The Effect of Welding Current and Electrode Types on Tensile Properties of Mild Steel

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ABSTRACT— The effect of welding current on the structure, tensile properties and performance of mild steel weld joints was studied. Mild steel plate (AISI 1018), 4mm thick, was used as base metal for preparing butt weld joints using shielded metal arc welding (SMAW) process. Welding currents of 65A, 70A, 75A and 80A were applied using 2.5mm diameter welding electrodes (E6011 and E6013). The tensile properties of the butt weld joints were determined using a universal tensile testing machine model S/N 8889 in accordance with ASTM procedures. Macrostructural investigations showed good penetration in all the weld joints. Welding current of 75A produced maximum yield strength, ultimate tensile strength values of 358.50MPa, 421.70MPa respectively for weldments produced with E6011 while weldments produced with E6013 gave a maximum ultimate tensile strength and yield strength values of 383.20MPa and 319.37MPa respectively all of which were lower than those of the base metal. The percentage elongation of the base metal, (14.28%), was found to be lower than that of the weld joints produced.

Key words: Elongation, Welding current, Weld joints, Tensile strength, Yield strength, Ultimate tensile strength.

1 INTRODUCTION

A good percentage of engineering materials at present consists of steels. Steels are mainly joined by welding, especially using the arc welding process because it is available, relatively easy to operate and uses consumable electrodes.

Welding can trace its historical development back to the ancient times, more than 2000 years ago, when small gold circular boxes were made by pressure welding lap joints (Cary, 1998). Many tools and many other materials made by welding approximately 1000BC have been found and are exhibited in the British museum, London.

Welding is the most economical and efficient way of joining metals permanently. It is important in manufacturing and construction and therefore vital to industrial development and growth.

The welding process finds widespread applications in almost all branches of industry and construction. Welding is extensively employed in the fabrication and erection of steel structures, in industrial construction and civil engineering, for example, structural members of bridges and buildings etc.; vessels of welded plate construction (steel reservoirs, boilers, pressure vessel tanks and pipelines etc.) and concrete reinforcement (Sharma et al, 2004). Due to the versatile nature of demand for welding, the optimal situations under which most desired properties would be attained by the weldment must be known.

To consistently produce high quality welds, using arc welding, experienced welding personnel is required. One reason for this is the need to properly select optimal welding parameters to provide good weld quality which is identified by its microstructure and mechanical properties. Therefore, the use of control system in arc welding eliminates much of the "guess work" often employed by welders and specify welding parameters for a given task (Kim et al, 2005).

Welding current is the most influential parameter for it controls the rate at which the electrode is melted and also controls its deposition rate, the heat affected zone, the depth of penetration, affects bead shape, and the amount of base metal melted. Penetration and reinforcement increase with increase in welding current.

If the current is too high at a given welding speed, the depth of fusion or penetration will also be too high so that the resulting weld may tend to melt through the metal being joined. High current also leads to waste of electrodes in the form of excessive reinforcement, produces digging arc and undercut, increases weld shrinkage and causes greater distortion. Bead width increases with welding current until a critical value is reached and then decreases if the polarity used is DCEP. When DCEN polarity is employed, bead width increases with the increase in current for the entire range.

However, for the same flux, heat affected zone also increases with the increase in welding current (Gupta and Gupta, 1988). If the current is too low, inadequate penetration or incomplete fusion may result. Too low current also leads to unstable arc, inadequate penetration and overlapping.

In welding, quality weld joint is one which has its physical and mechanical properties, at least almost equal to those of

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parent metals being joined. Various researchers have demonstrated the effect of welding current on the macrostructure of weld metal. Kahraman et al (2010) working on pure titanium and Ghazvinloo et al (2010) working on AA6061 aluminium alloy reported an increase in weld metal penetration with increase in welding current, while Ghazvinloo et al(2010), Kannan et al (2006) and Lang et al (2008) reported an increase in weld bead width with increasing welding current in duplex stainless steel, and magnesium alloy respectively.

The macrostructure and microstructure are essential to strength and ductility, Bang et al, (2008) and Tewari et al, (2010) in their study showed that these properties are influenced by welding parameter such as welding voltage, welding current and welding speed.

An attempt has been made to study the effect of electrode type by Nnuka et al, (2005) on low carbon steel. However, very little attempt has been made to evaluate the effect of each parameter separately. Therefore this work is aimed at establishing the effect of welding current on the structure and tensile properties of mild steel weld joints using shielded metal arc welding process (SMAW).

