MICROSTRUCTURE ANALYSIS OF XAR STEEL PLATE WELDED BY MAG WELDING METHOD USING DIFFERENT WELDING CURRENTS

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ABSTRACT

The aim of this study is to investigate the effect of welding current on microstructure in combining XAR (eXtra Wear Resistance) steels with MAG welding method. The most important parameter during the welding process is the heat input. The desired microstructure can be obtained by controlling the heat input. Because microstructure is the most important factor affecting all mechanical properties. In this study, the effect of welding current intensity on microstructure in combining XAR 500 steel of 4 mm thickness used in heavy duty machine with MAG welding method was investigated. In the preparation of welded samples, MAG welding robot with speed, voltage and current control is used. Three different welding current densities were selected as welding current intensity 140A, 160A and 180A. Welding speed was kept constant at 350mm / min. In order to test the effect of the welding speed, the welding current was kept constant at 160A and at speeds of 300mm / min, 400mm / min and 450mm / min. Arc length is selected as 1mm. The gas flow rate was kept constant at 10mm / min. SG-2 welding wire with 1mm thickness was used as additional metal. Mixed gas with 86% CO2, 12% CO2 and 2% O2 was used as welding gas. The effect of welding current on microstructure was investigated in all welded samples. Microstructures obtained from welded joints were analyzed. As a result, it is observed that the microstructure is homogenous and the residual metal nitrides precipitate. It has been observed that the grain size decreases with the increase of heat input depending on the welding current.

KEYWORDS: XAR Steel, MAG Welding, Microstructures

PACS– 81.20.Vj Joining; welding

1. INTRODUCTION

In recent years, UHSS (Ultra High Strength Steel) is the most preferred steel group in the manufacture of heavy duty and well- equipped construction machines as mine research machines, crane equipment, excavation and constructions sector. Because of their high wear resistance, these steels have gained importance compared to other manufacturing steels[1-4]. Increasing rates of use also support this. XAR (eXtra Abrasion Resistant) steel is the most preferred steel from HSS steels because of its high strength, lightness and high wear resistance. These steels with high abrasion resistance are at least 5 times more resistant to abrasion than HSS steels. Due to the small amount of alloying elements in the chemical composition, they have a lower Ces. Therefore its weldability is good[4-10].

Due to the intensive use of these steels in large and comprehensive constructions, it has gained importance to joining of these steels. The most common joining method used in this context is welding. Gas metal arc welding method is the most preferred welding method because it is economical, practical, long-term welding and suitable for automation[11-15].

In this study, the effect of welding current intensity on microstructures properties in MAG welding method of XAR 500 steel was investigated

2. EXPERIMENTAL STUDIES

In this study, XAR 500 having 4 mm thickness steel was used during all specimens and was welded by MAG welding mothod in butt welding position. The mechanical and chemical propertiess of XAR 500 steel sheet is shown in Table 1 and Table 2, respectively.

Table 1. Mechanical properties of XAR 500 steel sheet.

CET %	0.41
CE %	0.62
Yield Strength [N/mm^2]	1300
Tensile strength [N/mm^2]	1600
Total elongation [%]	9

Table 2. Chemical composition of XAR 500 steel sheet. (%).

C %	Si %	Mn %	P %	S %	Cr %	Mo %	B %
<0.28	<0.80	<1.50	<0.025	<0.010	<1.00	<0.50	<0.005

Three different welding current density were selected such as 140 A, 160 A and 180 A . The welded plates obtained are given in Figure1 and Figure 2.

