Comparative Analysis Of FCAW And SMAW Welding Currents On ASTM A36 Steel Plate With Ceramic Backing Method At X Shipment On Tensile And Bending Strength

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***Abstract*—In the era of technological development in the current era, technology in the field of construction is developing very rapidly. Welding technology is the most important thing in the shipbuilding process. In the shipbuilding industry, welding is used to connect ship components in the form of plates or ship blocks. Welding technology in combining metals is very necessary to obtain strong and quality construction results. Steel plates used in ship construction itself are divided into three parts, namely mild steel, medium steel, and strong steel. ASTM A36 plate is a type of carbon steel that has a low carbon content of 0.29%. This ASTM A36 plate has rust and corrosion resistant properties so that it is widely used in the maritime world, especially in the shipping world, in general ASTM A36 plates can be found in ship construction. This study examines the effect of welding current in the Flux-Cored Arc Welding (FCAW) and Shield Metal Arc Welding (SMAW) processes on the tensile and bending strength of ASTM A36 steel plates. This study also provides results that will be useful for welders. In addition, this study can be an evaluation material for welders who work mainly on FCAW and SMAW welding with ASTM A36 steel plate material with a thickness of 10mm.**

***Index Terms*—ASTM A36; Bending test ; FCAW welding; SMAW welding; Tensile test**

I. INTRODUCTION

In the development of technology in the current era, technology in the construction sector is developing very rapidly. Humans use processed materials, both natural and industrial materials that have a very important strength for construction materials. In an era that continues to progress, there are many ship constructions using steel construction because it has a very strong resistance structure. The shipbuilding process itself cannot be separated from steel welding, because welding plays a vital role in the steel construction process [1].

Welding technology is an important thing in the shipbuilding process. In shipyard companies, welding plays an important role in connecting ship parts, such as plates and ship blocks. Welding technology in the metal joining process is very much needed to ensure sturdy construction results. To get good welding, there needs to be rules when carrying out welding work that focuses on WPS (Welding Procedure Specification) [2].

The metal welding process in the process of building a ship often requires a welder to do welding work on both sides of the ship. This is the author's case study at shipyard x that when the two-sided welding process takes a long time, so the company will spend a very large budget. Media Backing Ceramic is a solution in the form of a ceramic base that functions to print better welding results and the work process becomes faster. In the welding process itself, it cannot be avoided from welding defects, welding defects that occur in the welding of the ship's steel itself are porosity welding defects and slag inclusions. The tolerance limit for welding defects has been regulated by the ASME (America Society of Mechanical Engineers) Section IX standard, which is a maximum of 20% of the thickness of the plate itself, if the welding defect exceeds the specified limit, the welding results will not be accepted [3].

Testing in the shipping industry is very important, the purpose itself is to ensure the quality and quality of the welded construction. In welded construction, strength is the main requirement. However, there are also other requirements that must be met according to the purpose and use, for example for ships there should be no leaks. Based on the statement above to see the comparison of the mechanical characteristics of a strength and hardness on this ASTM A36 plate, a test was carried out by damaging the test specimen (destructive test) namely by tensile testing and bending testing. This test uses a comparison method between SMAW and FCAW welding with a current of 140A assisted by backing cramic. For this reason, this test is intended to determine "Comparative analysis of FCAW and SMAW welding currents on ASTM A36 steel plates with the backing cramic method at shipyard x against tensile tests and bending tests".

II. THEORETICAL FUNDAMENTALS

A. Welding Procedure Spesification

Based on ASME Section IX, Welding Procedure Specification (WPS) or welding procedure specification is a written document that has been qualified and serves as a guide in the production weld process in accordance with applicable standards. WPS is used to provide instructions to welders to ensure that welding is carried out in accordance with the requirements set out in the standards used. The contents of a complete WPS must describe all essential variables, nonessential variables, and supplementary essential variables (if necessary) for each welding parameter listed in the WPS.

