THE EFFECT OF WELDING CURRENTS ON MICROSTRUCTURES IN WELDING OF S690QL SERIES STEELS IN USED HEAVY DUTY MACHINES

Hüseyin EFE
Department of Manufacturing Engineering, Faculty of Technology, Pamukkale University, Denizli, TURKEY

Volkan ONAR
Department of Manufacturing Engineering, Faculty of Technology, Pamukkale University, Denizli, TURKEY

M. Görkem ÇINAR
Department of Manufacturing Engineering, Faculty of Technology, Pamukkale University, Denizli, TURKEY

Corresponding Author: Volkan ONAR
Department of Manufacturing Engineering, Faculty of Technology, Pamukkale University, Denizli, TURKEY
e-mail address:vonar@pau.edu.tr

ABSTRACT

The aim of study, was investigated the effect of welding current on microstructures of welded joints in MAG welding method of S690QL steels. When the application areas of S690QL series steel are examined, it is observed to use at heavy duty applications which as in truck industry, crane industry and mining machines etc. MAG welding method is a extensively used joints method, especially in the heavy duty machines sector. That's why the welding of S690QL steels gained importance. It is necessary to optimize the welding parameters in order to obtain the appropriate welding joints.The most important parameter is heat input in the welding process. Therefore, control of the heat input is with controlling the welding current intensity. Thus, the desired microstructure at the welding can be obtained. Microstructure is the most important factor affecting all mechanical properties. In this study, was investigated the effect of welding currents on microstructures in MAG welding of S690QL series steels sheets having 3 mm thickness in used heavy duty machınes. A welding speed, voltage and current controlled MAG welding robot was used to prepare the welded specimens. Welding currents were chosen three different welding currents as 120A, 140A and 160A. The welding speed was kept constant at 350 mm/min. The arc lenght was selected 1 mm and gas flow rate was kept constant 10 mm/min. SG-2 wire has 1mm thickness was used as additional metal and welding gas with %86 Ar, %12 CO_2, %2 O_2 chemical composition was used. The effect of welding currents on microstructures have been examined at all welded specimens. At the all of parameters were obtained successful joints. The microstructure and of the welded joints obtained were analyzed. Microstructure investigations of welded specimens was made by optical microscope. As a resutls, at microstructures was observed homogen weld zone and residual precipitation of metal nitrite. Depending on the welding current intensity, It was observed that the grain size decreased while the heat input increased.

Keywords: S690QL Steel, MAG Welding, Microstructures

PACS– 81.20.Vj Joining; weldings

1. INTRODUCTION

Nowadays, production and usage of new generation steel is increasing. the most preferred new generation steel group is UHSS (Ultra High Strength Steel) steels. In these steels, S690QL steels which are low alloyed should be given importance. Their microstructure is quenched and tempered[1-6].

Thus steels are used for manufacturing of the heavy duty machines, crane and heavy constructions. Therefore, the welding of these steels is very important. However, is the most important problem, weldability of the thicker parts. Because, cold cracks and residual stresses may occur at the welding of these steels. This problem can be eliminated by the control of heat input during welding process[7-14].

Gas metal arc welding is the most commonly used welding method in the welded of manufacturing steels in industry. Because, gas metal arc welding process is continuous and suitable for automation[15-18].

2. EXPERIMENTAL STUDIES

In this study, N-A-XTRA 700 having 3 mm thickness steel was used during all samples and two plates with 150x100x4 mm dimensions have welded welded by robotic MAG welding method in butt welding position. The chemical and mechanical properties of N-A-XTRA 700 (S690QL) steel sheet is shown in Table 1 and Table 2, respectively.

Table 1. Chemical composition of N-A-XTRA 700 steel sheet. (%).

C %	Si %	Mn %	P %	S %	Cr %	Mo %
<= 0,20	<= 0,8	<= 1,6	<= 0,020	<= 0,010	<= 1,5	<= 0,6

Table 2. Mechanical properties of N-A-XTRA 700 steel sheet.

