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Comparative Analysis of GTAW, GMAW, and FCAW Welding Results on A36 Steel Against Tensile Test and Macrostructure

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ABSTRACT

Offshore building construction is inseparable from the fabrication process. Fabrication process that has an important role in terms of engineering, material repair and welding process. In offshore building construction, a precise welding method is needed on A36, where A36 steel is one of the main materials in the fabrication process of offshore buildings. In this study a comparison of welding results of GTAW, GMAW, and FCAW on A36 steel against Tensile Test and Macrostructure Test. The results of this research show that the best tensile test results are the GTAW welding method with an average value of ultimate strength of 462,168 MPa. Macrostructure testing which has the widest HAZ width is the GTAW welding method of 18,71 mm.

Keywords: *A36 Steel, GTAW, GMAW, FCAW, Tensile Test, Macrostructure Test.*

1. INTRODUCTION

Currently, the oil and gas exploration industry always experience an increase every year, as the needs of the community continue to increase in the consumption of oil and gas fuels, once oil and gas exploration focused on land is now experiencing growth by shifting oil and gas production to the deep sea. Simple welding can be interpreted as the process of joining two metals up to the point of metal recrystallization using either added or not materials and using thermal energy as a melting material to be welded [1]. Metal splicing using welding techniques is considered the most economical compared to other metal splicing techniques. Welding also gives advantages to the construction of technology or economic aspects [2].

Various kinds of welding methods can be done, such as GTAW (Gas Tungsten Arc Welding), SMAW (Shield Metal Arc Welding), FCAW (Flux Cored Arc Welding). GTAW is welding where the heat source comes from electric arc jumps between electrodes made of tungsten and welded metal [3].

Comparing welding methods is useful research for the construction and fabrication industry, similar studies have previously been carried out that compared GTAW and SMAW welding on Super Duplex SA790 material against pitting corrosion [4] and compare GTAW and SMAW welding against risk and cost [5].

So in this study will be compared the results of welding GTAW, GMAW, and FCAW on steel A36 against tensile test and macrostructure test. Tensile Test is a test to find out the yield point and maximum strength of a material macrostructure testing serves to determine the width of the HAZ (Heat Affected Zone) area and defects in the welding of a material.

2. MATERIAL AND METHODS

2.1 Material and Tools Preparation

At this stage, material and equipment preparation was carried out. This research used A36 steel material. Then the equipment was prepared to carry out experiments such as welding machines, grinding machines, cutting machines, bending test equipment, and macrostructure testing.

2.2 Welding

The welding process was carried out at Surabaya State Shipbuilding Polytechnic Welding Lab. The material used in this study was ASTM A36 steel material. Test specimens were rectangular in size as follows Length: 300 mm, Width: 150 mm and Thickness: 10 mm in the form of a single V-groove 60^{o} seam. each will be welding in the GTAW, GMAW, and FCAW methods. GTAW welding used S6 E-70 electrodes, GMAW welding used ER 70 S-6 electrodes, and FCAW welding used E 71-T electrodes.

2.3 NDT Radiography Test

Metallographic testing is carried out to find out the surface structure of the welding results, both macro and micro. This

test is carried out following the ASTM E3-01 Standard Guide for preparation of metallographic specimens. For magnification used, a macro magnification is used on a macro photo using an optical microscope. Whereas for microphotographs, 100x and 400x magnification is used by using an electron microscope. The area observed is in the base metal, HAZ, and weld metal parts.

2.4 Tensile Test

After the material passed the NDT test stage, the material was formed according to the standard tensile test specimen and then proceed with the tensile test. Tensile testing is carried out to determine the mechanical properties of the material in the form of maximum tensile strength and yield strength on previously welded material. The standard used in tensile testing is ASME Section IX.

2.5 Macrostructure Test

In this metallographic test, a macrostructure photo was taken in the HAZ (Heated Affected Zone) area. Macro photos used a DSLR with 50x and 100x magnification. The standard used is ASTM E3-01 "Standard Guide for Preparation of Metallographic Specimens".

2.6 Data Analysis

At this stage, the authors analyze the data obtained and processed from the results of experiments that have been carried out. From all these data, an analysis will be carried out under relevant standards and scientifically supported. So from the results of the analysis, the author can discuss the objectives of the problem formulated.

3. RESULTS AND DISCUSSION

3.1 Welding Process

The welding process in the GTAW, GMAW, and FCAW methods is carried out under predetermined WPS. The average heat input from GTAW welding is 0.99 kJ / mm, the average heat input from GMAW welding is 0.983 kJ / mm, and the average heat input from FCAW is 0.986 kJ / mm.

3.2 Radiography Test

Radiographic NDT testing is performed to see whether the welding results have welding defects or not. The results of the radiographic NDT test stated that the welding results of GTAW, GMAW, and FCAW contained welds in the form of porosity defects in the order of 1.4mm; 1.2 mm; 1.7 mm; 1.3 mm; 1.5 mm; 1.4 mm; 1.2 mm; 1.4 mm; 1.8 mm.

