependent on the heat input and cooling rate, and contains a combination of grain boundary ferrite, side plate ferrite, acicular ferrite, bainite and martensite. These features are fairly consistent with the microstructures obtained with continuous cooling of low carbon steel.

Table 3 Metallurgical analysis of specimens

Parameter Cluster No.	HAZ 1cm Left	Weld zone	HAZ 1cm Right	Base Metal
3	Ferrite + Pearlite (5%)	Coarse Pearlite	Ferrite + Pearlite (5%)	Ferrite + Pearlite (0.2%)
4	Ferrite + Pearlite (5%)	Very Fine Pearlite	Ferrite + Pearlite (5%)	Ferrite + Pearlite (0.2%)

At the start of cooling of the weld, grain boundary ferrite formation is initiated and subsequently, diffusion rates decrease with further cooling to low temperatures. Acicular ferrite nucleates and grows with intragranular inclusions. On the other hand, higher heat input enhances diffusion and promotes grain boundary ferrite. However, under higher cooling rates, the nucleation rate is faster and, hence, transformations begin earlier. Therefore, comparatively, the samples which have experienced a low-temperature regime show a mixed microstructure comprising acicular ferrite and lath- martensite

Conclusion

The following conclusions could be derived and summarized for SMAW welding of 5mm thickness mild steel plates/flat bars with 2.5 mm diameter E6013 electrodes with general joint preparation at the lowest cost suitable for the actual industrial environment. High hardness values are obtained for all specimens of all three clusters (Table 2) due to higher cooling rates at the surface. Therefore, it is observed that hardness is not much affected by the SMAW process for 24 mm width and 5 mm thick mild steel flat members. But it could be varied and to be investigated with the higher length of welding for both weld-zone and heataffected zones (HAZ). Best quality of weldment with highest ultimate tensile stress (UTS) (with brittle property) is obtained when the current, voltage and groove angles are 123A, 27V and 600 respectively with the result of mechanical tests. Toughness levels of SMAW against weld geometry is very important in assuring the reliability of the welded joint. The work found that toughness or impact resistance of the weldments of manual SMAW is comparatively very low as shown in Tables 2 and 4. According to the results, the highest toughness is 35% that of the base metal during the SMAW process. Furthermore, it is revealed that impact toughness severely decreased with the decreased groove angle. It is expected to continue this area of research in optimizing the SMAW process with more input parameters, output/quality parameters with metallographic characterization.