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Effect of Electrode and Current Variation of Smaw Welding With V-Shape on The Bending Strength of ASTM A36 Ship Steel Plate Material

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ABSTRACT

This study aims to analyze the effect of current and type of electrode on bending strength with V-shoulder and using SMAW (Shielded Metal Arc Welding) welding on ASTM A36 steel plate. The SMAW welding method was chosen because of its wide use in the industrial field, one of which is in the field of steel ship construction. The welding process is carried out with current variations of 90A, 100A and 130A and the types of electrodes used are AWS E6013 and AWS E7016. Bending tests were conducted using relevant ASME Section IX standards to evaluate the strength and ductility of the joints. After obtaining data from the test results of several samples from different electrodes with different currents, the average value is obtained, namely, the sample using the E7016 electrode with a current of 100A is 1771,63 MPa, the sample using the E6013 electrode with a current of 90A is 1485,21 MPa. From these results, it can be concluded that there is a difference in bending strength between each specimen, which indicates that variability in test conditions, such as current variation and electrode variation, plays an important role in influencing the final results in bending testing. Experimental studies are carried out by testing bending on specimens that have been welded with welding current and electrode.

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INTRODUCTION

Development in the field of technology is growing rapidly, one of which is in the field of shipping. Construction with steel plates currently involves a lot of welding, especially in the design of the wake, because welding joints require high skills to achieve good quality. Welding is very important in shipping construction using steel plates. In the shipping industry, ASTM A36 steel plates are used for ship hulls, more precisely in the bilge keel section, which usually uses 10 mm plates. This steel has a carbon content of less than 0.3%, so it has high toughness and ductility, but low hardness and wear resistance. Welding is one of the metal joining techniques that involves partially melting the parent metal and filler metal with or without pressure and with or without additional metal, producing a continuous connection (Sonawan and Suratman Rochim, 2006).

The process of joining two or more metallic elements with thermal energy is called welding. This process results in rapid thermal cycling that causes complex metallurgical changes, deformation, and thermal stresses around the weld site. As a metal joining technique, welding is basically a metallurgical bonding of joints between metal alloys carried out in a molten or liquid state. The welding technique has features and advantages compared to other metal joining systems, such as keeling (Khotasa, 2016).

In testing the corrosion rate, it can be concluded that the welding current can also affect the corrosion rate because it can change the structure and hardness value of the material and the presence of thermal cycles. Because it can change the structure and hardness value of the material and the presence of thermal cycles (Konsuci *et al.*, 2024).

The welding production process includes the manufacturing stage, the tools and materials required, the sequence of execution, and the welding preparation (including the selection of welding machines, the appointment of welders, the selection of electrodes, and the selection of the type of seam) (Wiryosumarto and Okumura, 2000).

ASTM A36 steel has weldability properties that are influenced by tensile strength and sensitivity to weld cracking (Arifin, Purwanto and Syafa'at, 2017).

According to (Tarkono, Sugiyanto and Andriyanto, 2010), different types of electrodes used will affect the tensile strength of the weld and elongation. The type of welding seam is also one of the causes that affect the strength of the welded joint. According to (Rahman and Imran, 2020), a weld seam is a part of the parent metal that will later be filled by a weld deposit or weld metal. The weld seam is initially a weld pool which is then filled with weld metal.

The welding result will depend on the setting of the welding current strength. The electric arc will be difficult to ignite if the current used is too low. The resulting electric arc becomes unstable. Small, irregular welding flames, and shallow penetration result from insufficient heat being generated to melt the electrode and base material. On the other hand, excessive current will cause the electrode to melt too quickly, creating deeper penetration and a larger weld surface. This will reduce the arc strength and make the weld more brittle.

According to (Amzamsyah, Kosjoko and Umar, 2021) If the weld input generated from the welding arc is high, it will affect the micro grains formed. If the micro grains produced are larger, the material will have hard but brittle characteristics.

The strength of the welding results is influenced by arc voltage, arc size, welding speed, penetration magnitude, and electrical polarity. Determining the amount of current strength in metal joining using arc welding greatly affects the efficiency of the work and welding materials (Pratama, Ismiyah and Rizqi, 2022).

