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Effect of Welding Current on the Hardness of Austenitic Stainless Steel Weld Joints

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Abstract: The influence of welding current on the hardness of austenitic stainless steel was investigated using 3 mm thick austenitic stainless steel (AISI 304L) plate and ER309L (2mm) filler rod to prepare a butt-weld joint. A gas tungsten arc welding(GTAW) process and welding currents of 91-95 amperes at 1 ampere interval were employed. The hardness values were determined on Rockwell B scale using 1.6mm steel ball. The result showed that thehardness values of the weld joints registered a decrease as the welding current increased and were slightly higher than but comparable to that of the base metal.

Key words: Hardness · GTAW process · Austenitic Stainless Steel · Welding Current

INTRODUCTION

Austeniticstainless steels are the most common and abundantly used stainless steels in the process industry. They are easily recognised as non-magnetic and make up over 70% of total stainless steel production [1, 2]. Ideally, they exhibit a single phase, the face centred cubic (FCC) structure that is maintained over a wide range of temperatures. They contain a maximum of 0.15% C, a minimum of 16% Cr and sufficient nickel and/or manganese to retain an austenitic structure at all temperatures, from the cryogenic region where they exhibit high toughness to high temperatures where they exhibit high oxidation resistance [3, 4, 5]. They also exhibit freedom from transformation to martensite [6].

Austenitic stainless steels are extremely formable and weldable and a high proportion of these steels is welded in the fabrication of pressure vessels, storage tanks, chemical plants and domestic appliances. In each case the welds are required to be of high integrity and provide corrosion resistance and/or mechanical properties (strength, hardness and toughness) that, at least, match those of the parent material [6]. The studies of Bang *et al*. [7] and Tewari, Gupta and Prakash [8] have revealed that these properties are influenced by heat input i.e. the combination of welding current, welding voltage and welding speed. The investigations were carried out by varying them (welding current, welding voltage and welding speed) simultaneously to change heat input. From literature only little attempts have been made to evaluate the effect of welding current, separately, on the mechanical properties. Hence, this study is on the effect of welding current on the hardness of austenitic stainless steel weld joints.

Hardness: Hardness is the property of a material that enables it to resist plastic deformation, penetration, indentation and scratching. It is one of the most basic mechanical properties of engineering materials. Hardness test is practical and provides a quick assessment and the result can be used as a good indicator for material selection and also employed for quality assurance in parts which require high wear resistance. Therefore, hardness is important from an engineering standpoint because resistance to wear by either friction or erosion by steam, oil and water generally increases with hardness. Thus, the value of hardness serves an important need in industry. This study is on the effect of welding current on the hardness of austenitic stainless steel weld joints.

Effect of Welding Current on Hardness: In their study on the effect of TIG welding on microstructure and mechanical properties of butt-joined-unalloyed titanium, Uygur and Dogan [9] showed that increase in welding

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current resulted in coarse grains and decrease in hardness. This agreed with the observation of Zou *et al.* [10] from their investigation on the effect of heat input on microstructure and properties of the welded joint of magnesium (AZ31B) alloy.

Experimental Procedure

Materials: The materials used for this study include 3mm austenitic stainless steel plate (base metal) and 308L (2 mm) filler rods with the chemical compositions shown in Table 1. Also 2% thoriated non-consumable tungsten electrode for carrying current to the arc and high purity argon gas as shielding gas were employed.

Procedure: Prior to welding, the coupons to be welded, measuring 400 mmx 50 mmx 3 mm, were prepared by grinding filing and cleaning in accordance with AISI SS Standard to ensure good quality weld joint. To minimize distortion the coupons were held in position by clamping devices and the initial joint configuration obtained by tack-welding to secure the specimens in position. A backing plate was attached to the tacked coupons to create a vacuum that will ensure effective gas purging of the underside of the weld joint for good penetration. The welding process was carried out with a manually operated, air-cooled welding machine (Precision TIG 225) in the down-hand (1G) welding position to produce a square butt weld joint. Five welding currents were employed ranging from 91-95 amperes at 1 ampere interval. During welding heat input was varied by varying the welding current while other parameters were held constant according to the following equation:

$$H = \frac{60EI}{1000S}$$

where,
H = heat input (KJ/mm)
E = arc voltage (volts)
S = welding speed
I = welding current

The shielding gas flow rates were maintained at 12 litres/min and 7.5 litres/min for welding and purging respectively. When welding was completed the shielding gas flowed for 10 minutes after the arc was stopped to protect the weld until it was no longer subject to contamination. The welded joints were then air-cooled, examined for defects and prepared for hardness test.

Hardness Test: This test was carried out to determine the resistance of the specimen to permanent (plastic) deformation. The specimen preparation and test procedure were in accordance with ASTM E18 standard.

