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Effect of Welding Current and Filler Metal Types on Macrostructure and Tensile Strength of Gtaw Welded Stainless Steel Joints

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Abstract – **The present investigation studied the effect of welding current and filler metal types on the macrostructure and strength of stainless steel weld joints and determined the best combination for quality weld. Austenitic stainless steel plate (304L grade) 3mm thick, was used as base metal for preparing butt weld joints using gas tungsten arc welding (GTAW) process. Welding currents of 91-95A at intervals of 1A and austenitic stainless steel filler metals 308L, 309L and 316L were used. The macrostructure and tensile strength were determined using standard equipment and ASTM standard procedures. The results showed that full penetration was achieved in all cases of welding current and filler metal type used and there was increase in weld bead width with increase in welding current and increase in diameter of filler metal. The 316 filler metal produced the highest weld bead width for all currents because of its larger diameter. The ultimate tensile strength and yield strength of joints decreased with increase in welding current for all filler metal types. The highest strength for each filler metal was obtained using 91A welding current. From the investigation it was found that the best combinations of welding current and filler metal type for quality weld joint were obtained using 308L and 309L filler metal and welding current of 91-93A.**

Keywords – **Welding Current, Filler Metal, Austenitic Stainless Steel.**

I. INTRODUCTION

Welding is the most economical and efficient way to join metals permanently. It is the only way of joining two or more pieces of metals to make them act as a single piece or monolithic structure. It can be used to join all types of commercial quality metals and strength. It is very important in manufacturing and construction and therefore vital to economic development and growth. The advantages of welding as a joining process include high joint efficiency, simple set up, flexibility and low fabrication costs [1]. In welding practice a good quality weld joint is one which has its mechanical properties, at least, equal to those of the parent metals being joined. The essential mechanical properties are strength, elongation, hardness and toughness. The studies of [2] and [3] have shown that these properties are influenced by welding parameters such as welding voltage, welding current and welding speed. Many researchers, [4], [5], [6] and [7] have investigated the effect of these parameters on the mechanical properties of weld metal, using various materials and various welding processes by varying them simultaneously to change heat input. However, very little attempt has been made to evaluate the effect of each parameter separately and no attempt at all has been made to study the effect of electrode type [8] especially, on stainless steel welds using gas tungsten arc welding (GTAW) process.

Macrostructure

The macrostructure is usually assessed by visual inspection using the naked eye or low magnifying glass and includes weld penetration and weld bead width. These can be affected by welding current and filler metal type.

Effect of Welding Current on Macrostructure

Various researchers have demonstrated the effect of welding current on the macrostructure of weld metal. Reference [9] indicated that working on pure titanium and [10] working on AA6061 aluminium alloy reported an increase in weld metal penetration with increase in welding current, while [11], [12] and [7] reported an increase in weld bead width with increasing welding current in duplex stainless steel, and magnesium alloy respectively. Reference [10] recorded a decrease in weld bead width in low carbon steels.

Effect of Filler Metal Type on Macrostructure

This involves the use of filler metals with different chemical compositions. Researches carried out in the area of welds have not considered the effect of filler metal type on weld penetration and weld bead width.

Strength

Strength is that property of a metal that allows it to withstand or support an external force without rupture. It plays a decisive role in designing various structures and components. This property (ultimate tensile strength and yield strength) is generally affected by welding parameters such as welding current, welding voltage and welding speed and has been described to be the most important factor affecting the quality, productivity and cost of weld joints [13]. Therefore this work is aimed at establishing the effect of welding current and various filler materials on the tensile strength of stainless steel weld joints using GTAW process.

Effect of Welding Current on Tensile Strength

Reference [10] in their study of the effect of welding current on the tensile strength of weld metal in low carbon steel using fluxed core arc welding (FCAW) process, demonstrated that increase in welding current lowered the ultimate tensile strength (UTS) and yield strength (YS).

