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Effect of Filler Metal Diameter on Weld Joint of Carbon Steel SA516 Gr 70 and Filler Metal SFA 5.17 in Submerged Arc Welding SAW

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***Abstract*—**This work describes an investigation on the effect of filler metals diameter to weld joint, and low alloy carbon steel A516 Grade 70 is the base metal. Commercially SA516 Grade70 is frequently used for the manufacturing of pressure vessels, boilers and storage tank, etc. In fabrication industry, the hardness of the weld joint is between the important parameters to check, after heat treatment of the weld. Submerged arc welding (SAW) is used with two filler metal diameters, and this solid wire electrode is used for SAW non-alloy and for fine grain steels (SFA 5.17). The different diameters were selected (Ø = 2.4 mm and Ø = 4 mm) to weld two specimens. Both specimens were subjected to the same preparation conditions, heat treatment, macrograph, metallurgy micrograph, and micro-hardness test. Samples show almost similar structure with highest hardness. It is important to indicate that the thickness used in the base metal is 22 mm, and all specifications, preparation and controls were according to the ASME section IX. It was observed that two different filler metal diameters performed on two similar specimens demonstrated that the mechanical property (hardness) increases with decreasing diameter. It means that even the heat treatment has the same effect with the same conditions, the filler metal diameter insures a depth weld penetration and better homogenization. Hence, the SAW welding technique mentioned in the present study is favorable to implicate for the industry using the small filler metal diameter.

***Keywords*—**ASME, base metal, filler metal, micro-hardness test, submerged arc welding.

I. Introduction

SAW is a welding method of arc welding process. SAW could be operated in the automatic or mechanized mode, nonetheless, semi-automatic SAW works with pressurized or with gravity flux feed delivery are available. Admitting currents ranging from 300 to 2000A are frequently utilized.

Many advantages are waiting for this process like increasing the protection of weld metal from atmospheric contamination (gas), so improved properties of weld joint and reduced cooling rate of weld metal. HAZ due to shielding of the weld pool by molten flux and solidified slag in turn leads to smoother weld bead and reduced the cracking tendency of hardness steel.

Among the essential areas of application of the SAW method is the manufacture of pressure equipment, such as boilers storage tanks, etc. and especially non-alloy and low alloy steels such as SA 516. This nuance is used for pressure, low and medium temperatures.

Pressure equipment requires high quality and mechanical properties that meet building codes; qualified personnel and procedure for any type of permanent assembly of pressure equipment. Welding, brazing and gluing, are subject to the ASME Repository, American Society of Mechanical Engineers.

The quality [1] of the welding seal especially requires the quality and the specifications of the filler metal, in this study the filler metal chosen is SFA 5.17, the classification of the fluxes and the wires used in SAW following ASME II Part C (AWS) is SFA 5-17 / 5-23.

Our study consisted of investigating for the effect of reducing the filler metal diameter from 4 mm to 2.4 mm and comparing the results of the two diameters of the filler metal [1].

The tests revealed a considerable improvement in hardness after using a diameter of 2.4 mm less than that of 4 mm.

II. Procedure for Preparation

At the base of the welding method of SAW, we took two samples of the same technical specification, metallurgical and even heat treatment process, [2] with a change of only one important parameter, it is the diameter of the filler metal, to compare the hardness in the fused part of the A & B weld.

The specimens used in this communication used for PQR and the result of the test done by a Spanish laboratory.

A. Welding Specification

- Weld joint: QW-402
- Support: No
- Base metal: SA-516 Gr 70N E = 25 mm
- Filler metal:
- Specification: SFA 5.17
- Classification: EH 14
- Diameters: A: Ø = 4mm, and B: Ø = 2. 4 mm
- Flow electrode: F7P7-EH14
- Trade name flow: OP 121TT NEUTRAL
- Welding position: Flat: PA / 1G
- Preheating: minimum preheating temperature: 100 °C
- Maximum temperature between passes: 300 °C
- Post-weld heat treatment: 610 ± 10 °C
- Time interval: 165 min

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Those specifications are used for the preparation of the PQR for pressure vessels, and are used for the conditions optimal for having the best result of the welding and avoiding any welding defects. The technical specification respects all requirements of ASME.

The technical specifications are shown in Tables I-IV.