Preparation of Sample: The specimen was cut into 10 mm x 10 mm size using hacksaw. The surface was ground, polished and etched to ensure that it was flat, smooth and clean.

Test Procedure: The method consisted of indenting the test material with a diamond cone indenter which was forced into the test material under a preliminary minor load of 10 Kgf. When equilibrium was reached, an indicating device, which follows the movements of the indenter and so responds to changes in depth of penetration of the indenter, was set to a datum position. While the preliminary minor load was still applied an additional major load 150 Kgf was applied with resulting increase in penetration. When equilibrium was again reached, the additional major load was removed but the preliminary minor load was still maintained. The permanent increase in depth of penetration, resulting from the application and removal of the additional major load was read off from the dial as the Rockwell hardness number. Test results are shown in Table 2.

RESULTS AND DISCUSSIONS

Chemical Composition: The chemical composition of the base metal and filler rod are shown in Table 1.

Metallography Results: The microstructures of the welded joints are presentedbelow.

The micrographs of the base metal and weld metals are displayed in Figures 1-6. The dark structure seen is a secondary ferrite phase known as delta ferrite, a body centred cubic (BCC) structure, dispersed the in primary austenite phase, a face centred cubic (FCC) structure. It can be observed that minor modifications had occured in the microstructure of the weld metal when compared with that of the base metal. The difference is in the increase in the quantity and grain size of their delta ferritecontent resulting from the welding process. This agrees with the report of Tosten and Morgan, [11] on the study of the microstructure of welds in 304L and 21Cr-6Ni-9Mn stainless steels.

Table 1: Chemical Composition of Base Metal and Filler Rod

Material	C	Si	Mn	P	S	Cr	Ni	Mo	Cu	V	Al	SN	N	Ti
Base metal 304L	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														
ER309L	0.016	0.41	1.84	0.019	0.002	23.28	13.68	0.03	0.04					

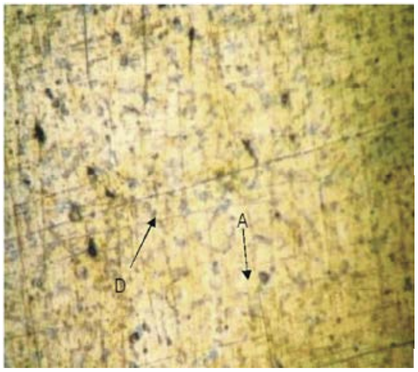

Fig. 1: Base metal (un-welded sample)
Magnification: x200
A = Austenite matrix DF = Delta Ferrite

