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Electric current effect on mechanical properties of SMAW-3G on the stainless steel AISI 304

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Abstract. Parameters in the welding need to be known because the effect on the mechanical properties of the material after the welding process. This research purposes to find out the influence of variation of SMAW welding current on Stainless Steel AISI 304, with variation of electric current equal to 70A, 80A and 90A.The electrode of AWS A5.4 E308-16 with diameter of 2.6 mm is used. Dye penetrant test, tensile test and metallographic test applied to analysis the characteristic. Based on data from tensile test results obtained the highest value on the specimen welding current 90A is equal to 632 MPa. The lowest tensile strength value recorded on the specimens of current 70A is 498.66 MPa.

1 Introduction

The industrial field today has been widely used various types of welding technology with a variety of different functions. Starting from simple welding technology such as OAW (Oxy-Acetylene Welding) to automatic welding technology with a very complex sophistication [1]. The scope of the use of welding technology in construction is very broad, including shipping, bridge construction, pipeline, steel frame, pressure vessels, vehicles, and various other applications

In general, welding is defined as a process of joining between two or more metals by using heat energy so that the metal can be fused on the part that has been in the heat [2]. The welding not only joining similar metals but also joining dissimilar metals by application of heat [3]. The heat generated during the welding process can reach a melting point of steel that is about 1.370^o C or 2,500^o F [4, 5].

The metals object of this research is stainless steel (American Iron & Steel Institute) AISI 304 which belongs to Austenitic stainless steel. ASS is an alloy steel having levels of 0.03-0.35% C, 16-26% Cr, 0.75-19.0% Mn, 1-40% Ni [6]. The welding process causes an impact on the mechanical properties of materials and equipment performance. Residual stresses due to heating can decrease the strength of a material [4]. Because it makes the material tend to crack.

Often the welding process must be done in a certain place because it is formed from a construction, such as the welding of the pressure pipe connection that must be buried in the ground or welding on the corner of the building, on the ceiling, ect. so that required different welding position [7]. Given the necessity of a particular welding position, it will give different results to the strength and hardness of welding results

The SMAW process, known as the SMAW process (Manual Metal Arc Welding), the parent metal is subjected to melting due to heating of the arc arising between the tip of the electrode and the workpiece surface [8]. The existing electric arc is produced from the welding process.

Fig. 1. Result SMAW 3g position.

In the welding process to obtain a good welding results required considerable energy to melt the parent metal and fill metal [9]. In the SMAW welding process the energy generated comes from the electrical energy converted into heat energy [10]. This heat energy is influenced by three main parameters in the welding that is current, voltage and speed of welding. The speed of welding also affects the heat energy because during the welding process the resulting heat energy does not stay in place but experienced a process of moving at a certain speed [11][10]. The relationship between these three parameters produces heat energy welding or commonly called Heat Input is written in the following equation [9]:

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$$Hi(Heat\ Input) = \frac{A.V.(0.06)}{s} \quad (1)$$

Hi : heat input required in ampere volts min/mm
A : welding current A in Amps
V : Arc voltage in volts
s : welding speed in mm/min

Stainless steel is a type of high alloy steel with properties and characteristics of materials that are resistant to corrosion or oxidation and resistant to low or high temperatures. The properties of the material obtained from the main element content of chromium (Cr) a minimum of 12%. In addition stainless steel has a toughness and better cutting properties. It's why stainless steel is widely used in the world of industrial and household appliances [12].

One of the factor that also greatly affect the welding result is the welding position. The position of welding is setting to the position movement of the electrode. The position of the welding depends on the location and position of the groove of the parent material or the workpiece slit to be welded. In welding techniques there is a code to determine the position of welding to be done so that a welder does not make mistakes in determining welding procedures. There are two encoding systems for welding positions, the first is a system defined by AWS (American Welding Society) which refers to the type of connection. The second coding system is a system defined by ISO (International Standards Organization) where this system refers to the position of the electrode during the welding process occurs.

2 Methodology

The material used is AISI 304 stainless steel with 3 mm thick and electrode for welding used AWS type A5.4 E308-16 NC-38. Variations of current at welding are 70A, 80A and 90A. Specimens were formed 18 sets of plates. The chemical composition and characteristics of the specimens are shown in Table 1.

Table 1. Chemical composition of AISI 304.