2.0 MATERIALS AND METHOD

2.1 Materials and Equipment

The materials used for the study were basically mild steel (AISI1018), 2. 5 diameter high cellulose electrode (E6011), high titanium consumable welding electrode (E6013), universal tensile testing machine, shielded metal arc welding (SMAW) welder, hacksaw, chipping hammer, wire brush, X-ray fluorescent (XRF) analyzer, and pedestal grinder for edge preparation.

2.2 Experimental Method

A 4mm thick mild steel plate was cut into specimens of required dimensions (400 x 50mm) with a power saw. These plates were cleaned from dirt, grease and other foreign materials to ensure good quality weld. The mild steel plates were placed on a welding table in order to avoid undesired distortion. The initial joint configuration was obtained by securing the plates in position using tack welding.

The welding process was carried out using SMAW machine. One run in a flat welding position was used to produce a butt weld joint. The welding conditions and process parameters such as welding currents of 65A, 70A, 75A and 80A respectively and welding speed of 2mm/s which was kept constant throughout the process. An arc voltage of 32.4 volts and an open circuit voltage of 69V were maintained throughout the welding process.

The Arc voltage has a direct effect on the heat input which was varied by varying the welding current according to the equation:

$$H = \frac{(60EI)}{(1000S)} \quad (1)$$

Where H is heat input (KJ/mm),

E is arc voltage (volts),

I is welding current (ampere),

S is welding speed (mm/min)

The welded joints were then prepared for macrostructural investigation and tensile test, all the tests were carried out according to American Society for Testing and Materials (ASTM) Standards.

3.0 RESULTS AND DISCUSSIONS

3.1 Chemical composition

Table 1: Chemical composition of the base metal.

element	**C**	**Fe**	**Mn**	**P**	**S**	**Trace**
Weight %	0.15	97.3	0.7	0.04	0.02	1.79

Table 2: chemical composition of the electrodes (E6011and E6013)

Electrode type	C	Mn	Si	P	S	Mo
E6011	0.10	0.50	0.30	0.013	0.012	0.001
E6013	0.8	0.45	0.18	0.012	0.009	—

3.2 Macrostructure

Table 3: Result of Macroscopic inspection values

Electrode type	Current(A)	Penetration (mm)	Bead width (mm)
E6013	65	3	9
	70	3	9
	75	3	9
	80	3	9
E6011	65	3	8
	70	3	8
	75	3	8
	80	3	8

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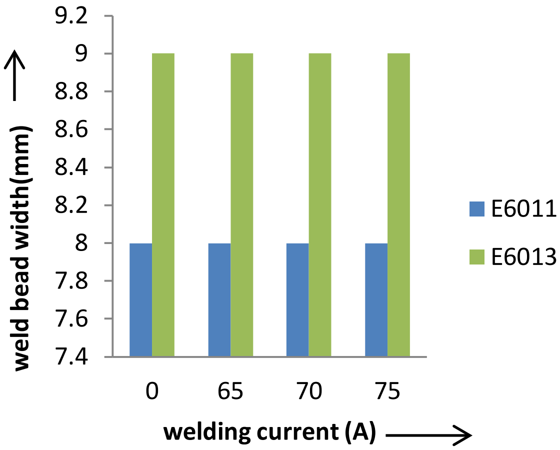

Fig1: Relationship between electrode type, current and weld bead width

From Table 3 and Figure 1 it can be seen that while the depth of penetration was the same for all welding currents and electrode types, change in welding current did not affect the weld bead width. However the weld bead width was affected by the electrode type. Electrode with high cellulose content (E6011) produced less evenly spaced weld beads unlike weldments produced with electrodes having high content of titania (E6013).

3.3 Tensile Strength

Table 4: Tensile properties of the weld joints

Electrode type	Current (A)	UTS (MPa)	YS (MPa)	(%) Elongation
E6013	65	320.10	283.13	17.50
	70	365.15	292.12	24.30
	75	354.63	285.10	22.59
	80	383.20	319.37	23.64
E6011	65	382.10	310.52	18.50
	70	412.67	346.30	21.98
	75	421.70	358.50	20.10
	80	400.75	332.60	23.65
Base metal		458.39	365.29	14.28