CET %	0,32
Yield Strength [N/mm^2]	700
Tensile strength [N/mm^2]	770-940
Total elongation [%]	14

The surfaces of the plates were cleaned before welding as shown Figure 1. Then three different welding current density were selected such as 120 A, 140 A and 160 A. The welded plates obtained are given in Figure2.

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Figure 1. Surface cleaning process

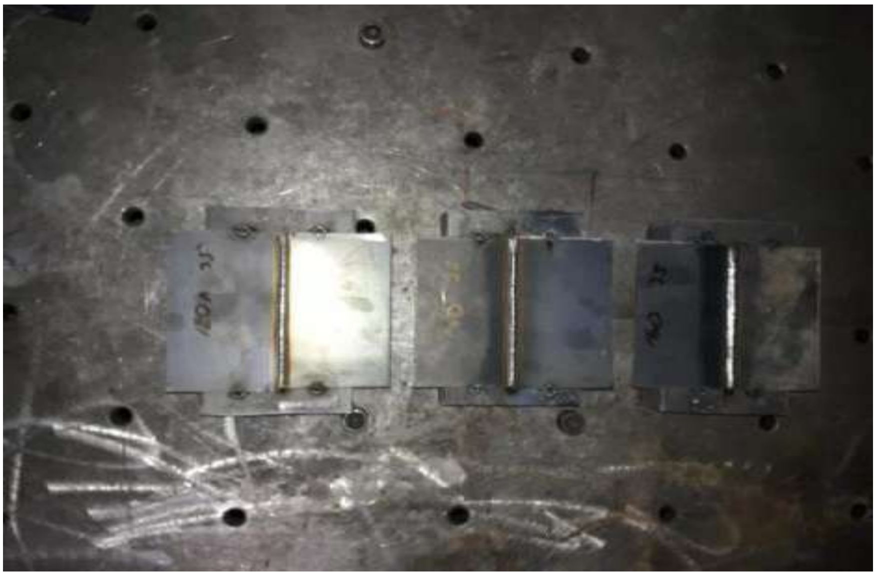

Figure 2. Welded plates obtained at different welding currents

The welding speed was kept constant at 350 mm/min. The arc length was selected 1 mm and gas flow rate was kept constant 10 mm/min. SG-2 welding wire has 1mm thickness was used as additional metal and welding gas was used as protective gas with %86 Ar, %12 CO_2, %2 O_2 chemical composition during welding process. Chemical composition of welding wire and is shown Table 3

Table 3. Chemical composition of welding wire

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

The most important parameter applied to the material in the welding process is the heat input. heat input directly affects the microstructure of welded materials, consequently, it is determining the strength of the welded material. 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 (Ƞ: 0,8). Heat input is calculated by the following Formula 1. Heat inputs calculated from welded specimens are shown Table 4.

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

Table 4. Experimental details

Sample Number	Welding Amperes [A]	Arc Voltage [V]	Welding Speed [mm/min]	Arc Efficiency Factor [Ƞ]	Gas Feed Speed [l/min]	Heat Input [kJ/mm]
1	120	16,40	350	0,8	10	0.271
2	140	17,70				0.345
3	160	19,14				0.423

Obtained welded specimens were cut with precision cutting machine. Specimens obtained in selected parameters have polished for microstructure inspections after cutting. Specimens obtained in selected parameters have polished and etching with 5% Nital solution for microstructure inspections. Then Optical analyses were made with Nikon Eclipse L150A microscope.

3. RESULTS

3.1 Microstructures

Microscopic investigation consisted of N-A-XTRA 700 (base metal) with looking high magnification (50 ×,100 ×, 200 ×) as shown Figure 3. Metal carbide / metal nitride precipitates was observed in the base metal as indicated by the manufacturer (Figure 3).