B. Flux Cored Arc Welding

FCAW (Flux-Cored Arc Welding) is a welding method in which the welding wire is mechanically fed continuously into an electric arc. The electrode or welding wire used in this process is in the form of a thin cylindrical tube filled with flux as needed. In principle, FCAW welding is similar to GMAW (Gas Metal Arc Welding), but the difference lies in the shape of the electrode which is in the form of a tube and contains flux in it. In the FCAW process, the energy source used can be DC or AC current, which is obtained from a power plant or through a transformer. One of the welding processes used in the maritime industry and steel construction is one of them is electric arc welding electrode fed with pure CO2 shielding gas or FCAW welding.

C. Shield Metal Arc Welding

Shielded Metal Arc Welding (SMAW) is a welding method in which the heat generated from an electric arc is used to join metals. This process occurs between the tip of a consumable electrode and the surface of the base material to be joined. In the SMAW mechanism, two or more pieces of similar metal are joined using heat from an electric current. The flux-wrapped electrode functions as an additional material or filler to create a strong joint. This method is commonly used to weld processed steel, carbon steel, alloy steel, and cast iron [4]. In this welding process, the parent metal melts due to heating from the electric arc formed between the tip of the electrode and the workpiece. This electric arc is generated by a welding machine, while the electrode used is in the form of a wire with a flux coating as a protector.

D. Backing Cramic

Ceramic backing is a practical method carried out in the welding process where ceramics are used as a support or molding material to support welding from the back of the weld joint. Ceramic backing can be interpreted as a special support used as a layer or pad on the back of the weld joint. Ceramic backing is commonly used in various welding applications, including welding stainless steel, carbon steel, and other materials that require full penetration welding. Its function is very important in the welding process, especially to improve the quality and time efficiency of welding work. The main function of this ceramic backing is to hold the liquid weld metal from falling or flowing from the back of the joint, as well as ensuring better weld penetration and more optimal joint quality.

E. ASTM A36 Plate

The steel plates used in ship construction are divided into three parts, namely mild steel, medium steel, and strong steel. ASTM A36 plate is a type of carbon steel that has a low carbon content of 0.29%. This ASTM A36 plate has rust and corrosion resistant properties so that it is widely used in the maritime world, especially in the shipping world, in general ASTM A36 plates can be found in ship construction, especially in ship hull construction. ASTM A36 is a steel that has low carbon components (low carbon steel) with material components and mechanical properties.

F. Mechanical Testing

Mechanical testing is a testing process that aims to determine the strength properties and hardness levels of a metal material. The mechanical properties of a material are the properties of a material outside the influence of external forces and deformations that occur. In terms of shape, mechanical properties are obtained from the atomic bonding forces of the material and the structure of the material. In destructive testing, a specimen of a material is damaged. This test will reveal how the metal reacts to external forces. These mechanical properties are very important to ensure that the material used is appropriate for its application. In destructive testing, the metal will experience permanent deformation until it finally breaks.

III. Research Method

A. Research Design

In the preparation of the final assignment, first determine the problem so that it can determine the formulation of the problem that will be raised into a test and research. In writing this research, the author applies the quantitative experimental method. The author chooses the focus of the problem on the comparative analysis of FCAW and SMAW welding currents on ASTM A36 steel plates with the ceramic backing method on tensile and bending test strengths.

B. Tools and Materials

The equipment and materials used in this study include ASTM A36 plates, tensile testing machines, and bending testing machines. The specifications of the test objects used in this study are as follows:

- The thickness of the steel plate used is 10 mm
- The welding position applied is 1G
- The welding used is FCAW and SMAW
- Using ceramic backing media
- The current variables used are 100 A, 120 A, and 140A
- The type of weld applied is the V weld type

After collecting or making designs and determining the needs of tools and materials used. According to BKI in "Rules for the classification and construction", part 1 Vol VI: Rules for welding, section 5, the tensile testing standard used for testing is ASTM E8/E8M-09 with dimensions of 200mm x 20mm x 10mm. The bending testing standard is based on the ASTM E190-14 standard with dimensions of 152mm x 38mm x 10mm [5].