Effect of Filler Metal on Tensile Strength

Reference [8] studied the effect of electrode types on mechanical properties and structure of low and medium carbon steel welds using mild steel electrodes (gauges 10 and 12) and stainless steel electrode. The result of the study showed that the tensile strength of each welded joint was lower than that of the unwelded base metal. They also reported that the joints made with stainless steel electrode recorded the highest tensile strength because of the alloying elements it contains.

II. EXPERIMENTAL PROCEDURE

Austenitic stainless steel sheets of type AISI 304L measuring 400 x 50 x 3mm were welded to produce square butt weld joints with edge preparation. The chemical composition of the AISI 304L stainless steel is given in Table 1. The welding process was carried out with a manually operated air-cooled welding machine (Precision TIG 225) to produce a square butt weld joint. High purity argon gas was used for shielding and purging at the rates of 12 litres per minute and 7.5 litres per minute respectively. Using a post-flow timer the post-weld

shielding gas flow was 10 minutes. The welding consisted of two runs, the root and cap, in the 1G position using three filler metals, 308L (2.0mm), 309L (2.0mm), 316L (2.4mm) and five welding currents ranging from 91ampere – 95 ampere at one ampere interval. During the welding operation the heat input was varied by varying the welding current (other parameters were held constant) according to the equation

$$H = 60EI/1000S$$

Where

H = heat input (KJ/mm)

E = arc voltage (volts)

I = welding current (ampere)

S = welding speed (mm/min)

After the welding process the welded joints were air-cooled, examined for defects and prepared for macrostructure examination and all-weld tensile test.

Macrostructure Examination

This was carried out to determine the contour of the weld deposit in order to evaluate the effect of welding current and filler metal type on the width and penetration of the weld metal. However before the examination the specimens were prepared by grinding to 00 emery paper (or 1200 grade of silicon paper grade) and etching using a mixture of 50% hydrochloric acid (HCl) and 50% water (H_2O) [15].

The weld width and penetration were then measured with the aid of metal rule and veneer calipers. The results are shown in Table 2 and Figures 1 and 2.

Tensile Test

The welded coupons were cut to size using power hacksaw and subjected to all-weld tensile test using a tensile testing machine, model 316Q with 300KN maximum load. The test was carried out following the ASTM E8 Standard procedure for all-weld tensile test. The coupons were fitted into the jaws of the testing machine and subjected to tensile stress until they fractured. The results are shown in Figures 3 and 4.

III. RESULTS AND DISCUSSIONS

Chemical composition

The chemical composition of the base metal and filer metals are shown in Table 1.

Table 1. Composition of Base Metal and Filler Metals

Material	C	Si	Mn	P	S	Cr	Ni	Mo	Cu	V	Al	SN	N	Ti
Base metal	0.02	0.42	0.05	0.031	0.001	18.80	7.18	0.008	0.029	0.079	0.013	0.004	0.042	0.005
Filler Metal Type														
ER308L	0.013	0.43	1.86	0.023	0.002	19.85	9.95	0.05	0.07					
ER309L	0.016	0.41	1.84	0.019	0.002	23.28	13.68	0.03	0.04					
ER316L	0.014	0.41	1.74	0.023	0.002	19.22	12.29	2.19	0.11					

Macrostructure

The result of macroscopic examination using visual/optical inspection technique is presented in Figures 1, 2 and 3. Figure 1 represents the effect of welding current and filler metal type on weld penetration, Figure 2 that of the effect of welding current on width of weld bead and Figure 3, the effect of filler metal type on width weld bead.

From the result it can be seen that while the depth of penetration is the same for all welding currents and filler metal types, the weld bead width showed slight increase with increase in welding current. This contradicts the observation of [10] on the weld bead width for low carbon steel but agrees with the observation of Kannan and[14] on the weld bead width for duplex stainless steel. It can also be observed that the weld bead produced by 316L filler

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metal is higher than those produced by the 308L and 309L filler metals for all welding currents. This can be related to the drop size of metal separated from the end of the filler metal since it has a larger diameter.