Figure 1. Welded plates obtained at different welding currents

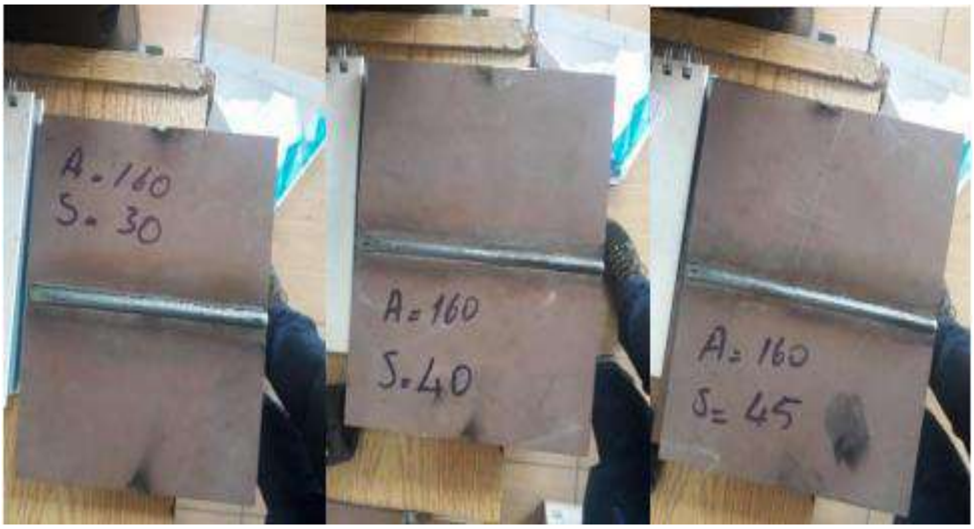


Figure 2. Welded plates obtained at different welding speed

Two plates with 150x100x4 mm dimensions have welded with robotic MAG welding. In first samples, the other welding parameters, such as welding speed 350 mm/min was kept constant. In second samples, welding currentdensity was selected such as 160 A and welding speed were selected such as 300 mm/min, 400 mm/min and 450 mm/min. SG2 welding wire was used in all samples during welding and HB212 gas was chosen as the protective gas. Chemical composition of welding wire and protective gas are shown Table 3 and Table 4, respectively.

Table 3. Chemical composition of welding wire

Welding Wire	C	Si	Mn
SG2	%0,08	%0,85	%1,50

Table 4. Chemical composition of protective gas

Gas	Ar	CO_2	O_2
HB212	%86	%12	%2

The heat input at the welding is an important parameter. It directly affects the microstructure of the welding specimens. Equations 1 show the calculation of the heat input (H: kJ/mm) in welded joints varies according to different parameters such as welding current (I: Amps), welding voltage (E: voltage), welding speed (S: mm/min) and welding coefficient (η: 0,8). Heat input is calculated by the following formula. Heat inputs calculated from welded specimens are shown Table 5.

$$H = \eta . \frac{I \cdot E \cdot 60}{S \cdot 1000} \quad (1)$$

Table 5. Experimental details

<table>
<tr><th>Sample Number</th><th>Welding Amperes [A]</th><th>Arc Voltage [V]</th><th>Welding Speed [mm/min]</th><th>Arc Efficiency Factor [η]</th><th>Gas Feed Speed [l/min]</th><th>Heat Input [kJ/mm]</th></tr>
<tr><td>1</td><td>140</td><td>17,76</td><td rowspan="3">350</td><td rowspan="6">0,8</td><td rowspan="6">10</td><td>0.341</td></tr>
<tr><td>2</td><td>160</td><td>19,18</td><td>0.421</td></tr>
<tr><td>3</td><td>180</td><td>21,59</td><td>0.533</td></tr>
<tr><td>4</td><td rowspan="3">160</td><td>19,179</td><td>300</td><td>0.491</td></tr>
<tr><td>5</td><td>19,166</td><td>400</td><td>0.368</td></tr>
<tr><td>6</td><td>19,16</td><td>450</td><td>0.327</td></tr>
</table>

Samples were cut with precision cutting machine after welding process. Samples obtained in selected parameters have polished for microstructure inspections after cutting. Then etched with 5% Nital solution. Then Optical analyses were made with Nikon Eclipse L150A mikroskop.

3. RESULTS

3.1 Microstructures

Microscopic investigation consisted of XAR 500 (base metal) joints with looking high magnification (50 ×,100 ×, 200 ×) as shown Figure 3. metal nitride or metal carbur precipitates was observed in the base metal as indicated by the manufacturer (Figure 3). Heat Affected Zone (HAZ) is given Figure 4.

