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

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ABSTRACT:

An investigation on the influence of welding current and filler metal type on the hardness of austenitic stainless steel was carried out. Austenitic stainless steel (AISI 304L) plate, 3mm thick, and ER308L (2mm) filler rod were used to prepare a butt-weld joint using a GTAW process and welding currents of 91- 95 amperes at 1 ampere interval. The hardness values were determined on Rockwell B scale using 1/16-inch steel ball. The result showed that there was no significant increase in hardness of the weld joints for all welding currents but registered a decrease as the welding current increased. Also the hardness values for all the welding currents recorded were slightly higher than but comparable to that of the base metal.

KEYWORDS: *Hardness, GTAW process, Austenitic Stainless Steel, Welding Current*

Introduction

Austenitic stainless 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 (Nansaarng and Chaisang, 2007 and Wikipedia, 2011). 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 (Uhlig, 1985, Kou, 2003 and ASM, 2008). They also exhibit freedom from transformation to martensite (Llewellyn and Hudd, 1998).

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 (Llewellyn and Hudd, 1998). The studies of Bang et al, (2008) and Tewari, Gupta and Prakash (2010) 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 these 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 (2005) showed that increase in welding current resulted in coarse grains and decrease in hardness. This agreed with the observation of Zou et al (2004) in their study on the microstructure and properties of the welded joint of magnesium alloy AZ31B.

Experimental Procedure

Materials

The materials used for this study include 3mm austenitic stainless steel plate (base metal), 308L (2mm), 309L (2mm) and 316L (2.4mm) filler rods with the chemical compositions shown in Table1. 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 400mmx50mmx3mm, 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 10mm x 10mm 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 150Kgf 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 Table2

Results and Discussions

Chemical Composition

The chemical composition of the base metal and filler rods are shown in Table1.

Table1. 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														
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					

Hardness Test

The result of the hardness test is recorded in Table 2 and Figure1.

Table 2: Hardness

Current (A)	Filler Metal Type	Hardness (HBR)
91	308L	76.50
	309L	76.90
	316L	77.00
92	308L	76.40
	309L	76.70
	316L	76.80
93	308L	76.30
	309L	76.50
	316L	76.60
94	308L	76.08
	309L	76.30
	316L	76.50
95	308L	76.00

	309L	76.oo
	316L	76.30
Control	-	76.00

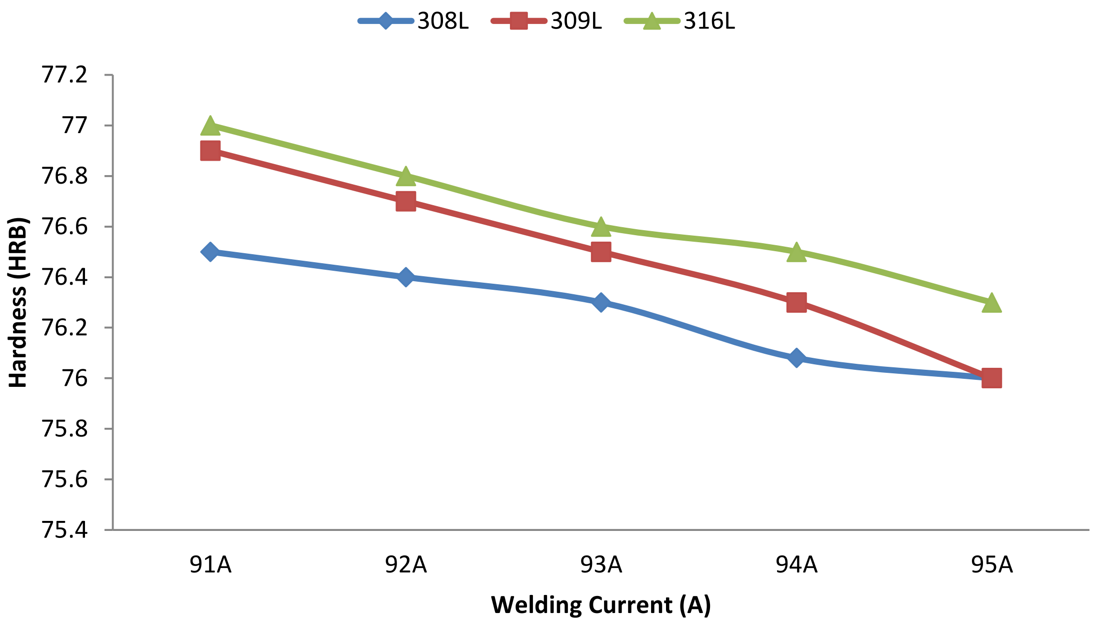

Figure1. Effect of Welding Current on Hardness of Welded Joint

Table 2 and Figure1 show that there was no significant effect of filler metal type on hardness (Nnuka, Ovat and Oseni, 2005) for all welding current. However the 308L filler metal showed lowest values for all welding current and this can be due to its very low carbon content. The result also showed only very marginal difference in hardness between the weld metal and the base metal for all filler metals and welding currents. 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. This is due to the high thermal coefficient of expansion of this grade of steel. This agrees with literature as recorded by Mishra et al (1999) and Yilmaz and Uzun (2002). Also, it can be observed that increase in welding current resulted in decrease in hardness values due to the resulting coarse grain structure. This agrees with the findings of Prasad and Dwivedi (2008), Kahraman, et al (2010) and Bahman and Alialhosseini (2010).

Conclusion

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

References

ASM Handbook, vol. 6 (1993). ASM International, Materials Park, OH, p. 4

Bahman A. R. and Alialhosseni E. (2010). Change in hardness, yield strength and UTS of welded joints produced in St37 grade steel. Indian Journal of Science and Technology, vol. 3, No. 12, 1162-1164

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.

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.

Kou, S. (2003). Corrosion-Resistant Materials: Stainless Steels". Welding Metallurgy, 2nd edition, pp 431-454. John Wiley & Sons, Inc., Hoboken, New Jersey.

Llewellyn, D. T. And Hudd, R. C. (1998). "Welding of stainless steels". Steels: Metallurgy and Applications, 3rd edition, pp334-336. Butterworth Heinemann, oxford OX2 8DP

Mishra, M.P., Borgstedt, H. U., Mathew, M. D., Mannan, S. L., Rodriguez, P. (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, 11-118

Nansaarng, S. And Chaisang, C. (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, 21-23.

Prasad, K. And Dwivendi, D. K. (2008). Some investigation on microstructure and mechanical properties of submerged arc welded HSLA steel joints. International Journal of Advanced Manufacturing Technology, 36, 475-483.

Uhlig. H. H. (1985). Corrosion and Corrosion Control. Wiley, New York, NY.

Uygur, I. and Dogan, I. (2005). The effect of TIG welding on microstructure and mechanical properties of butt-joined-unalloyed titanium. METAK 44 (2) 119-123.

Wikipedia (2000). Stainless steel". Retrieved from http://en.wikipedia.org/wiki/stainless_steel on 1/7/2014.

Yilmaz R. And Uzun, H. (2002). Mechanical aproperties of austenitic stainless steels welded by GMAW and GTAW. Journal of Marmara for Pure and Applied Sciences, 18, 97- 113

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