According to (Nata, Hidayat and Rohman, 2021) the greater the electric current and the type of welding wire used during the welding process, the greater the strength of the bending test value.

The application of the weld seam form depends on the thickness and type of plate material used. Variations of welding seams include single and double V seams, single and double U seams, and I seams. Appropriate seam selection is essential to producing a quality joint. In addition, seam selection also considers the thickness of the material being welded. For example, if the plate is between 5 mm and 12.5 mm thick, then the weld joint needs to be formed using a seam.

The use of a V seam provides a more even weld penetration, so it is often used in the shipping industry. According to the impact test (Khotasa, 2016), the welded joints using a V groove have a higher hardness level compared to other grooves such as bevel groove and U groove. So, in this study, the material connections will be compared by means of bending tests to find the strength of the bending test results on each connection.

The specimens used are ASTM A36 steel plates welded with a 30° angle V joint, with variations in welding current and electrode. The welding current used starts at 90A, 100A, and 130A, and the types of electrodes used are E6013 and E7016, with a diameter of 2.6 mm.

METHODS

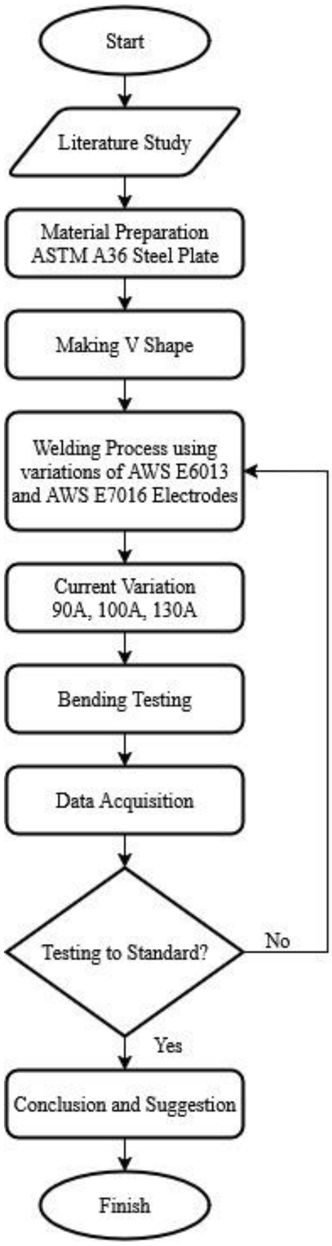

Figure 1. Flow Chart

The methods used in this research are explanation at Figure 1 start with literature studies this method is carried out by collecting and studying theories and references from previous research related to research on welding and the materials used. (2) Experimental studies are carried out by testing bending on specimens that have been welded with welding current and electrode parameters. The welding current used ranges from (90A, 100A, 130A).

The materials used in this study can be seen in Table 1. The material used is a low-carbon steel plate (ASTM A36). The initial size of the material is 75 mm x 96 mm x 10 mm. The electrodes used are E6013 and E7016 types with a diameter of 2.6 mm. Welding position using underhand position. The welding current used is 90A, 100A, 130A. The camp used is the type of V camp. The plate gap distance is 2 - 4 mm. The shape of the test specimen refers to the ASME section IX 462.2 standard for bending testing.

Table 1. Materials

No	Materials	Amount	Description
1	Steel Plate ASTM A36	12	ASTM A36 steel plate with dimensions 75mm x 96mm x 10mm
2	Electrodes E6013 and E7016	1 Kg	Welding wire is used as the bonding metal (Ø 2.6)

Bending Test Process

Bending testing is one of the tests of the mechanical properties of materials carried out on specimens and materials, both materials used in construction and components that receive loads. This test is performed by applying a load to the center point of the material supported by two supports. The bending test is one of the techniques used to evaluate the visual quality of materials. This test also measures the strength of the material when stressed and the flexibility of the weld joint in the heat-affected zone (HAZ) as well as the weld metal. In this study, three point bending method was used. The point bending methods are used in this research, and the theory for three bending methods is shown in Figure 2.