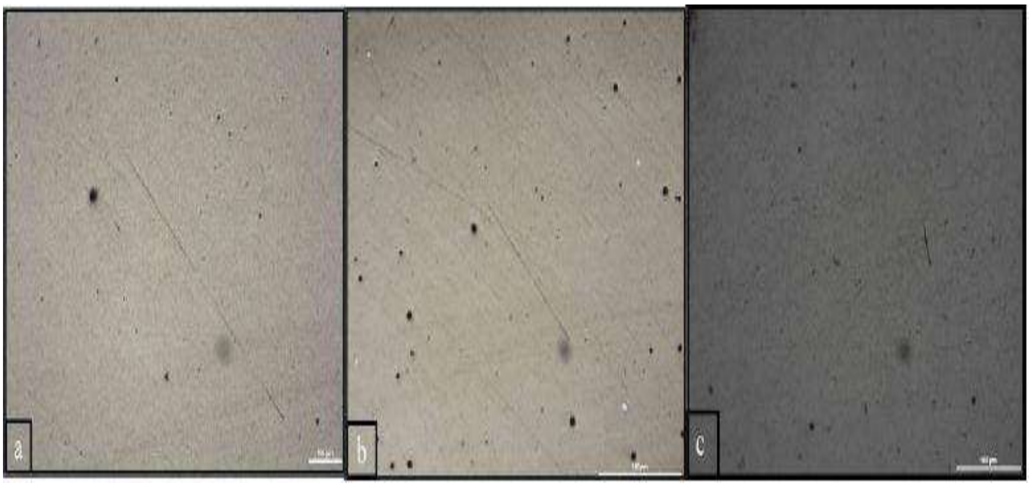


Figure 3.Base metal a) 100x , b) 50x and c) 200x magnification

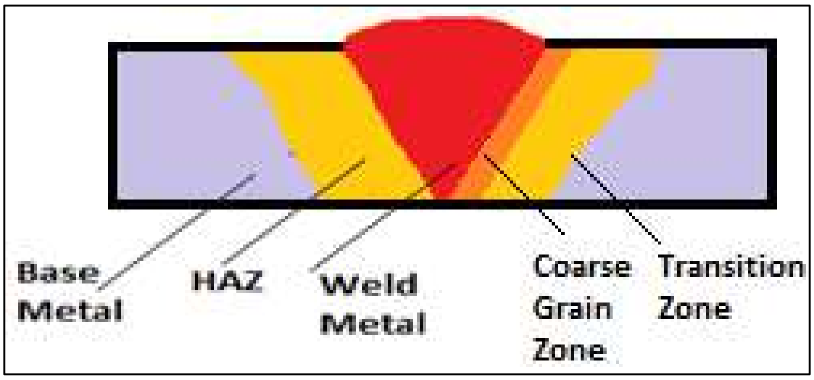


Figure 4. Heat Affected Zone

There are tempered martensite in coarse grained zone. The microstructure of the XAR 500 steel is indicated by the manufacturer of the martensite structure. therefore, the tempered martensite structure is the maximum in the coarse grained zone. It is seen that the metal nitride or metal carbide precipitate is almost absent in the coarse grained region.This information supports the studies in the literature [10].

At the end of the coarse grained region, solidification has begun and has progressed to create a dentritic structure towards the weld center. Metal nitride/ metal carbide precipitates have been in the weld metal. Metal nitrides/ metal carbides size were observed to decrease with increase of heat input. The microstructure images (200 × magnification) obtained at different welding currents at constant welding speed and the microstructure images obtained at different welding speeds at constant welding current are given in Table 6 and Table 7, respectively.

Table 6. Microstructure images (200 × magnification) obtained at different welding currents at constant welding speed

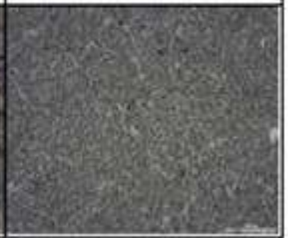
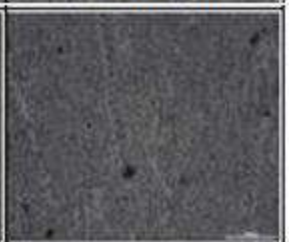
	Transition Zone	Coarse Garin Zone	Weld Metal
140 A 350 mm/min			
160 A 350 mm/min			
180 A 350 mm/min			

Table 7. Microstructure *images* (200 × magnification) obtained at different welding speeds at constant welding current

	Transition Zone	Coarse Garin Zone	Weld Metal
160 A 300 mm/ min			
160 A 400 mm/min			
160 A 450 mm /min			

3.2 Makrostructures

HAZ (Heat Affected Zone) was clearly seen after the samples were etched. At the welded samples has been the full penetration due to increased heat input with high amperes as seen Figure 5.

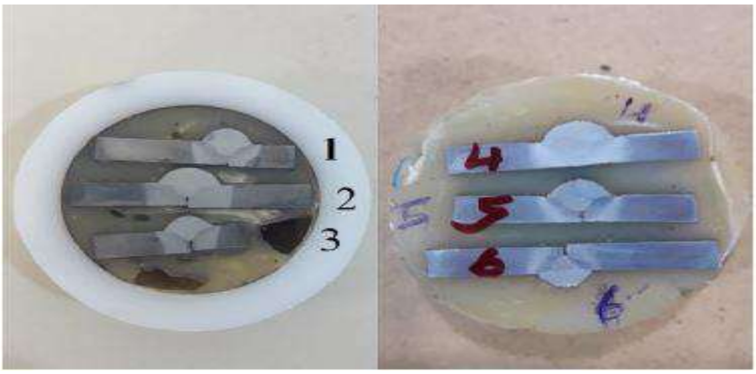


Figure 5. Different penetrations obtained at welded samples

4 CONCLUSION

In this study, obtained results can be summarized as below;