TABLE I
PROCESS / PASSES

Specimens	Process	Passes
A	SAW	3
B	SAW	3

TABLE II
CLASS/ DIAMETER

Specimens	Class	Diameter (mm)
A	EH14	4
B	EH14	2.4

TABLE III
VOLTAGE/ AMPERE

Specimens	Polarization	Ampere
A	DCE+	450/580
B	DCE+	450/580

TABLE IV
VOLTAGE /TRAVEL SPEED

Specimens	Voltage (v)	Travel speed (cm /min)
A	27/31	45/55
B	27/31	45/55

B. Chemical Composition

The chemical composition for the base metal is SA516Gr70 and for the filler metal is SFA 5.17-EH 14 (AWS/ASME Sec).

The chemical composition respects the ASME specification and the nuance of SA516Gr70 contains 0.17%C. The filler metal contains a poor percentage of carbon to cover the immigration from the base metal to the fusion area.

The hardness values are granted by the chemical composition, heat treatment, and mechanical treatment.

TABLE V
CHEMICAL COMPOSITION % C / SI

Specimens	% C	% Si
SA516Gr70	0.17	0.30
SFA 5.17-EH 14	0.07	0.07

TABLE VI
CHEMICAL COMPOSITION % Mn / P

Base metal/filler metal	% Mn	% P
SA516Gr70	1.44	0.011
SFA 5.17-EH 14	1.96	0.09

III. RESULTS AND DISCUSSION

A. Heat Treatment

According to ASME, our study for the heat treatment will respect the heat up and soak time as follows:

The heat treatment consists of:

- Heat up and cool down rates 610 °C around 100 °C/hour.
- Soak time 600min to 610 °C.
- Heat up and cool down rates <300 °C free.

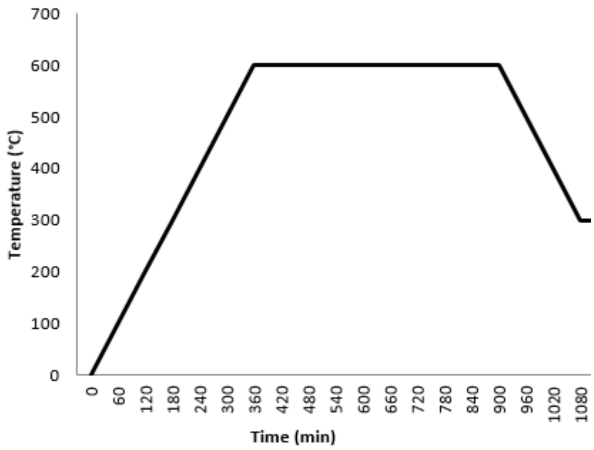

Fig. 1 Heat treatment cycle of both A & B welds

The heat treatment is a usual treatment used for amelioration and homogenization of welding joint. The amelioration is in the all parts of the weld, ZAT and welded part. In our study, we are concentrating specially on the welded part. Because of the effect of the heat treatment directly to the hardness, we have used the same condition of preparation and treatment.

According to the ASME specification, the heating up of the specimen until arriving at 600 °C with respecting the rate of the temperature of 100 °C/hour. The respect of the heat treatment parameters affects the result of the welded metal result.

B. Macrography

The specimens are prepared according to the standard specification of the micrographic. From surface preparation to chemical attack in order to get the acceptable results, these results are done in the Spanish laboratory.

The results of the test are indicated in the Figs. 2 and 3, where Fig. 2 indicates the macrographic of A specimen and Fig. 3 indicates the macrographic of B specimen.

Fig. 2 Macrographic specimen A

The micrographic specimens A and B are fine, showing a homogeneous weld seam disposition, HAZ, and fusion area.

They do not reveal any defects such as porosity, inclusions, slag, cracks etc.

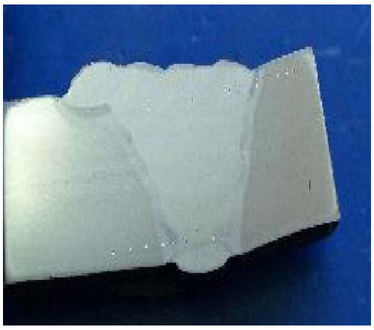

Fig. 3 Macrographic specimen B

C. Micrograph

The specimens are prepared according to the standard specification of the micrographic, from surface preparation to chemical attack in order to get the acceptable results these results are done in the Spanish laboratory.