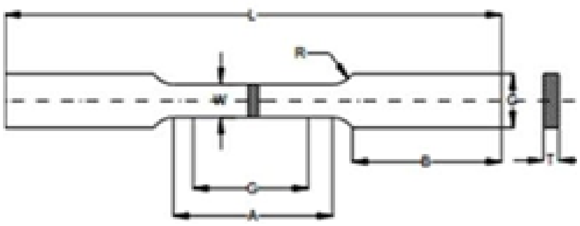

Fig. 1. Tensile Test Dimensions

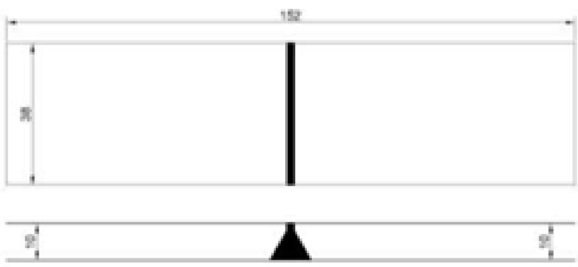

Fig. 2. Bending Test Dimension

TABLE I. TENSILE TEST SPECIMEN DIMENSION

Information	Dimensions (mm)
Gage Length (G)	50
Length of reduced section	57
Width (w)	12
Thickness (T)	10
Radius of fillet (R)	12,5
Overall Length (L)	200
Width of grip section	20

TABLE II. BENDING TEST SPECIMEN DIMENSION

Information	Dimensions (mm)
Overall Length	152
Widht (W)	12
Thickness (T)	10

IV. Result and Discussion

A. Welding Process

In this study, the welding method of tensile and bending test specimens was carried out using FCAW and SMAW welding with different welding currents. The welding wire used in FCAW welding is the E71T-1C type which uses a connection or single V butt Joint with a bevel angle of 60o. In this FCAW welding, a welding current of 100 A was used at a speed of 12cm/minute for the first specimen, 120 A at a speed of 14cm/minute for the second specimen, and 140 A at a speed of 16cm/minute. The volt rangers used from the three welding currents were 20 volts for all current variations. Welding of tensile and bending test specimens using FCAW welding using the E71T-1C electrode type.

Fig. 3. FCAW Electrode Type

Based on the welding results that have been carried out by applying FCAW (Flux Cored Arc Welding) welding in the 1G position and using the Single V Butt Join weld, different Heat input results were obtained in each welding process, as listed below:

- Based on the welding FCAW 100A , formula is obtained Heat Input 100A = 60x20x100 / 12 cm/minute = 10.000 Joule/cm (as shown in Figure 4)
- Based on the welding FCAW 120A , formula is obtained Heat Input 100A = 60x20x100 / 14 cm/minute = 10.285 Joule/cm (as shown in Figure 5)
- Based on the welding FCAW 140A , formula is obtained Heat Input 100A = 60x20x100 / 16 cm/minute = 10.500 Joule/cm (as shown in Figure 6)

Fig. 4. Welding Results FCAW 100A

Fig. 5. Welding Results FCAW 120A

Fig. 6. Welding Results FCAW 140A

The welding wire used in SMAW welding is the E7018 type which uses a connection or single V butt Joint with a 60° bevel angle. In this SMAW welding, a welding current of 100 A is used at a speed of 14 cm / minute for the first specimen, 120 A at a speed of 16 cm / minute for the second specimen, and 140 A at a speed of 18 cm / minute. The volt rangers used from the three welding currents are 20 volts for all current variations.