The bending test in the ASME Section IX standard is a test method used to evaluate the weldability of metallic materials through bending testing. This test aims to assess the quality of the weld joint and ensure the absence of defects that affect the strength and integrity of the material. ASME Sec. IX Acceptability Requirements for Bending Tests:

1. Cracks in Weld Metal or HAZ: Maximum 3 mm on convex surfaces that have been bent. Corner cracks are not counted, except those caused by slag inclusion, lack of fusion, or other defects.
2. Overlay Cladding: No open cracks exceeding 1.5 mm at the surface and 3 mm at the interface.

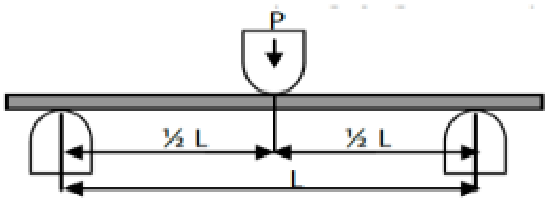

Figure 2. Three Point Bending Method

The three-point bending method can be calculated with the Formula (1) (Muhsin, Suardy and Suryadi, 2018).

$$M\frac{P}{2}x\frac{L}{2} \quad (1)$$

M = Moment
P = *Load* (N)
L = *Span/ support span* (mm)

So that the bending strength can be calculated with Formula (2) as follows (Khamid, 2011).

$$\sigma b = \frac{3PL}{2bd^2} \quad (2)$$

σb = Bending Strength (MPa)
P = *load* (N)
L = *Span / support Span* (mm)
b = *Width* (mm)
d = *Depth* (mm)

Materials Preparation

ASTM A36 steel plate has been carried out the welding process by combining two plates with the initial size of 10mm x 75mm x 96mm. The plate will then be welded using SMAW welding and cut into 18 parts according to the bending testing standard with dimensions 150mm x 30mm x 10mm. The dimensions for the testing specimen are shown in Figure 3.

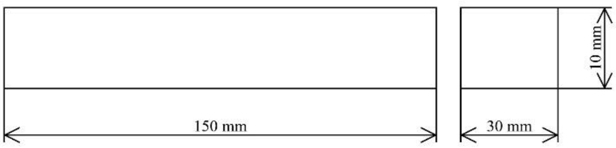

Figure 3. Bending Test Specimen

DISCUSSION

Welding on ASTM A36 steel material is carried out using a current variation of 90A, 100A, and 130A, and using E6013 and E7016 electrodes in 1G welding position. The welding process is done by joining two plates measuring 120 x 75 x 10 millimeters formed with a 60 ° angle in the V camp. The figure for welding results is shown in Figure 4.

After welding, the plate is cut according to the bending test specimen standards that follow ASME Section IX, with dimensions of 150 x 30 x 10 millimeters. Each sample is made of three samples at each current variation as a comparison. Test samples that have been tested are listed in the bending test results table. Bending testing is done using a bending test machine. The bending test results show the value based on the maximum load force when the mandrel bends the specimen. From this test, the load force (P_{load}) is obtained. Each type of current was tested with three specimens. The results of the specimen after the bending test are shown in Figure 5.

Figure 4. Welding Result

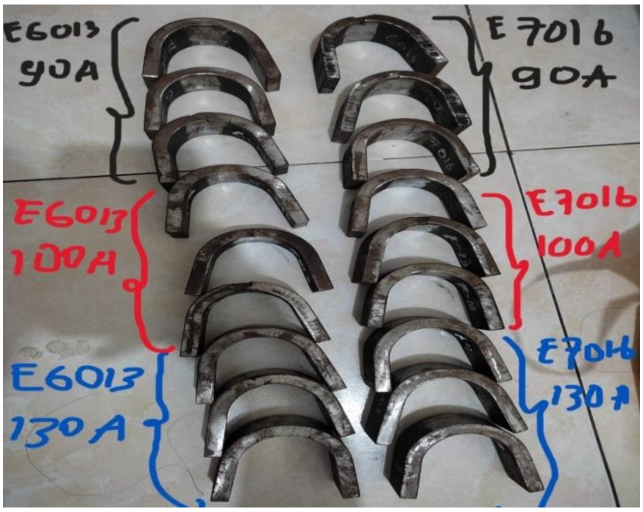

Figure 5. Result After Bending Test

The data of the bending test results are shown in Table 2. From the results of the above data testing results in the calculation of bending strength with the average value of each specimen, the calculation of this data uses mathematical calculations with Formula (3) (Khamid, 2011).