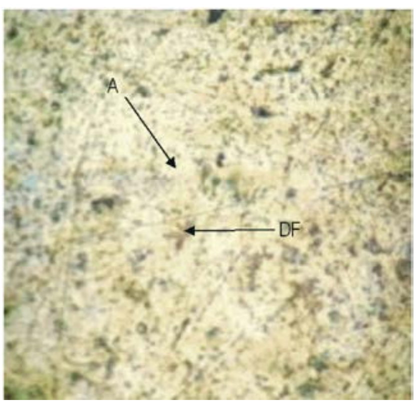

Fig. 2: Micrograph of weld metal at 91A.
Magnification: x200

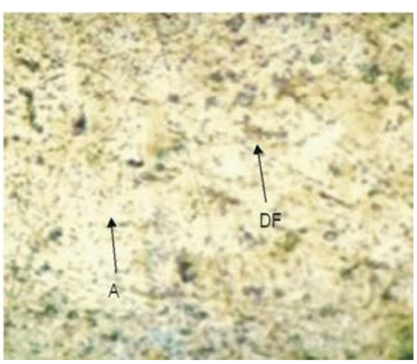

Fig. 3: Micrograph of weld metal at 92A.
Magnification: x200

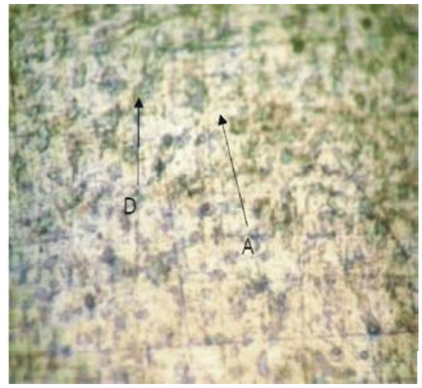

Fig. 4: Microstructure of weld metal at 93A
Magnification: x200

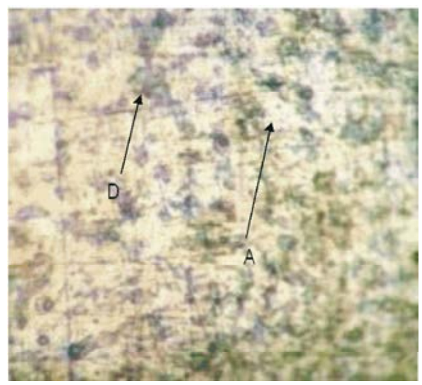

Fig. 5: Microstructure of weld metal at 94A
Magnification: x200

Fig. 6: Microstructure of weld metal at 95A.
Magnification: x200

Figure 1 shows the microstructure of the base metal and reveals fine uniformly dispersed delta ferrite, δ, (dark particles) in the austenite matrix (white background) resulting in high hardness value. This agrees with the observations of Oladele and Omotoyibo [12], Kim, Hong, LU, *et al.* [13] on aluminium alloy and Huinan and Thomas [14] on polymer composites.

Figure 2 represents the microstructure of the weld metal for the current of 91A. This reveals well dispersed δ-ferrite phase resulting in higher hardness value than that of the base metal but compares well with it.

Figure 4 represents the microstructure of the weld metal for 93A weld current. It reveals a more slightly coerced but uniformly dispersed δ-ferrite phase than that of the 91A current. This is due to the increase in welding current (high heat input) and decrease in cooling rate. This is responsible for the decrease in hardness since the larger the grain size the less the number of grain boundaries. This softens the weld metal and decreases the hardness. This is in agreement the arguments of Kou [15], Calik [16], Ghazvinloo & Honarbakhsh [17].

In Figure 6 the microstructure of the weld metal for the 95A was revealed. It can be observed that the second phase i.e. The δ-ferrite phase has coarser grains which are less uniformly dispersed in the austenite matrix of the weld metal due to increase in welding current. The result is further decrease in the hardness value which can be attributed to the coarsening of the grain structure resulting from the slow cooling in the region due to the poor thermal conductivity of austenitic stainlesssteels.

Hardness Test: The result of the hardness test is recorded in Table 2 and Figure 1.

Table 2 and Figure 1 showed that there was no significant effect on hardnessfor all welding currentswhich agrees with the report of Nnuka, Ovat and Oseni [18]. However the result showed marginal difference in hardness between that of the weld metal and the base metal for all welding currents. This also agrees with the observations of Okonji, Utu and Akaluzia [19]. This can be attributed to the introduction of thermal stresses with increase in dislocation density, resulting from the restriction of the base metal during welding and the high thermal coefficient of expansion of this grade of steel. This agrees with literature as recorded by Mishra *et al.* [20] and Yilmaz and Uzun [21]. Also, it can be observed that increase in welding current produced a decrease in hardness values due to the coarse grain structure resulting from increase in welding heat input, according to the findings of Prasad and Dwivedi [22], Kahraman, *et al.* [23] and Bahman and Alialhosseini [24].

Table 2: Hardness

Current (A)	Filler Metal Type	Hardness (HBR)
91	309L	76.90
92	309L	76.70
93	309L	76.50
94	309L	76.30
95	309L	76.00
Control	-	76.00

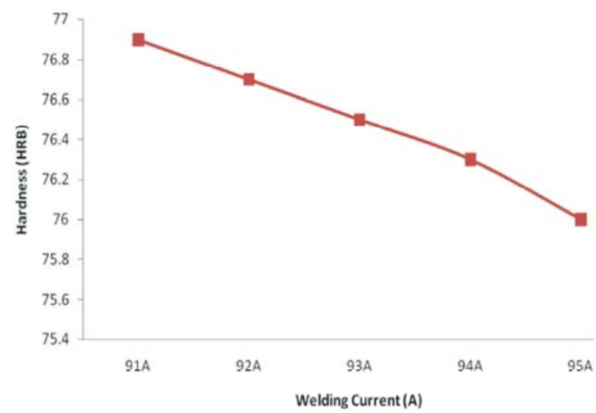

Fig. 1: Effect of Welding Current on Hardness of Welded Joint

CONCLUSION

There was only marginal difference in hardness values obtained for the weld metal and base metal for all welding currents. However reduction in the hardness values of the weld metal with increase in welding current was observed.

REFERENCES

1. Nansaarng, S. And C. Chaisang, 2007. Influence of parameters for gas metal arc welding on macrostructures and mechanical properties of austenitic stainless steels. 6th WSEAS International Conference on System Science and Simulation in Engineering. Venice, Italy, November, pp: 21-23.
2. Wikipedia. 2010. Stainless steel". Retrieved from http://en.wikipedia.org/wiki/stainless steel on 1/7/2014
3. Uhlig, H.H., 1985. Corrosion and Corrosion Control. Wiley, New York, NY.