C max	Mn max	Si max	Cr	Ni
0,08%	2,00%	1,00%	18,00-20,00%	8,00-12,00%

The specimen is welded using SMAW welding with groove design as shown. Figure 2**:**

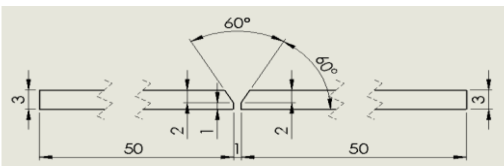

Fig. 2. Speciment design.

The equipment used are SMAW 200A welding machine, tensile testing machine, Microscop Optic as well as tools such as: cutter grinding, polish paper, and others.

3 Results

3.1 Dye penetrant test

Inspection using dye penetrant serves to check the defects on the surface or defects on the inside of the material through to the surface. Test results on AISI 304 stainless steel welding using AWS A5.4 E304-16 NC-38 electrode are shown in table 2:

Table 2. Defect Inspection.

No	Current	Defect	Corrosion
1	70 A	No defect	No crack
2		No defect	No crack
3		No defect	No crack
4	80 A	No defect	No crack
5		No defect	No crack
6		No defect	No crack
7	90 A	No defect	No crack
8		No defect	No crack
9		No defect	No crack

Fig. 3. Dye penetrant test.

Cracked or porosity defects may reduce the strength of the specimen and will be easily broken when subjected to tensile test or other material tests [2][13]. Table 2 shows that the results test of AISI 304 stainless steel welding there is no defects, either cracked defects or porosity defects.

3.2 Tensile test results

The specimen dimensions refer to ASTM E8 / E8M-09 standards as Figures 3 and Table 3.

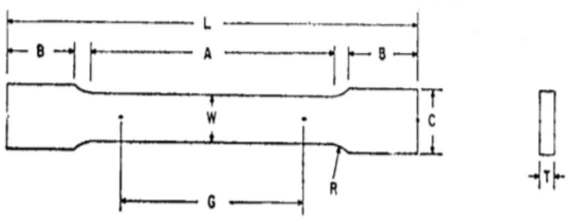

Fig. 4. Tensile test specimen ASTM E8/E8M-09.

Table 3. Dimensional specimen of tensile test.

G (mm)	W (mm)	T (mm)	R (mm)	L (mm)	A (mm)	B (mm)	C (mm)
50	12.5	3	12.5	200	75	50	20

The tensile test results data are presented in figure 5.

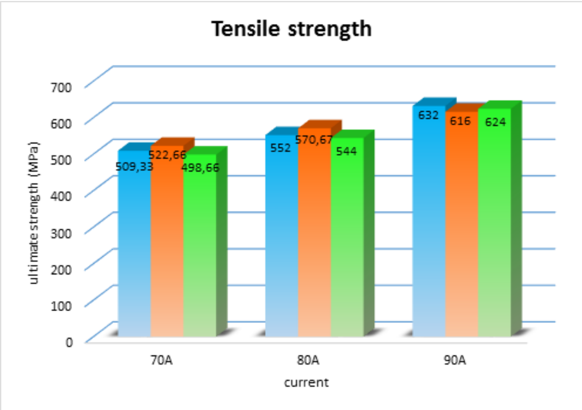

Fig. 5. Tensile Strength Diagram.

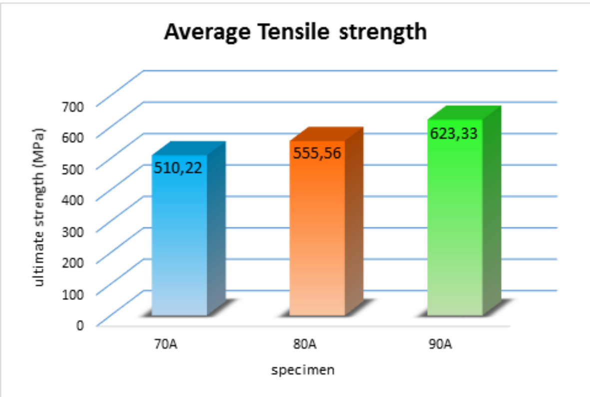

Fig. 6. The diagram of average tensile strength.

Fig. 6 shows that current of 70A obtained the lowest tensile strength 498.66 MPa and the highest tensile strength of 522.66 MPa. At the current of 80A the lowest tensile strength value is 544 MPa and the highest tensile strength is 570.67 MPa. The specimens with the welding current 90A got the lowest tensile strength value is 616 MPa and the highest tensile strength is 632 MPa.

The average tensile strength indicates that the welding current 70A has the lowest tensile strength of 510.22 MPa.at the current of 80A obtained the average of tensile strength value 555.56 MPa which means having 45.34 MPa difference compared to the current of 70A. The highest average of tensile strength 623.33 MPa is obtained at welding current of 90A .