The specimens are prepared according to the standard specification of the micrographic test [3]. The result of the test is shown in Figs. 4 and 5. Fig. 4 indicates the macrographic of A specimen, and Fig. 5 indicates the macrographic of B specimen.

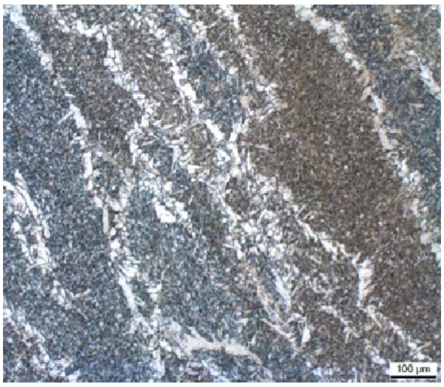

Fig. 4 Micrographic specimen A

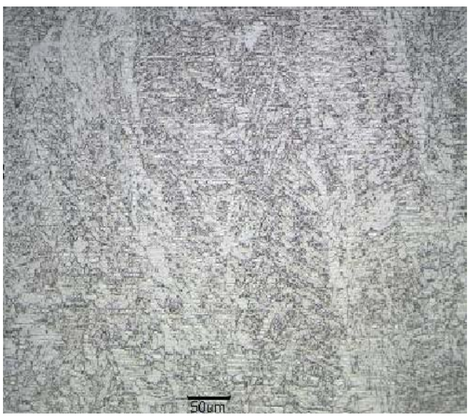

Fig. 5 Micrographic specimen B

The both specimen A and B on the weld metal (filler metal with the base metal) are made of ferrite widmanstätten and bainite.

The results are similar because of chemical composition, the heat treatment, and same preparation conditions.

Our conditions give the evidence of the metallurgy composition and the formation of grains as showed in Figs. 4 and 5. The next parameter that will be controlled is the hardness of Vickers HV10.

D. Hardness (Vickers HV10)

The values of the mechanical proprieties (hardness) are respecting the ASME specifications. The hardness will be used in three levels I, II and III for both specimens A (4mm) and B (2.4 mm). The method of the hardness measurement used in this work, for determination of hardness is Vickers.

The results are shown in Tables VII and VIII. Table VII shows acceptable hardness values for three levels. Table VIII shows the acceptable hardness values but with amelioration important of the hardness values.

The explanation of these results is that with the smaller electrode of filler metal, the current required will be less, thus lower heat. The grain forms are smaller compared to bigger diameters of filler metal. On the other hand, the homogenization of passes gives the different grains form according to the diameter of the filler metal.

TABLE VII
HV10/WELD A

Lines	Weld A - Ø=4 mm		
I	137	142	146
II	161	156	156
III	136	139	141

TABLE VIII
HV10/WELD B

Lines	Weld B - Ø=2.4 mm		
I	154	167	178
II	175	179	177
III	189	191	192

Hardness variations across the welds are shown in two Tables VII and VIII. In the two samples studied, the weld B showed higher hardness values than the weld A.

The 2.4-mm diameter solder used shows higher hardness values in the solder joint compared to the other 4-mm diameter weld.

IV. CONCLUSION

In this experimental study, the weld specified by base metal of SA516 Gr 70 and the filler metal of SFA 5.17 by [4], [5]. The process of the welding is Submerged arc welded (SAW) and, the diameters used are (Ø = 2.4 mm and Ø = 4 mm).

On the basis of the experimental results and the analysis, the following conclusions can be drawn;

1. The mechanical properties can be improved only by changing parameters such as the diameter of the filler metal especially with the same grade and same classification. The hardiness of the weld seam is approved also by the welding conditions and preparation [10].

In other words, the weld joint hardness (the fused part) improves by reducing and decreasing the diameter of the filler metal in the SAW method.

2. The most suitable [6] filler metal for similar welding of carbon steel A516 gr 70 SFA 5.17 specification filler metal is the diameter of 2.4mm and less [7], [8].

The next work will be about the study of the characterization of the filler electrode by changing the difference nuances by starting just about the steel carbon. The study will be concentrated on hardness, traction and folding test [9]. The finite element modelling will be an important part in this study.

There are many other parameters that we will use in next studies specially the traction test folding test.

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The next studies that we are working in are the welding defects, characterization of the filler metal and modeling.