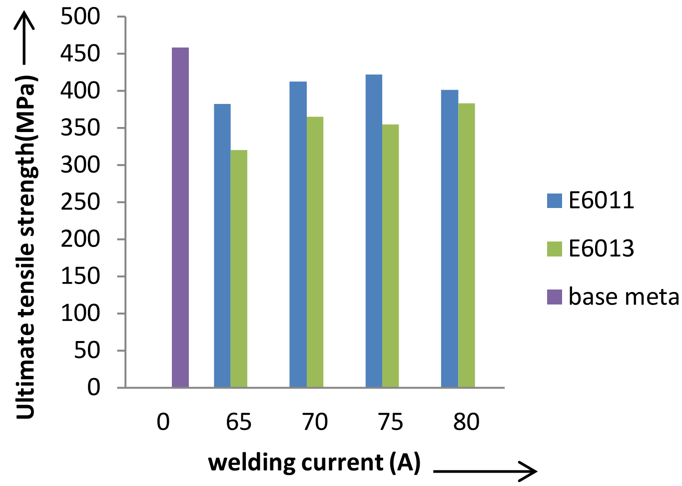

Fig2. Relationship between welding current and ultimate tensile strength

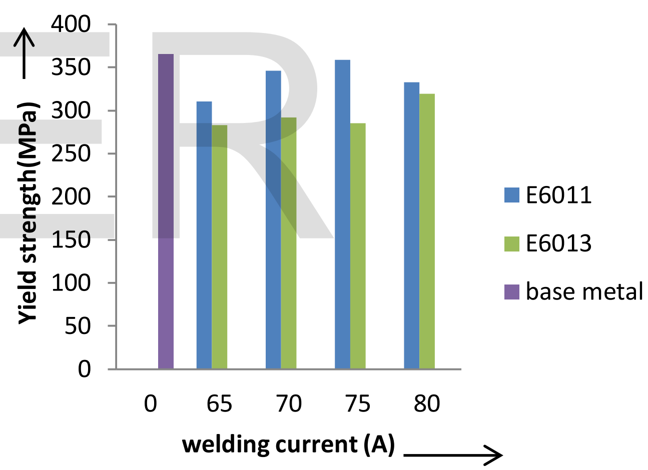

Fig3. Relationship between welding current and yield tensile strength

Figure 2 and 3 show the effect of welding current on the ultimate tensile strength (UTS) and Yield Strength (YS) respectively. It was observed from the results obtained that the ultimate tensile strength and yield strength values of weld joints produced with E6011 increased with increase in welding current till it reaches an optimal value which was at a welding current of 75A before decreasing on further increase in welding current. However, weldments produced with E6013 gave none linear pattern. Maximum ultimate tensile strength and yield strength values were obtained at a welding current of 80A.

It was also observed that the Uts and Ys values for all the weldments produced were generally lower than those of the base metal. This could be attributed to the presence of defects and distribution of phases in the microstructure of the weld metal.

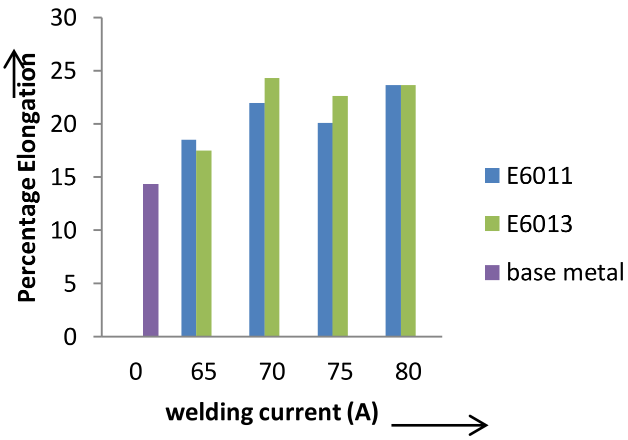

Fig4. Relationship between welding current and percentage elongation

As seen in Figure 4, weldments made with both electrodes gave none linear trend with increase in welding current. They both showed the same trend. It seems that due to increase in welding current the ductility of the weldment with E6013 increased up to maximum value at 70A before decreasing on further increment of current while weldments made with E6011 gave its own maximum percentage elongation at 80A. The base metal gave the least percentage elongation when compared to the weld joints.

4.0 CONCLUSION

It is evident that welding current, voltage and electrode type are important parameters that must be monitored in order to produce weld joints of enhanced mechanical properties.

The effect of welding current on the structure and mechanical properties of mild steel joints made with E6011 and E6013 having been studied, a review of results obtained leads to the following conclusion:

i. The depth of weld penetration and weld bead width remained unaffected by the welding current, even though both electrode types used gave different weld bead width values.

ii. The yield strength and ultimate tensile strength values of weld joints were lower than those of the base metal. The best combination of the tensile properties tested for weldments made with E6011was obtained at a welding current of 75A while that made with E6013 was obtained at a welding current 80A.

iii. The percentage elongation of the base metal is lower than that of the weld joints.

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