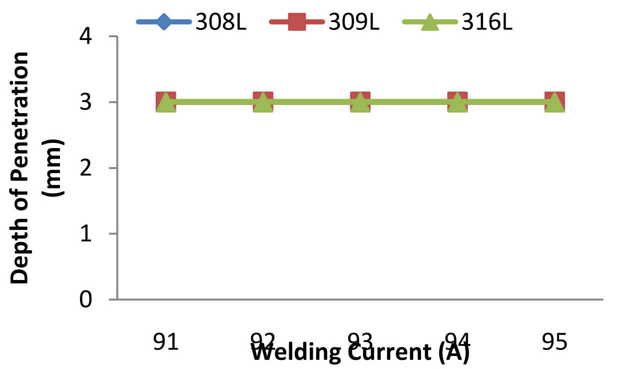

Fig.1. Effect of welding current and filler metal type on weld penetration

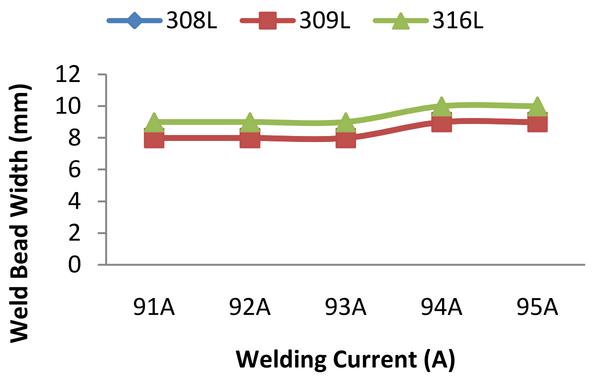

Fig.2. Effect of Welding Current on Weld Bead Width

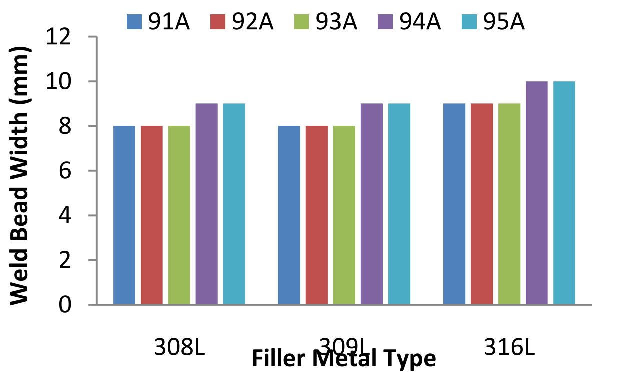

Fig.3. Effect of Filler Metal Type on Weld Bead Width

Tensile Strength

Effect of welding current on ultimate tensile and yield strengths

Figure 4 and Figure 5 show the effect of welding current on the UTS and YS respectively. It can be observed that the highest values of UTS and YS were obtained with welding current of 91A for each filler metal type. This could be due to high cooling rates associated with the low heat input resulting from low welding current of 91A and producing fine and uniformly dispersed grains. However as the welding current increased from 91A to 95A there was a reduction in cooling rate due to the poor thermal conductivity of austenitic stainless steel. This resulted in increase in grain size with decrease in strength. It can also be observed that the UTS and YS values for the various welded joints were generally higher than that of the base metal. This could be attributed to the presence of delta ferrite in the microstructure of the weld metal, which has the potential to reduce grain growth and increase strength properties in steel. This agrees with the observation of [15].