$$\sigma b = \frac{3PL}{2bd^2} \quad (3)$$

Table 2. The Highest Bending Pressure Value

No	Current	Electrode	Sample (N)		
			1	2	3
1	90A	E6013	21723, 69	19846, 7	17838, 29
2	100A	E6013	20480, 20	21311, 8	21778, 6
3	130A	E6013	20091, 86	21442	20503, 74
4	90A	E7016	22278, 74	22292, 5	21996, 31
5	100A	E7016	25063, 83	23410, 4	22416, 04
6	130A	E7016	22365, 04	18956, 2	19699, 59

From the test results, the above data results in the calculation of bending strength with the average value of each specimen. The bending strength calculation data can be seen in Table 3.

Table 3. Bending Strength Data

No	Variable		Sample (MPa)			Average
	Current	Electrode	1	2	3	
1	90A	E6013	162927	148850	133787	148521
2	100A	E6013	153601	159838	163339	158926
3	130A	E6013	150688	160815	153778	155093
4	90A	E7016	167090	167193	164972	166418
5	100A	E7016	187790	175578	168123	177163
6	130A	E7016	167378	142171	147746	152431

A graph of the bending strength test results can be made from the table above. Figure 6 shows a graph of the E6013 electrode.

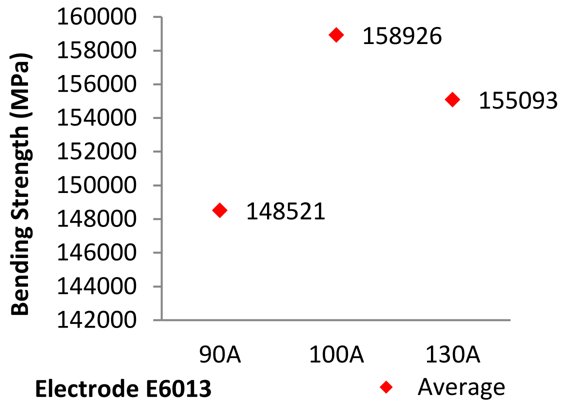

Figure 6. Graphic of Bending Strength Calculation Results with E6013 Electrode.

The graph of the calculation results on the E7016 electrode can be seen in Figure 7. After obtaining data from the test results of several samples of different electrodes with different currents, the average value (mean) of bending strength for loading in units of (MPa) is calculated, the highest average value is obtained, the sample using the E7016 electrode with a current of 100A is 1771,63 MPa. While the lowest average value obtained from the sample using the E6013 electrode with a current of 90A is 1485,21 MPa.

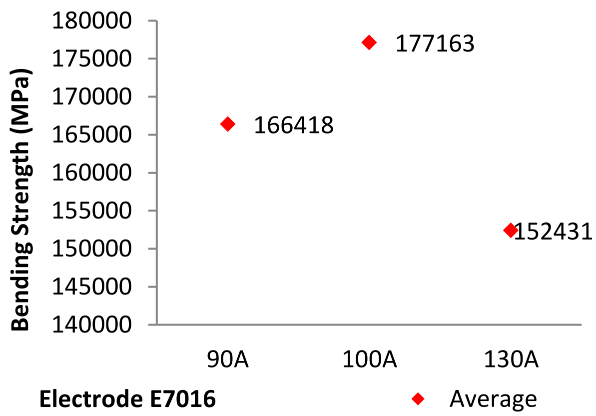

Figure 7. Graphic of Bending Strength Calculation Results with E7016 Electrode.

The lowest average value obtained from the sample using the E6013 electrode with a current of 90A is 1485,21 MPa. From these results, it can be concluded that there is a difference in bending strength in each specimen, which shows that variability in test conditions, such as current variation and electrode variation, plays an important role in influencing the final results in bending testing.

These factors cause each specimen to respond to bending stresses in different ways. The electrode with the AWS E7016 variation has the highest value because the E7016 electrode is made from a flux that has a low hydrogen content that is usually used for welding heavy-duty plates and structures. The results of E7016 electrode welding are very smooth, deep penetration, crack resistance, ductile, good weld appearance and stable arc.

