Analysis of Welding Position and Current on Mechanical Properties of A36 Steel using Shield Metal Arc Welding

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Abstract. Welding is an assembly process that is most often used in the world of construction today. Welding is often used for repairing and maintenance of all tools made of metal, both as a process for filling cracks, temporary joining, or cutting metal parts. This study aims to determine the effect of welding current and position on the tensile strength and Vickers hardness (HV). This study uses ASTM A36 steel plate as base material. The variation of welding currents used are 90A, 110A, and 130A combine with variations in positions 1G, 2G, and 3G. The electrode used in this study is E6013 electrode with a diameter of 3.2 with a butt joint connection. All of processes are performed in room temperature with a strict condition. The results are as follow, the highest Ultimate Tensile Strength is obtained at 90A current and 3G position with a value of 471.93 MPa. For the highest hardness in the Vickers test, it is also obtained at 90A current and 3G position with a value of 242.20 Kg/mm².

1. Introduction
Shielded Metal Arc Welding (SMAW) is welding using an electric arc as a heat source to melt the welding electrode. This welding uses a flux wrapped electrode. During the welding process, the flux will enclose the molten metal as a protective mechanism for the molten metal against oxidation[1]. One type of connection that is widely used in the connection type T and flat plate (butt), especially in the field of bridge construction and shipping. During the welding process, the heat source runs continuously and causes differences in the temperature distribution of the metal, resulting in uneven expansion and shrinkage [2]. As a result of residual stress and distortion will arise in the metal being welded. The results of the impact test of the Charpy method, the welding current of 70 amperes experienced a decrease in the impact value from the average value of -7.44% of the base metal, while the welding current of 75 amperes experienced an increase in the value of 3.54% of the weld metal and the hardness value of the welding current was 80 amperes has a very high number compared to the base metal of 20.77% meaning the impact value of the Charpy method obtained from the ampere variable has met the standard requirements of the minimum [3]. The difference in welding position as 1G, 2G, and 3G resulted in a different amount of heat input with the increase in heat input increasing the amount of distortion that occurred [4]. In these problems, authors try to analyze a difference in currents and welding positions to determine the ultimate tensile strength and hardness of the specimen.
2. Materials and Methods

2.1 Materials

A36 mild steel liner plate, also known as SS400 JIS 3101, in ASME Code Part II-A of the JIS specification of steel plate for general construction belongs to category SA-36. At JIS (Japan Industrial Standard) “SS” stands for structural steel and grade 400 which is similar to AISI 1018.

Table 1. The Composition of ASTM A36 base material with E6013 weld material

| Base metals | C  | Si  | Mn  | S  | P  | Cr | Ni | Mo | Tensile Strength, MPa |
|-------------|----|-----|-----|----|----|----|----|----|-----------------------|
| ASTM A36    | 0.146 | 0.28 | 1.03 | 0.05 | 0.04 | -  | -  | -  | 400-550 250           |
| Weld metals | <0.2 | 0.25 | <1.2 | 0.016 | 0.012 | <0.2 | -  | <0.3 | 527 458              |

2.2 Specimen Testing Methods

Tensile Test was applied for evaluating the strength of material with respect to shaft condition during applied longitudinal force. Round bar specimen test was lathed for specific dimension required (ASTM E8). The standard of Inner diameter (D) is 12.5 + 0.2 mm, Gage length (G) is 62.5 + 0.1 mm, radius is min 10 mm, and Length of reduced section is 75 mm are represented in Figure 1. Tensile test was done by using common universal hydraulic machine, with quasi static speed. Yield point can be achieved by calculating with offset method 0.2 % of L_{\text{max}}. Next thing to do was measuring overall dimension before and after specimen was tested. By using equation below, stress and strain can be calculated by assigning \( P \) with load (N), \( A_0 \) with cross section area (mm²), \( L_0 \) with initial length (mm), and \( L_1 \) with final length (mm) in Equation 1 and Equation 2.