Fig. 7. SMAW Electrode Type

Based on the welding results that have been carried out by applying SMAW (Flux Cored Arc Welding) welding in the 1G position and using the Single V Butt Join weld, different Heat input results were obtained in each welding process, as listed below:

- Based on the welding SMAW 100A , formula is obtained Heat Input 100A = 60x20x100 / 12 cm/minute = 10.000 Joule/cm (as shown in Figure 8)
- Based on the welding SMAW 120A , formula is obtained Heat Input 100A = 60x20x100 / 16 cm/minute = 9.000 Joule/cm (as shown in Figure 9)
- Based on the welding SMAW 140A , formula is obtained Heat Input 100A = 60x20x100 / 18 cm/minute = 9.333 Joule/cm

Fig. 8. Welding Results SMAW 100A

Fig. 9. Welding Results SMAW 120A

B. Tensile and Bending Specimen Manufacturing

After collecting data and designing tensile test samples based on ASTM E8/E8M-09 with dimensions of 200mmx20mmx10mm. The author uses the Welding School and Teaching Factory laboratory managed by the Naval Construction Engineering Technology study program and Vocational School located in the Vocational School faculty of Diponegoro University as a place to make tensile test specimens.

Fig. 10. Cutting Process with Cutting Machine

The formation of this specimen is done using a plasma cutting machine to make straight cuts to make it easier when cutting the curved specimen.

After cutting the previously welded steel plate, the next step is to make a tensile test specimen, namely forming the specimen shape according to ASTM E8/E8M-09.

Fig. 11. Example of a Tensile Test Specimen

Fig. 12. Example of a Bending Test Specimen

The manufacture of this Bending Test Specimen is in accordance with the Bending Test Standard based on the ASTM E190-14 standard with dimensions of 152mmx38mmx10mm. The manufacture of this ASTM A36 Bending Test Specimen is carried out using a plasma cutting machine to create a shape that is in accordance with the rules.

C. Tensile Test Testing Process

This tensile test is carried out to see the tensile strength produced by a sample of the material. This tensile test is in accordance with the ASTM E8 / E8M-09 standard which uses the Electromechanical Universal Testing Machine so that it can produce a stress graph with units (Mpa). Strain graph with units (%) and to determine the value of the modulus of elasticity. This tensile test was conducted in the welding laboratory of Ship Construction Engineering Technology, Diponegoro University.

- Tensile Test

The stress and strain received by the specimen object have different magnitudes at each increase in size. Data on tensile strength in this study can be seen in the table below:

TABLE III. TENSILE STRENGTH SMAW 100A

Sample	Length (mm)	Thick (mm)	Areas (mm2)	max style (N)	tensile strength (Mpa)
1(100A)	200	10	120	4300	358,4
2(100A)	200	10	120	4300	358,4
3(100A)	200	10	120	4300	358,4
Rata-Rata (∑)				4300	358,4

TABLE IV. TENSILE STRENGTH SMAW 120A

Sample	Length (mm)	Thick (mm)	Areas (mm2)	max style (N)	tensile strength (Mpa)
1(120A)	200	10	120	491,5	409,6
2(120A)	200	10	120	530,6	442,2
3(120A)	200	10	120	530,6	442,2
Rata-Rata (∑)				517,5	431,3

TABLE V. TENSILE STRENGTH SMAW 140A

Sample	Length (mm)	Thick (mm)	Areas (mm2)	max style (N)	tensile strength (Mpa)
1(140A)	200	10	120	441,2	367,7
2(140A)	200	10	120	418,9	349,1
3(140A)	200	10	120	441,2	367,7
Rata-Rata (∑)				437,5	364,4

TABLE VI. TENSILE STRENGTH FCAW 100A

Sample	Length (mm)	Thick (mm)	Areas (mm2)	max style (N)	tensile strength (Mpa)
1(100A)	200	10	120	525,0	437,5
2(100A)	200	10	120	525,0	437,5
3(100A)	200	10	120	525,0	437,5
Rata-Rata (∑)				525,0	437,5

TABLE VII. TENSILE STRENGTH FCAW 120A

Sample	Length (mm)	Thick (mm)	Areas (mm2)	max style (N)	tensile strength (Mpa)
1(120A)	200	10	120	574,5	478,8
2(120A)	200	10	120	574,5	478,8
3(120A)	200	10	120	540,3	450,3
Rata-Rata (∑)				563,1	469,3

TABLE VIII. TENSILE STRENGTH FCAW 140A

Sample	Length (mm)	Thick (mm)	Areas (mm2)	max style (N)	tensile strength (Mpa)
1(140A)	200	10	120	568,8	474,0
2(140A)	200	10	120	568,8	474,0
3(140A)	200	10	120	568,8	474,0
Rata-Rata (∑)				568,8	474,0

From the tensile test data that has been presented from the research conducted, a graph is obtained that can determine the comparison of tensile test strength with current variables of 100A, 120A, 140A with the FCAW and SMAW welding processes.