Figure 1. Radiography Test on GTAW Materials

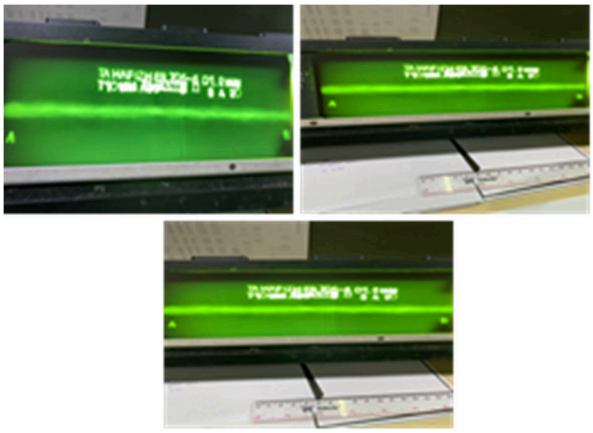

Figure 2. Radiography Test on GMAW Materials

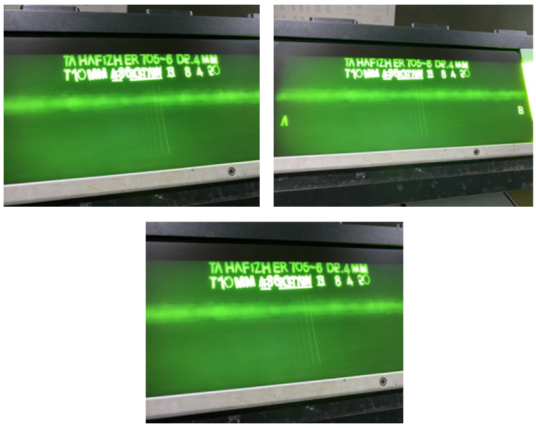

Figure 3. Radiography Test on FCAW Materials

3.3 Tensile Test

Tensile testing is carried out to determine the yield point and maximum strength of a material. Obtained the average yield strength on GTAW welding is 299,240 MPa and the average ultimate strength is 462,168 MPa. Obtained the average yield strength on GMAW welding is 289,656 MPa and the average ultimate strength is 456,361 MPa. The average yield

strength for FCAW welding is 293,188 MPa and the average strength is 459,177 MPa.

The results of the tensile test on all welding methods have passed the established standard of 400 MPa. The results of the tensile test on all welding methods also stated that the fracture occurred at the base metal.

Figure 4. GTAW Specimen for Tensile Test

Figure 5. GMAW Specimen for Tensile Test

Figure 6. FCAW Specimen for TensileTest

The best tensile test results are GTAW welding results with an average ultimate strength of 462.168 MPa, having a difference of 5.817 MPa (1.26%) with GMA and a different of 2.991 MPa (0.65%) with FCAW, the difference between each welding method not significant due to differences in heat input which is also not significant.

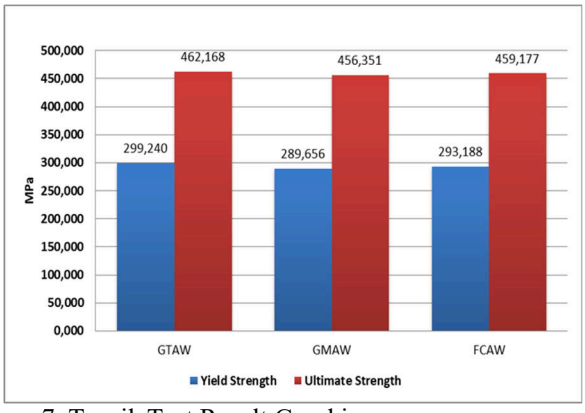

Figure 7. TensileTest Result Graphic

4.4 Macrostructure Test

Macrostructure testing was conducted to determine the width of the HAZ area. In this macrostructure test, the magnification is done as much as 100x because the focus of this test is to get the details of the HAZ area after the welding test.

The results of testing this macrostructure will be shown in the figure below.

Figure 8. Macrostructure Photo Results for GTAW

Figure 9. Microstructure Photo Results for GMAW

Figure 10. Microstructure Photo Results for FCAW

The results of microstructure results will be shown in the table below

Table 1. Results of Microstructure Test

Number	Specimen	HAZ (mm)
1.	GTAW	18,71
2.	GMAW	16,84
3.	FCAW	17,26

4. CONCLUSION

Based on tests and results described in this study, which the stone armor stability was evaluated for toe protection of the sea wall, the following conclusions can be achieved:

1. The best tensile test results are GTAW welding results with an average ultimate strength of 462.168 MPa, having a difference of 5.817 MPa (1.26%) with GMAW and a difference of 2.991 MPa (0.65%) with FCAW, the difference between each welding method not significant due to differences in heat input which is also not significant.
2. This is directly proportional to the results of observations of the macrostructure where the greater the value of the heat input it will produce the best test. Then welding with the best mechanical test results in this study is the GTAW welding method.

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