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Evaluation of the Effects of Welding Current on Mechanical Properties of Welded Joints Between Mild Steel and Low Carbon Steel

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Abstract

Welding is a process of joining two similar or dissimilar materials together by application of heat. Welding processes are used with the aim of obtaining a welded joint with the desired weld-bead parameters, excellent mechanical properties with minimum distortion. The evaluation and discussion of effects of welding current on mechanical properties of welded joints for hot rolled low carbon steel plate and mild steel plate, having dimension of 60mm by 40mm by 8mm is investigated. The aim is to ascertain and compare the mechanical properties of the joints. The welded joints samples were cut machined and subjected to tensile test, impact toughness test, and hardness and their mechanical properties were determined. Generally, as the welding current increases, hardness of the weld increases for the two samples up to 115A and 116A for mild steel and low carbon steel respectively but shows a decrease with a further increase in welding current. The ultimate tensile strength decreases with increase in welding current but increases at the welding current of 200A and 115A for mild steel and low carbon steel respectively. The yield strength and impact strength shows a decrease for the two samples with an increase in the welding current.

Keywords

Mild Steel, Welding, Low Carbon Steel, Toughness, Hardness, Tensile Strength

1. Introduction

Mild steel is the most common form of steel as its price is relatively low while it provides material properties that are acceptable for many applications. Low carbon steel contains approximately 0.16–0.29% carbon and mild steel contains 0.05–0.15% carbon, therefore it is neither brittle nor ductile. Mild steel is cheap and malleable but has a relatively low tensile strength. Surface hardness can be increased through carburizing which involves heating the alloys in a carbon rich environment [1]. According to [2-4] steel has been the dominant material used in the manufacturing automobile parts since 1920s. The application of steel and welding joints can also be seen in the works of [5]. Welding generally requires a heat source to produce a high temperature zone to melt the material, the common process of this type are grouped as fusion welding which is basically a fusion of two or more pieces of metals by the application of heat and sometimes pressure. Thus welding involves a wide range of scientific variables such as time, temperature, electrode, power input and welding speed [6-9]. The advantages of welding, as a joining process, include high joint efficiency, simple set up, flexibility and low fabrication costs [10]. Any weld design must aim at ensuring the integrity of the weld and effectively minimize the weld defects.

Authors of [11] while studying the Influence of macro/microstructure on the toughness of all weld multi-pass submerged arc welded C-Mn steel deposits concluded that welding parameters have no effect on the chemical composition, the overall hardness and microstructure in the as-welded condition. Impact toughness decreased with the increase in welding current. [12] While studying the effect of submerged arc welding parameters and fluxes on element transfer behavior and weld-metal chemistry concluded that welding current and voltage have an appreciable influence on element transfer, as well as on weld composition. Weldments properties such as strength, toughness and solidification cracking behavior are affected by chemical composition. Owolabi et al [13] studied the novel application of slag fluxes and salts in metallurgical industry. Authors of [14] conducted a study on influence of the chemical composition of flux on the microstructure and tensile properties of submerged-arc welds shows the importance of the selection for flux composition in order to improve the mechanical properties of steel welds, while [15] studying the combined effect of flux and welding parameters on chemical composition and mechanical properties of submerged arc weld metal concluded that the results show that flux mixture related variables based on individual flux ingredients and welding parameters have individual as well as interaction effects on responses. Amongst welding parameters, polarity is found to be important for all responses under study.

Mohammed et al [16] investigated the mechanical and metallurgical properties of medium carbon steel using shielded metal arc welding process (SMAW) with reference to the weld metal, heat affected zone and parent metal. From the results, shielded metal arc welding (SMAW) of medium carbon steel increased the strength of the welded joint in particular the heat affected zone (HAZ), as revealed by lower impact strength, higher tensile strength an d hardness values as compared with the parent and weld metal which is attributed to the fine ferrite matrix and fine pearlite distribution as compared to the weld and parent metal. However, there was a loss of ductility at the welded joint resulting to brittleness of the material.