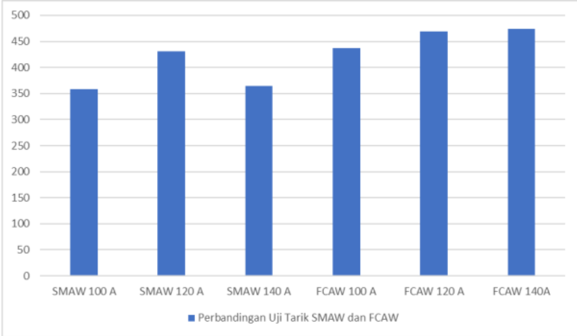

Fig. 13. Comparasion Graph of Welding Results

- Modulus of Elasticity

The modulus of elasticity is a measure used to measure the ability of a material to undergo elastic deformation when given a load on its sample. Data processing is presented in the form of a comparison between stress and strain on a test object.

TABLE IX. MODULUS OF ELASTICITY SMAW 100A

Sample	Stress (Mpa)	Strain	Modulus elasticity(Pa)
1(100A)	358,4	-16	-22,4 x 106
2(100A)	358,4	-36	-9,95 x 106
3(100A)	358,4	-20	-17,9 x 106

TABLE X. MODULUS OF ELASTICITY SMAW 120A

Sample	Stress (Mpa)	Strain	Modulus elasticity(Pa)
1(120A)	409,6	11,6	35,3 x 106
2(120A)	442,2	22,4	19,74 x 106
3(120A)	442,2	22,4	-19,74 x 106

TABLE XI. MODULUS OF ELASTICITY SMAW 140A

Sample	Stress (Mpa)	Strain	Modulus elasticity(Pa)
1(140A)	367,7	-20	-18,3 x 106
2(140A)	349,1	-8,2	-42,5 x 106
3(140A)	367,7	-20	-18,3 x 106

TABLE XII. MODULUS OF ELASTICITY FCAW 100A

Sample	Stress (Mpa)	Strain	Modulus elasticity(Pa)
1(100A)	437,5	16	27,3 x 106
2(100A)	437,5	16	27,3 x 106

3(100A)	437,5	16	27,3 x 106

TABLE XIII. MODULUS OF ELASTICITY FCAW 120A

Sample	Stress (Mpa)	Strain	Modulus elasticity(Pa)
1(120A)	478,8	17,1	28 x 106
2(120A)	478,8	51,2	9,35 x 106
3(120A)	450,3	22,4	20,1 x 106

TABLE XIV. MODULUS OF ELASTICITY FCAW 140A

Sample	Stress (Mpa)	Strain	Modulus elasticity(Pa)
1(140A)	474,0	38,4	12,3 x 10^6
2(140A)	474,0	25,6	18,51 x 10^6
3(140A)	474,0	44,8	10,5ss x 10^6

Based on the tensile tests that have been carried out on the three specimens, the fracture point was found to occur in the HAZ (Heat Area Zone), which is the area that is produced when a metal is exposed to very high temperatures.

D. Bending Test Testing Process

Bending testing is carried out on welding test specimens that comply with the ASTM E190-14 standard. This test aims to obtain data on the strength of the welding, which includes an assessment of the toughness of the material after going through the welding process. Toughness is defined as the capacity of the material to withstand force until it reaches the fracture point.