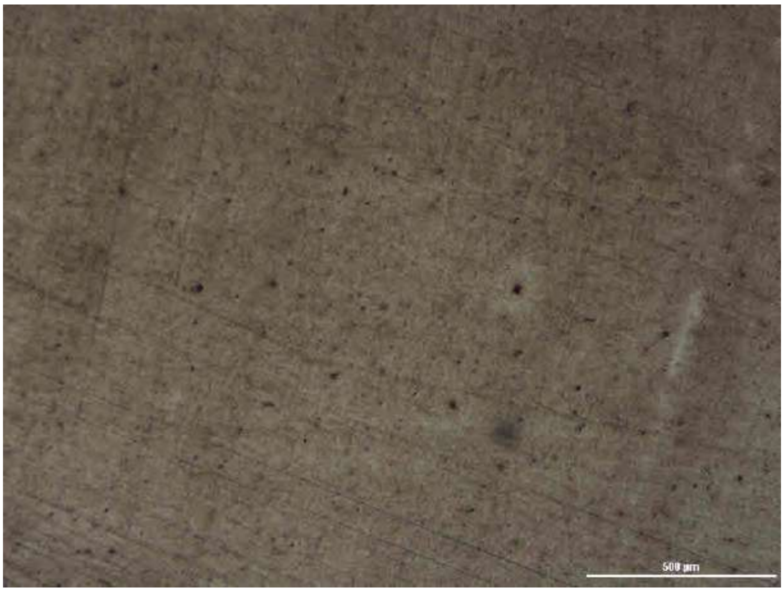

Figure 3.Base metal (200 × magnification)

The microstructure of the N-A-XTRA 700 steel has been said by the manufacturer of the martensitic structure. Therefore, has a fragile structure. But after the tempering process, it exhibits 4 times more strength than structural steels. Welding process is very important because the structure should not be disturbed. Although the precipitates seen in the base metal are collected in the coarse grained area in the low heat input, they are homogeneously distributed in the weld metal in the welding currents where the heat input is increased. For example, in welded joints made in 160 A and 350 mm/min, no precipitate was observed in the coarse grained zone and in HAZ.. This information supports the studies in the literature [19].

In 120 A welding current intensity, precipitates were obtained homogeneously and sizes of precipitates have increased in coarse grained zone. This is also seen in Figure 4(100 × magnification)

Figure 4. Heat Affected Zone (HAZ) (1) Transition Zone (2) Coarse Grain Zone (3) Weld Metal

However, it was observed that the precipitates decrease and shrinks in 140 A welding current intensity. This is also seen in Figure 5(100 × magnification).

Figure 5. Heat Affected Zone (HAZ) (1) Transition Zone (2) Coarse Grain Zone (3) Weld Metal

Finally, in 160 A welding current intensity, precipitates were not obtained in coarse grained zone. It has been detected that the precipitates were dispersed homogeneously into the weld metal. The microstructure images (100 × magnification) obtained at different welding currents at constant welding speed are given in Figure 6

Figure 6. Heat Affected Zone (HAZ) (1) Transition Zone (2) Coarse Grain Zone (3) Weld Metal

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 7.

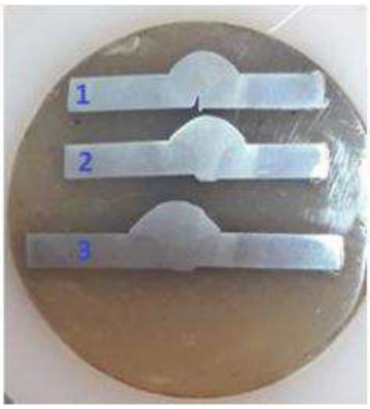

Figure 7. Different penetrations obtained at welded samples

4 CONCLUSION

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

i. The maximum welding penetration has obtained at the welding current intensity of 160A and welding speed of 350mm / min. Minimum welding penetration was obtained at a welding current intensity of 120A and welding speed of 350 mm/min

ii. When the heat input increases in the HAZ, the welding penetration increases.

iii. 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 160A at a welding speed of 350 mm / min.

iv. Metal nitride and / or metal carbide precipitates had been observed that in the microstructure of the welded samples in low welding current intensity. Similar studies in the literature [3] it had been found compatible with.

v. Metal nitride / metal carbide precipitations have not observed with the increase of heat input in the HAZ region.

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