3.3 Metallographic test results

Metallographic test [6] is aimed to know the micro structure of the grain size in the weld area, the HAZ area and the parent material area, the result of the test is shown in Figure 7:

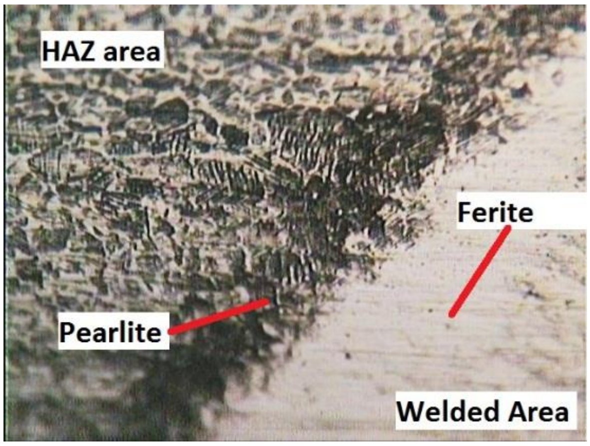

Fig. 7. Specimen with welding current of 70 A.

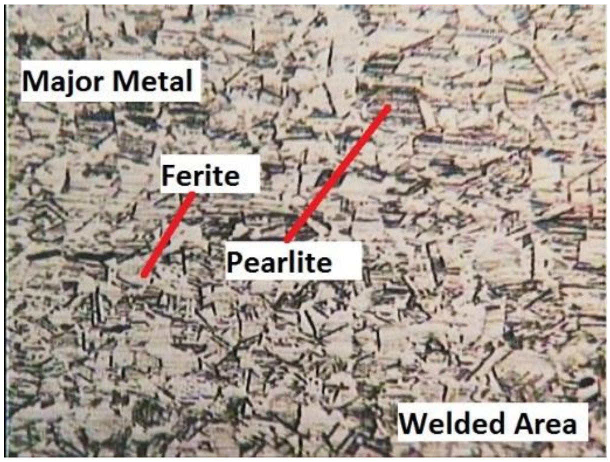

Fig. 8. Specimen with welding current of 80 A.

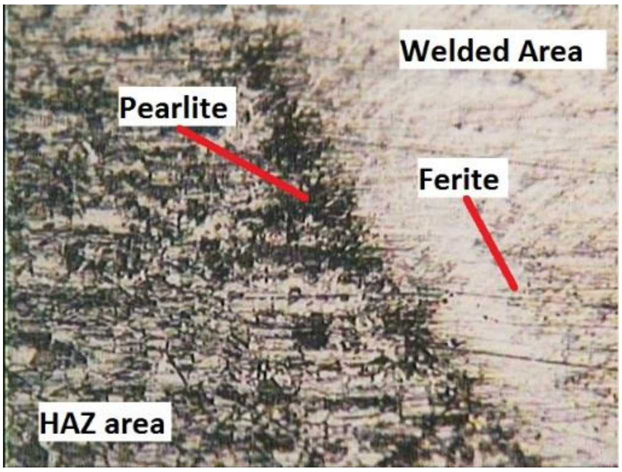

Fig. 9. Specimen with the current of 90A.

Observation of microstructure with metallographic results on surface of parent material, weld surface, and HAZ. Figure 9 shows the average weld area dominated by ferrite grains (white / light), the ferrite grains tend to have lower hardness levels because the lower carbon content. The HAZ area is more dominated pearlite carbide or Fe-Cr (black / dark). This area has a higher hardness number than the weld area because it contains more carbon content.

4 Conclusions

Based on the results of testing and data analysis can be drawn conclusions as follows:

- The result of dye penetrant test shows that in the welding area and HAZ area of all specimens there is no defect, either the porosity defect or the cracked defect.
- The largest tensile strength number occurs in 90A welding current specimen that is equal to 632 MPa, while the largest tensile strength value is found on specimen 70A welding current 498,66 MPa. Likewise, the largest mean tensile stress of 90A and the lowest current at 70A with a tensile difference of 113.11 MPa
- The highest length increase in the 90A welding specimen was 13% and the lowest was in the 70A welding current specimen of 4.6%.
- The microstructure of all specimens has almost the same form of structure, in the average weld area more dominated by the shape of the ferrite structure with the percentage of low pearlite but increasing with increasing welding current. The HAZ area along with the increase of current, the microstructure form is more smooth and evenly between the ferrite and pearlite structure (Fe-Cr).

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