- SMAW Welding

TABLE XV. MODULUS OF ELASTICITY FCAW 140A

Sample	Length (mm)	Width (mm)	Thickness (mm)	Bending Stress (Mpa)
SMAW 100A	200	38	10	16,37
SMAW 120A	200	38	10	27,09
SMAW 140A	200	38	10	19,46

- FCAW Welding

TABLE XVI. MODULUS OF ELASTICITY FCAW 140A

Sample	Length (mm)	Width (mm)	Thickness (mm)	Bending Stress (Mpa)
FCAW 100A	200	38	10	33,1
FCAW 120A	200	38	10	38,3
FCAW 140A	200	38	10	41,25

The bending test results of the six specimens showed variations in the bending test strength values with the largest value in the SMAW welding specimen being 27.09 Mpa at a current of 120A and the largest value in the FCAW welding specimen being 41.25 Mpa at a current of 140A. The bending test used the root bend position on the test material.

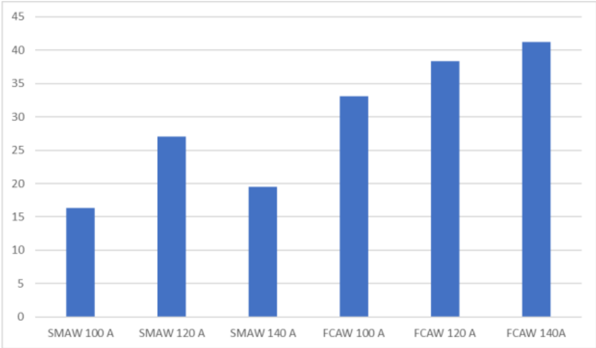

Fig. 14. Graph Bending Test

E. Comparasion Of Tensile And Bending Test

From the results of the previous testing, the following comparison results were obtained :

TABLE XVII. TENSILE TEST COMPARASION RESULTS

Current	SMAW Welding	FCAW Welding
100 A	358,4 Mpa	437,5 Mpa
120 A	431,3 Mpa	469,3 Mpa
140 A	364,4 MPa	474,0 MPa

TABLE XVIII. BENDING TEST COMPARASION RESULTS

Current	SMAW Welding	FCAW Welding
100 A	16,37 Mpa	33,1 Mpa
120 A	27,09 Mpa	38,3 Mpa
140 A	19,46 MPa	41,25 MPa

V. CONCLUSION

Based on the tests that have been carried out from the welding joints on the ASTM A36 plate that apply SMAW and FCAW welding with different current variations, the tensile and bending test values are obtained. From the results of the optimal current test from the variables that have been determined, for SMAW welding, the current of 120 A is the most optimal current, while for FCAW welding it is 140 A. In the tensile and bending test analysis, the largest results from SMAW welding are 120A current with a tensile strength of 431.3Mpa and a bending strength of 27.09Mpa. And for FCAW welding, the current is

140A with a tensile strength of 474.0Mpa and a bending strength of 41.25Mpa.

The results of this study show that the WPS produced is ASTM A36, single v butt joint 600, FCAW welding current 140A with E71T-1C electrode, which produces a welding speed of 16cm/minute or 10,500Joule/cm.

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REFERENCES

[1] Azwinur, Jalil, S. A., & Husna, A, "*The Effect Of Welding Current Variation On Mechanical Properties In SMAW Welding Process*", POLIMESIN Journal, 2017.

[2] Rachmawan, M. A., & Pranatal, E, "*Strength Analysis of Ceramic Backing Welding Results in the Fcaw Welding Process of A36 Carbon Steel Material*", Ocean Engineering: Journal of Maritime Engineering and Technology, Vol.2 No.2, 2023.

[3] Y. M. Zulaida, M. I., "*Flux Core Arc Welding For Ship Hull Plate Welding Application*", Tech. J. Science and Technology, vol. 14, no. 2, p. 119, 2018.

[4] Liu, H., "*Welding In Encyclopedia of Materials: Metals and Alloys*", 3rd ed., pp. 39–65, 2022.

[5] C. W. Panggaben, UB, "*Effect of Current Variation and Polarity on Tensile Strength, Bending and Hardness of SMAW (Shielded Metal Arc Welding) Welding Results on SS 400 Steel*", J. Shipbuilding Tech., vol. 9, no. 4, pp. 350–359, 2021.