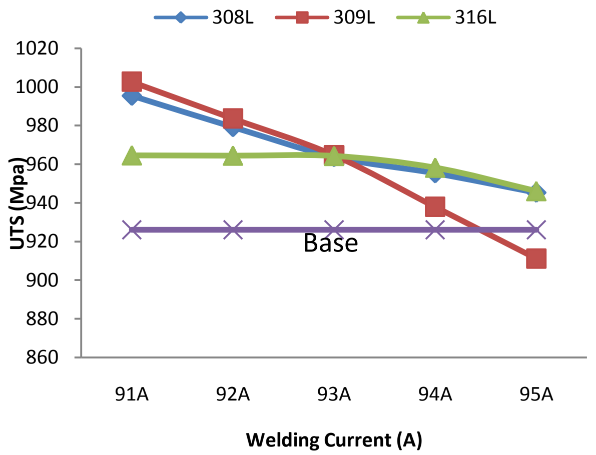

Fig.4. Effect of Welding Current on Yield Strength of Welded Joint

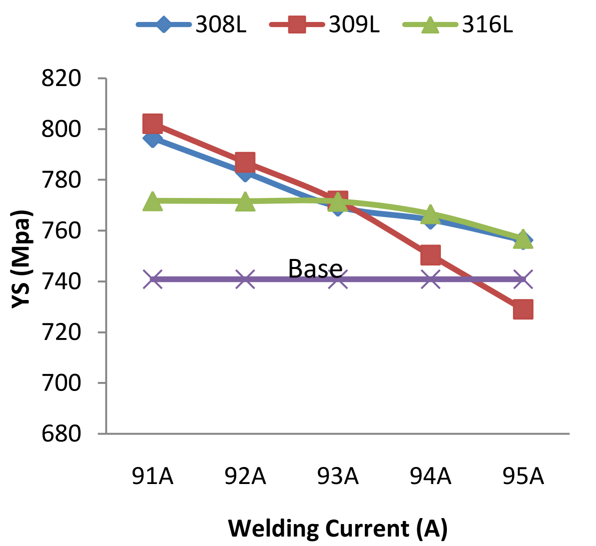

Fig.5. Effect of Welding Current on Ultimate Tensile-Strength of Welded Joint

Effect of Filler Metal Type on Strength (UTS and YS)

The effect of filler metal type on UTS and YS are shown in Figure 6 and Figure 7 respectively. It can be observed that the weld joints produced with all the filler metals, generally, have higher UTS values than the base metal for all the welding currents considered. This could be attributed to the higher carbon and chromium contents of the filler metals as well as the uniform distribution of grains.

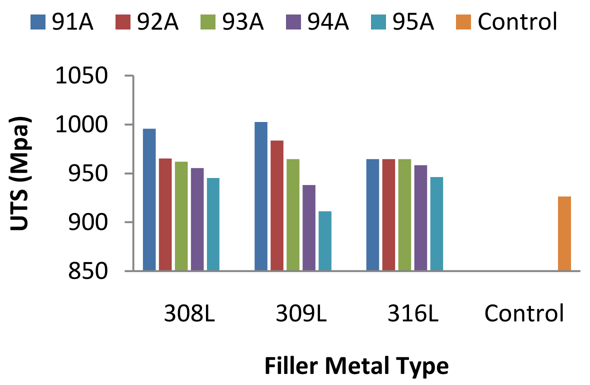

Fig.6. Effect of Filler Metal Type on Ultimate Tensile Strength of Welded Joint

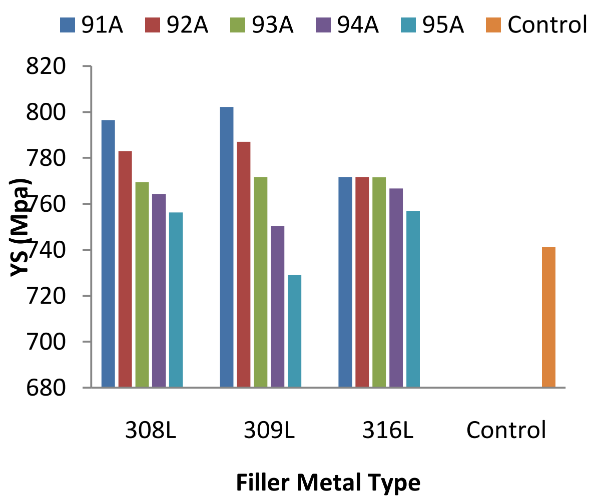

Fig.7. Effect of Filler Metal Type on Yield Strength of Welded Joint

IV. CONCLUSION

The effect of welding current and filler metal type on the macrostructure and strength (UTS and YS) of 304L austenitic stainless steel using ER308L, ER309L, and ER316L filler metal types and welding current range of 91-95A were studied. After a review of the results obtained from the experiments the following conclusions were drawn.