- The maximum welding penetration has obtained at the welding current intensity of 180A and welding speed of 350mm / min. Minimum welding penetration was obtained at a welding current intensity of 160A and welding speed of 450mm / min.
- When the heat input increases in the HAZ, the welding penetration increases.
- It has been observed that the size of the HAZ zone has been widened with the effect of increasing heat input. The maximum HAZ zone was obtained at a welding current of 180A at a welding speed of 350 mm / min.
- Metal nitride / metal carbide precipitations have not observed with the increase of heat input in the HAZ region.
- If high-strength welded joints are required at joining XAr steels, must be welded in high heat input. Because it was observed that metal nitride / metal carbide precipitates were not formed in the coarse grained zone under high heat input conditions.

Acknowledgments

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REFERENCES

[1] Frydman, S., and G. Pękalski. "Structure and hardness changes in welded joints of Hardox steels."Archives of Civil and Mechanical Engineering 8.4 (2008): 15-27

[2] Oskwarek M., Structural features and susceptibility to cracking of welded joints of Hardox 400 and Hardox 500 steels, Conference Proceedings, IV Scientific Conference of Students, Wroclaw University of Technology Publishing House, Wrocaw 2006.

[3]Buglacki H., Smajdor M.: Mechanical properties of abrasion – resistant Hardox 400, *Advances in Material Science*, Vol. 4, No. 2, 2003.

[4]Mithilesh P., Varun D., Ajay Gopi R., Reddy K., Ramkumar D., Arivazhagan N., Narayanan S., Investigations on dissimilar weldments of inconel 625 and AISI 304, Procedia Engineering, 75, 66–70, 2014.

[5] Li Z., Fontana G., Autogeneous laser welding of stainless steel to free-cutting steel for the manufacture of hydraulic valves, J. Mater. Process. Technol, 74 (1- 3), 174, 1998.

[6] Finsgar M., Milosev I., Corrosion behavior of stainless steels in aqueous solutions of methanesulfonic acid, Corros. Sci., 52 (7), 2430–2438, 2010.

[7] S.V. Konovalov, V.E. Kormyshev, V.E. Gromov, Formation Wear Resistant Costings on Martensite Steel Hardox 450 by Welding Methods, https://doi:10.1088/1757-899X/142/1/012079

[8] Konat, L., Bialobrzeska, B, Bialek, P., “Effect of Welding Process on Microstructural and Mechanical Characteristics of Hardox 600 Steel”, https://doi:10.3390/met7090349

[9] Ivanov, Yu. F., S.V. Konovalov, V. E. Kormyshev, V. E. Gromov, “Structure and Properties of Hardox 450 Steel with Arc Welded Coating”, https://doi.org/10.1063/1.5013754

[10] Frydman, S., Konat, L., Pekalski, G., “Archives of Civil and Mechanical Engineering”, 15-26, https://doi:10.1016/S1644-9665(12)60118-6

[11] Uluköy A., “Pulsed Metall Inert Gas (MIG) Welding And Its Effects On The Microstructure And Element Distribution Of An Aluminum Matrix Reinforced With Sic Composite Material” https://doi.org/10.1002/mawe.201700568

[12] Ada H., Aksöz S., Fındık T., Çetinkaya C., Bostan B., Candan İ.,“The Investigation of Effect of Welding Process on The Microstructure and Mechanical Properties of API 5L X65 Steel Welded with Gas Metal Arc Welding Method” https://dx.doi.org/10.21605/cukurovaummfd.311031

[13] Ekici M., Ozsaraç U., “Investigation of Mechanical Properties of Microalloyed Steels Joined by GMAW and Electrical Arc Welding” , https://doi.org/10.12693/APhysPolA.123.289

[14] Ekici M., Ozsarac U.,“Influence of Martensite Volume Fraction on Ductile to Brittle Transition of Triple Phase Ferrite-Perlite-Martensite Steels Joined by GMAW and Electrical Arc Welding”, https://doi.org/10.12693/APhysPolA.125.529

[15] Modenesi P.J., Avelar R.C., “The Influence Of Small Variations of Wire Characteristics on Gas Metal Arc Welding Process Stability”, https://doi.org/10.1016/S0924-0136(98)00315-X

[16] D.M. Evans, D. Huang, J.C. McClure,A.C. Nunes, Weld. J. 1998, 77, 53.

[17] K. Mutombo, M. Du Toit, Arc Welding, Intech Open Access Publisher, Rijeka2011.