CONCLUSION

In the calculation of bending strength, the highest average obtained using electrode E7016 with a current of 100A is 1771,63 MPa. While the lowest average value obtained from samples using E6013 electrodes with a current of 90A is 1485,21 MPa. Each specimen has a different bend strength, so the value obtained has different results even though the size and thickness of the specimen are the same between one and the other.

Current variation, and electrode variation, have an important role in the test where each specimen responds to bending pressure in a different way. The E7016 electrode with a current of 100A received the highest average value due to its stable flame and also made from a flux that has a low hydrogen content which is usually used for welding heavy-duty plates and structures.

The results of E7016 electrode welding are very smooth, deep penetration, crack resistance, ductile, good weld appearance and stable arc. The E6013 electrode with a current of 90A gets the lowest average value because the amperage is too low, and the arc flame is less stable.

SUGGESTION

The author suggests that further research be conducted to add an angle to the seam if necessary to find maximum bending results. A welding transformer with a high voltage capacity is recommended so that the flame remains stable during welding.

REFERENCES

Amzamsyah, R., Kosjoko, K. and Umar, M.L. (2021) ‘Pengaruh Variasi Kampuh dan Kuat Arus Pengelasan SMAW terhadap Kekuatan Bending pada Baja ASTM A36’, *J-Proteksion*, 5(2), pp. 20–24. Available at: https://doi.org/10.32528/jp.v5i2.4129.

Arifin, J., Purwanto, H. and Syafa’at, I. (2017) ‘Pengaruh Jenis Elektroda Terhadap Sifat Mekanik Hasil Pengelasan’, *Momentum*, 13(1), pp. 27–31.

Khamid (2011) *Perhitungan Metode Three Point Bending*.

Khotasa, S. (2016) ‘Analisa Pengaruh Variasi Arus Dan Bentuk Kampuh Pada Pengelasan Smaw Terhadap Kekuatan Impact Sambungan Butt Joint Pada Plat Baja A36’, *Departemen Teknik Kelautan FTK ITS* [Preprint].

Konsuci, W. *et al.* (2024) ‘Analisis Pengaruh Variasi Arus dan Ayunan Pengelasan SMAW pada Baja AISI 1040 terhadap Laju Korosi dan Kekerasan’, (Senastitan Iv), pp. 1–8.

Muhsin, Z., Suardy and Suryadi (2018) 'Analisis perbandingan kualitas las SMAW kampuh V dengan uji bending pada baja ST 37', *Teknologi*, 19(1), pp. 45–56.

Nata, O.D., Hidayat, M. and Rohman, S.A. (2021) 'Analisis Kekuatan Uji Bending Pengelasan Shielded Metal Arc Welding (Smaw) Material Ss400 Menggunakan Kawat Las E6013 Berbagai Variasi Arus Listrik', *Hexagon Jurnal Teknik dan Sains*, 2(1), pp. 12–15. Available at: https://doi.org/10.36761/hexagon.v2i1.871.

Pratama, M.F., Ismiyah, E. and Rizqi, A.W. (2022) 'Analisis Risiko (K3) Metode Hazard Identification Risk Assesment and Risk Control (HIRARC) di Departemen Laboratorium PT. ABC', *Jurnal Ilmiah Giga*, 25(2), p. 88. Available at: https://doi.org/10.47313/jig.v25i2.1922.

Rahman, H.A. and Imran (2020) 'Analisa pengaruh variasi kampuh terhadap hasil pengelasan SMAW pada stainless steel 304 menggunakan pengujian ultrasonic dan kekuatan tarik.', *Jurnal Polimesin*, 18(1), pp. 30–38. Available at: http://e-jurnal.pnl.ac.id/index.php/polimesin/article/view/1057.

Sonawan, H. and Suratman Rochim (2006) 'Pengantar Untuk Memahami Pengelasan Logam', p. 143.

Tarkono, Sugiyanto and Andriyanto (2010) 'Studi penggunaan jenis elektroda las yang berbeda terhadap sifat mekanik pengelasan SMAW Baja AISI 1045', *Jurnal Mechanical*, 1(1), pp. 51–62.

Wiryosumarto, H. and Okumura, T. (2000) 'Teknologi Pengelasan Logam', *Teknologi Pengelasan Logam*, 8.