There was no significant difference in the depth of weld penetration but the weld bead width increased with increase in welding current and increase in the diameter of filler metal. Higher strengths (UTS and YS) than that of the base metal were observed for all the joints. However, the UTS and YS decreased with increase in welding current for all filler metal types.

The best results for strength were obtained for welded joints produced by using welding current of 91A with filler metals of 308L and 309L.

REFERENCES

[1] Armentani, E., Espositor, R. And Sepe, R. (2007).The effect of thermal properties and weld efficiency on residual stresses in welding. Journal of Achievements in Materials and Manufacturing Engineering, vol. 20, 319-322

[2] Bang, K. S., Jung, D. H., Park, C. and Chang, W. S. (2008). Effects for welding parameters on tensile strength of weld metal in flux cored welding. Science and Technology of Welding and Joining, vol. 13, No.6, 508-514.

[3] Tewari, S. P., Gupta, A. and Prakash, J. (2010). Effect of welding parameters on the weldability of materials. International Journal of Engineering Science and Technology, vol. 2(4), 512-516.

[4] Vercesi, J. And Surian, E. (1996). The effect of welding parameters on high-strength SMAW all welded metal, part 1. Welding Journal, 85.191s-196s.

[5] Vercesi, J. And Surian, E. (1998). The effect of welding parameters on high-strength SMAW all welded metal, part 2. Welding Journal, 87, 164s-171s.

[6] De Rissone, N. M. R., Svoboda, H. G., Surian, E. S. and de Vedia, L. A. (2005). Influence of procedure variables on C-Mn-Ni-Mo metal cored wire ferritic all welded metal. Welding Journal, 94, 139s-148s.

[7] Lang, B., Sun, D. Q., Li, G. Z. and Qin, X. F. (2008). The effect of welding parameters on microstructure and mechanical properties of resistance spot welded magnesium alloy joints. Science and Technology of Welding and Joining, vol. 13, No. 8, 698.

[8] Nnuka, E. E., Ovat, F. A., and Oseni, M. I. (2005). The effect of electrode types on mechanical properties and structure of welded steel. Journal of Metallurgical and Materials Engineering.

[9] Kahraman, N., Taşkin, M., Gulenç, B., and Durgutlu, A. (2010). An investigation into the effect of welding current on the plasma arc welding of pure titanium.Koveve Mater. 48, 179-184.

[10] Ghazvinloo, H. R., Honarbakhsh-Raouf, A. And Shadfar, N. (2010).Effect of electrode to work angle, filler diameter and shielding gas type on weld geometry of HQ 130 steel joints produced by robotic GMAW. Indian Journaj of Science and Technology, 3(1), 26-30

[11] Ghazvinloo, H. R., Honarbakhsh-Raouf, A. And Shadfar, N. (2010).Effect of arc voltage, welding current and welding speed on fatigue life, impact energy and bead penetration of AA6061 joints produced by robotic MIG welding. Indian Journal of Science and Technology, vol. 3(2), 156-162.

[12] Kannan, T. And Murugan, N. (2006). Effect of flux cored arc welding process parameters on duplex stainless steel clad quality. Journal of Material processing Technology, 176: 230-239.

[13] Srivastastava, B. K., Tewari, S. P. And Prakash, J. (2010).A review of effect of arc welding parameters on mechanical behaviour of ferrous metals/alloys. International Journal of Engineering Science and Technology, vol. 2(5), 1425-1432.