\[
\sigma_{\text{eng}} = \frac{P}{A_0} \quad [\text{MPa}] \\
\varepsilon_{\text{eng}} = \frac{L_1 - L_0}{L_0} \times 100\% \quad [%]
\]

To measure Vickers hardness (HV), the indenter is pressed into the material under a defined test load. After a certain period, the test load is removed. The Vickers hardness value is defined as the quotient of the test load \( F \) and the surface area \( A \) of the residual indentation, the result of the permanent plastic material deformation component of the test. To determine the indentation area, the indentation diagonals \( d \) are measured on the specimen surface. Based on the Vickers indenter geometry, the Vickers hardness is defined as Equation 3.

\[
HV = \frac{0.102F}{A} = \frac{0.102F}{d^2} = \frac{0.1891F}{d^2} = \frac{0.1891F}{d^2} 
\]
3. Result and Discussions

3.1 Tensile test

The welding parameters have the significant impact on the strength of materials. In this work has been investigated the highest ultimate tensile strength is obtained at 90A current and 3G position with a value of 471.93 MPa. The highest heat input was needed for vertical (3G) welding position leading to the growth of grains and burning of some additives which causes a great chance of formation defects [5]. The decrease of both yield strength and ultimate tensile strength by increasing current. A decrease yield strength of A36 becomes more ductile. As shown as figure 2, more current input means lower strength. More current input means higher heat input, it makes loss of strength of steel.

Table 2. The yield strength and ultimate tensile strength of A36 welds

| Welding Position | Current (Ampere) | $\sigma_y$ (MPa) | $\sigma_{UTS}$ (MPa) |
|------------------|-----------------|-----------------|-----------------|
| 1G               | 90              | 191.23          | 344.74          |
|                  | 110             | 171.93          | 327.19          |
|                  | 130             | 160.53          | 302.63          |
| 2G               | 90              | 214.91          | 411.40          |
|                  | 110             | 204.39          | 386.84          |
|                  | 130             | 198.25          | 373.68          |
| 3G               | 90              | 244.74          | 471.93          |
|                  | 110             | 234.21          | 449.12          |
|                  | 130             | 221.05          | 432.46          |

Figure 2. (a) Yield Strength vs Welding Current (b) Ultimate Strength vs Welding Current
3.2 Vickers Hardness Test

Table 3. The Hardness Value of A36 welds (Hv)

| Welding Position | Current (Ampere) | Weld Metal | HAZ | Base Metal |
|------------------|-----------------|------------|-----|-----------|
|                  | 90              | 165,13     | 210,57 | 131,24 |
| 1G               | 110             | 158,55     | 181,98 | 131,24 |
|                  | 130             | 141,43     | 167,23 | 131,24 |
|                  | 90              | 168,19     | 228,93 | 131,24 |
| 2G               | 110             | 160,46     | 195,06 | 131,24 |
|                  | 130             | 146,51     | 176,50 | 131,24 |
|                  | 90              | 195,06     | 242,20 | 131,24 |
| 3G               | 110             | 168,19     | 195,06 | 131,24 |
|                  | 130             | 146,51     | 176,50 | 131,24 |

The welding parameters have the significant impact on the Vickers hardness of materials. It is obtained at 90 A current and position 3G position with a value of 242.20 kgf/mm² in HAZ has the highest Vickers hardness. The highest hardness values were obtained in the HAZ area, because the peak temperature of the HAZ area is the highest and fast welding cooling occurs there due to fast heat transfer [6]. The hardness is reduced with increase in current. This is due to the grains became coarser, and hence hardness decreased [7]. The vertical welding position (3G) has higher hardness compared to the horizontal (2G) and flat (1G) welding position.

4. Conclusions

The current and welding position affect mechanical properties of A36 steel. The highest ultimate tensile strength is obtained at 90A current and 3G position with a value of 471.93 MPa. For the highest hardness in the Vickers test, it is also obtained at 90A current and 3G position with a value of 242.20 Kgf/mm². The more current input means more heat input. As a result, it will decrease the strength of the steel.

5. References

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