Talabi et al [17] discussed the effect of welding variables on the mechanical properties of welded 10mm thick low carbon steel plate, welded using the Shielded Metal Arc Welding (SMAW) method. Welding current, arc voltage, welding speed and electrode diameter were the investigated welding parameters. The welded samples were cut and machined to standard configurations for tensile, impact toughness, and hardness tests. The results showed that the selected welding parameters had significant effects on the mechanical properties of the welded samples. Increases in the arc voltage and welding current resulted in increased hardness and decrease in yield strength, tensile strength and impact toughness. Increasing the welding speed from 40-66.67mm/min caused an increase in the hardness characteristic of the welded samples. Initial decrease in tensile and yield strengths were observed which thereafter increased as the welding speed increased. An electrode diameter of 2.5mm provided the best combination of mechanical properties when compared to the as received samples. This behavior was attributed to the fact that increased current and voltage meant increased heat input which could create room for defect formation, thus the observed reduced mechanical properties.

2. Materials and Methodology

The material used in the experiment include, a 8mm hot rolled mild steel plate, 10mm iron rib bar, 7018 low hydrogen electrode filter rod, emery paper. The equipment's and tool used are high voltage DC generators with rectifiers capable of supplying current of up to 600 Amperes (has the advantage of welding above 200 amperes), air and water cooled electrode holder, polishing machine, grinding machine, monsanto tensiometer, spectrometer analyzer, metallurgical microscope, impact testing machine, hardness testing machine, hack saw, scrapper, pliers, table vice, veneer caliper, and triangular file were used.

The method of preparation and testing of samples employed is same with the procedure in the works of Talabi et al (2014) [17]. The authors worked on the effect of welding variables on the mechanical properties of low carbon steel welded joint. Table 1 and table 2 show the composition of chemical analysis result of as-received low carbon steel and that of mild steel samples respectively.

Table 1. *Chemical analysis result of as – received Low carbon Steel (LCS).*

C	Si	Mn	P	S	Cr	Mb	Ni	Al	Cu	B	N	V
0.08	0.35	1.49	0.013	0.002	0.03	0.004	0.17	0.047	0.03	0.0001	0.0006	0.001

Table 2. *Chemical analysis result of as – received Mild Steel (MS).*

C	Si	Mn	P	S	Cr	Mb	Ni	Al	Cu	Zn	Fe	V
0.2267	0.2361	0.0412	0.0412	0.0616	0.1343	0.0212	0.1014	0.0025	0.2588	0.0059	98.095	0.0027

3. Result and Discussion

Welding current is the most influential variable in arc welding process, it is also the most important variable affecting melting rate, the deposition rate, depth of penetration and the amount of base metal melted [18, 19].

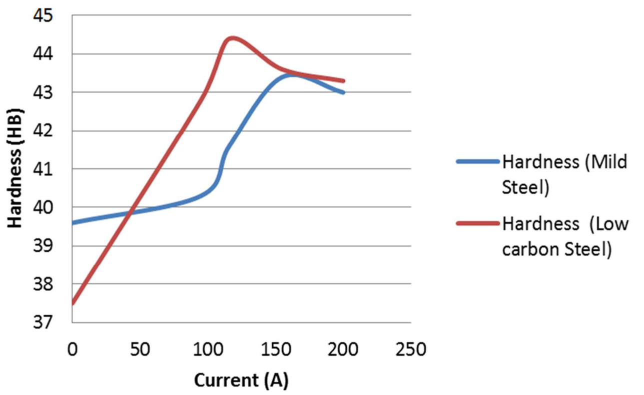

Figure 1. Effects of current on hardness.

From figure 1, at OA, the hardness of mild steel is 39.6HB while that of low carbon steel is 37.5HB. As the current increases the hardness of low carbon steel shows a rapid increase up to 44.4HB while that of mild steel shows an increase in hardness as current increases but at a slower rate when compared to low carbon steel. The peak hardness of mild steel is 43.4HB at the welding current of 115A while that of low carbon steel is 44.4HB at the welding current of 116A. The two metals have their least hardness at 0A. The increase in hardness in figure 1 is due to the formation of matensite or bainite in the weldement. Also increase in welding current increases the grain size in the micro structure of the metal thus giving rise to a coarse grain.