4. Kou, S., 2003. Corrosion-Resistant Materials: Stainless Steels". Welding Metallurgy, 2nd edition, pp: 431-454. John Wiley & Sons, Inc., Hoboken, New Jersey.
5. ASM Handbook, vol. 6 (1993). ASM International, Materials Park, OH, pp: 4.
6. Llewellyn, D.T. and R.C. Hudd, 1998. Welding of stainless steels. Steels: Metallurgy and Applications, 3rd edition, pp: 334-336. Butterworth Heinemann, oxford OX2 8DP
7. Bang, K.S., D.H. Jung, C. Park and W.S. Chang, 2008. Effects for welding parameters on tensile strength of weld metal in flux cored welding. Science and Technology of Welding and Joining, 13(6): 508-514.
8. Srivastastava, B.K., S.P. Tewari And J. Prakash, 2010. A review of effect of arc welding parameters on mechanical behaviour of ferrous metals/alloys. International Journal of Engineering Science and Technology, 2(5): 1425-1432.
9. Singh, R.P., R.K. Garg and D.K. Shukla, 2012. Parametric effect on mechanical properties in submerged arc welding process - A review. International Journal of Engineering Science and Technology, 4(02): 747-757.
10. Uygur, I. and I. Dogan, 2005. The effect of TIG welding on microstructure and Mechanical properties of butt-joined-unalloyed titanium. METAK, 44(2): 119-123.
11. Zou Gui-sheng, Wu Ai-ping, Ren Jai-lie. Yang Jun and Zhao Wen-qing, 2004. Effect of heat input on microstructure and properties of welded joint in magnesium alloy AZ31B. Transactions of Nonferrous Metals Society of China, 14(1): 58.
12. Testen, M.H. and M.J. Morgan, 2005. Microstructural study of fusion welds in 304L and 21Cr-6Ni-9Mn stainless steels. Westinghouse Savannah River Company, Savannah River Site, Aiken, South Carolina, pp: 29808.
13. Oladele, I.O. and J.A. Omotosho, 2010. Effect of welding current and voltage on the mechanical properties of wrought (6063) aluminium alloy. Materials Research, 13(2): 1-9.
14. Gigovic-Gekic, A., M. Oruc and M. Gojic, 2011. Determination of the content of delta ferrite in austenitic stainless steel nitronic 60. 15th International Research/Expert Conference: Trends in the Development of Machinery and Associated Technology. TMT 2011, Prague, Czech Republic, 12-18 September, 2011, pp: 157-160.
15. Kou, S., 2003. Effect of welding parameters on grain structure. Welding Metallurgy, 2nd edition, pp: 174-178, 43. John Wiley & Sons, Inc., Hoboken, New Jersey.
16. Calik, A., 2009. Effect of cooling rate on hardness and microstructure of AISI 1020, AISI 1040 and AISI 1060 steels. International Journal of Physical Sciences, 4(9): 514-518.
17. Ghazvinloo, H.R., A. Honarbakhsh-Raouf and N. Shadfar, 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, 3(2): 156-162
18. Nnuka, E.E., F. Ovat and M.I. Oseni, 2005. The effect of electrode types on the mechanical properties and structure of welded steel joint. Journal of Metallurgy and Materials Engineering, 2(1): 120-127.
19. Okonji, P.O., O.G. Utu and R.O. Akaluzia, 2017. Effect of welding current on the hardness of austenitic stainless steel weld joints. Journal of Engineering and Allied Discipline, ISSN: 2454-5222, 09/2017, www.dspgjournal.comVol 1, Issue 2, September, 2017
20. Mishra, M.P., H.U. Borgstedt, M.D. Mathew, S.L. Mannan and P. Rodriguez, 1997. A comparative study of creep rupture behaviour of modified 316L (N) base metal and 316L(N)/16-8-2 weldment in air and liquid sodium environment. Int. J. Pressure Vessels & Piping, 72: 11-18.
21. Yilmaz, R. and H. Uzun, 2002. Mechanical properties of austenitic stainless steels welded by GMAW and GTAW. Journal of Marmara for Pure and Applied Sciences, 18: 97- 113.
22. Prasad, K. and D.K. Dwivendi, 2008. Some investigation on microstructure and mechanical properties of submerged arc welded HSLA steel joints. International Journal of Advanced Manufacturing Technology, 36: 475-483.
23. Kahraman, N., M. Taskin, B. Gulenç and A. Durgutlu, 2010. An investigation into the effect of welding current on the plasma arc welding of pure titanium. Koveve Mater, 48: 179-184.
24. Bahman, A.R. and E. Alialhosseni, 2010. Change in hardness, yield strength and UTS of welded joints produced in St37 grade steel. Indian Journal of Science and Technology, 3(12): 1162-1164.