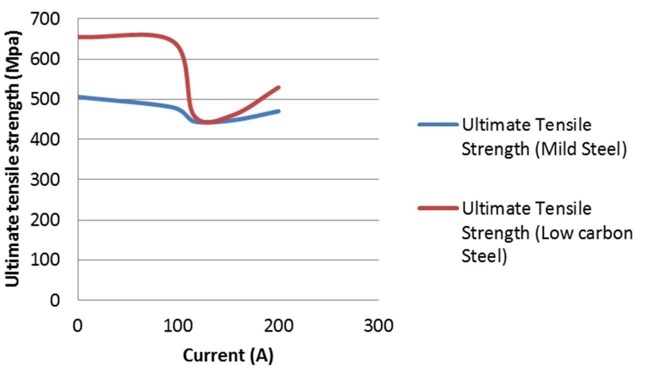

Figure 2. Effects of current on ultimate tensile strength.

Figure 2 shows the effects of welding current on the ultimate tensile strength of mild steel and low carbon steel. Generally, the ultimate tensile strength of both metals decreases with increase in welding current. At O A, the UTS of mild steel are 506.36MPa while that of low carbon steel is 654.73MPa. Still at this current, the two metals has the peak UTS. Because of the formation of matensite or bainite in the weldments, the ultimate tensile strength reduces as the welding current increases.

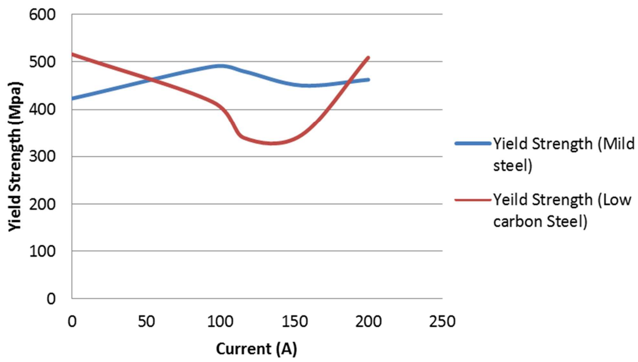

Figure 3. Effects of current on yield strength.

Figure 3 shows the effects of welding current on the yield strength of mild steel and low carbon steel. The yield strength of low carbon steel reduces with increase in welding current up to the current of 115A and increases to 508.96MPa at 200A, while the yield strength of mild steel increases with increase in welding current initially to 480.05MPa at the current of 116A. However, low carbon steel has the peak yield strength at 0A. At this optimum value for mild steel in figure 3, the rate at which the welding electrode is melted, the amount of base metal melted, dilution, depth of fusion, the amperage (the amount of current flowing through the electrode and the work), the deposition rates, the depth of penetration was good at this value and optimum weldability was achieved.

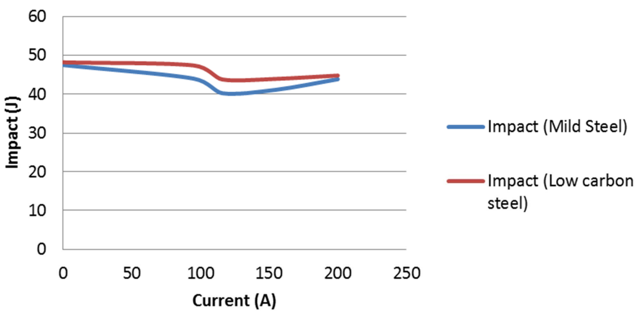

Figure 4. Effects of current on impact strength.

Figure 4 shows the effects of welding current on the impact strength of mild steel and low carbon steel. Both the impact strength of mild steel and low carbon steel decreases with increase in current to about 116A, before showing an increase with increase in the welding current as shown in figure 4.

4. Conclusion

Generally, as the welding current increases, hardness of the weld increases for the two samples up to 115A and 116A for mild steel and low carbon steel respectively but shows a decrease with a further increase in welding current. The ultimate tensile strength decreases with increase in welding current but increases at the welding current of 200A and 115A for mild steel and low carbon steel respectively. The yield strength and impact strength shows a decrease for the two samples with an increase in the welding current.

The hardness increased purely due to the distortion of the grain size and formation of matensite or bainite in the weldments when heat is applied. It becomes a necessity to apply heat treatment to the weldment and the parent metal after conducting a welding operation. Heat treatment helps to soften the metal, to change the grain size, to modify the structure of the material and to relieve the stresses set up in the material.

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