International Journal of Offshore and Coastal Engineering
Vol. 5 | No. 2 | pp. 58-61 | Nov 2021
e-ISSN: 2580-0914

Submitted: July 16, 2021 | Revised: September 15, 2021 | Accepted: October 14, 2021

Comparative Analysis of FCAW, and GMAW Welding With Heat Input Variations on A36 Steel Against Vickers Hardness Test and Macrostructure

Herman Pratikno[a*], Nugraha Adhi Pahlawan[a] and Wimala Lalitya Danista[a]

[a)] Department of Ocean Engineering, Institut Teknologi Sepuluh Nopember, Surabaya 60111, Indonesia
*Corresponding author: hermanp@oe.its.ac.id

ABSTRACT

In offshore building construction, a precise welding method is needed on A36 steel, where A36 steel is one of the main materials in the fabrication process of offshore buildings. In this study a comparison of the results of the welding GMAW and FCAW with variations of the heat input on the A36 steel to the Hardness test, and the macrostructure test and the selection of the most appropriate method based on the results of the mechanical test analysis. The heat input variations used are GMAW 1.50 kJ / mm and 2.03 kJ / mm while for FCAW 1.90 kJ / mm and 2.30 kJ / mm. The results of this study are the best hardness test results are the FCAW welding method with a heat input of 2.30 kJ / mm with an average ultimate strength of 149.06 HVN, in the macro test the results show that the greater the heat input, the wider the HAZ area, this is shown by welding FCAW heat input 2.30 kj / mm which has a HAZ width area of 20 mm.

Keywords: *A36 Steel, FCAW, GMAW, Hardness Test, Macrostructure.*

1. INTRODUCTION

Welding is one of the processes required in the fabrication and repair process in offshore buildings. Like when connecting legs between structures with bracing, then the joints in the jacket structure use the welding process which is welded with welded joints, and in the process of connecting plates and tanks on ships. Therefore, a Bachelor of Marine Engineering graduates needs an understanding and understanding of the process and knowledge of welding. It can simply be interpreted that welding is the process of joining two metals up to the point of metal recrystallization using either added material or not and using heat energy as a melting material to be welded [1].

In practice, in the construction of many marine structures, the connection between two metals is needed both during construction and during a repair. 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). Weld area consists of three parts, namely weld metal, heat affected area or HAZ (Heat Affected Zone) and parent metal which is not affected by the welding process [2]. Welding metal is a part of metal that melts and then freezes.

The HAZ area is the base metal next to the welding metal which during the welding process undergoes rapid heating and cooling cycles [3]. The base metal is the base metal base where the heat and temperature of the welding do not cause changes in structure and properties, and according to Indiarsa (2018) [4] FCAW Is a type of electric arc welding where the welding wire has flux (middle core protector).

Comparing welding methods is useful research for the construction and fabrication industries [5]. Then in this study, will be compared the results of welding FCAW, GMAW with heat input variations on the A36 steel against hardness test and macrostructure. A hardness test is one form of testing to determine the hardness of a material by pressing the surface of the material using an indenter that can be known in the amount of value. Macro testing functions to see differences in the width of the HAZ area on each welding.

2. BASIC THEORY

2.1 A36 Steel

A36 steel material is a type of steel that is widely used in the maritime industry. One of the ASTM A36 steel materials is often used as a basic material for shipbuilding plates. This steel is a type of carbon steel with low alloy or commonly referred to as mild steel. A36 steel has a tensile strength of 400-550 MPa, a yield point of 250 MPa, and a young modulus of 200 Gpa.

2.2 FCAW

FCAW welding is a type of welding that uses both automatic and semi-automatic processes that utilize wire roll electrodes to melt metal. In this FCAW welding, the energy source uses DC or AC electric current is taken from the power plant or through a transformer and/ or rectifier. FCAW welding is a type of electric welding whose work process is to supply electrodes or welding wires mechanically continuously into an electric arc.

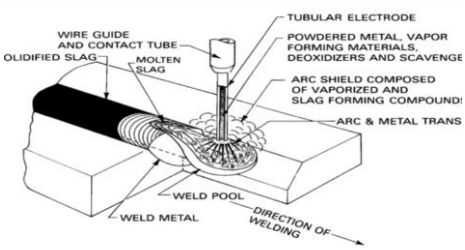

Figure 1. FCAW Welding

2.3 GMAW

Another name for GMAW (Gas Metal Arc Welding) welding is metal inert gas (MIG) where the electrode wire used is not encased and its supply properties are continuous. The weld area is protected from the atmosphere through gas produced from the welding device [7]. The protective gas used is Argon gas, helium or a mixture of the two. To stabilize the arc sometimes added O2 gas between 2 to 5% or CO2 between 5 to 20% [8].

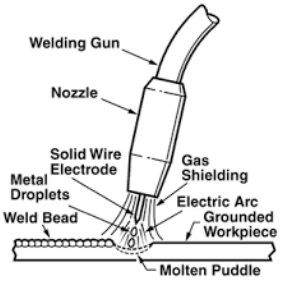

Figure 2. GMAW Welding

2.4 Heat Input

In the welding process, liquefaction of the parent metal and filler metal occurs due to the transfer of heat energy. The heat input itself can be interpreted as the transfer of heat energy per unit length in the welding process. The heat energy that occurs is caused by three parameters, namely the welding current, welding voltage, and welding speed.

2.5 Hardness Test

A hardness test is one form of testing to determine the hardness of a material by pressing the surface of the material using an indenter that can be known in the amount of value. In this research, the authors will use the Vickers hardness test method to get the results.

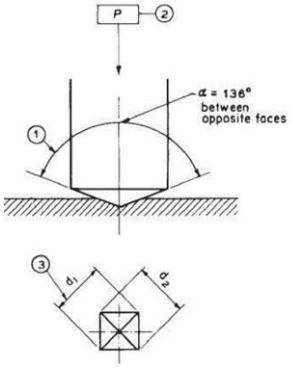

Figure 3. Vickers Hardness Test

2.6 Macrostructure

Macro testing is a test of the structure of material through enlargement using the eye directly or by using a magnifying glass with low magnification. By testing the macrostructure, it can be observed the shape of the macro material in the welding area, namely the fusion line, Heat Affected Zone, and Weld Metal so that the shape of the weld can be seen then the surface must be smooth by machining, grinding, and polishing then the weld area is etched with liquid. chemicals including Acid nitrides, HCl acids and water, so that the shape of the weld between weld metal, HAZ, and fusion is visible. The results of this macro test is a visual quality of welds and weld shapes.

3. RESEARCH METHODOLOGY

3.1 Material and Tools Preparation

At this stage, material and equipment preparation is carried out. This research used A36 steel material. Then the equipment will be prepared for carrying out experiments such as welding machines, grinding machines, cutting machines, tensile testing devices, and micro tests.

3.2 Welding

The welding process will be carried out at Surabaya State Shipbuilding Polytechnic Welding Lab. A36 steel material with a length of 250mm, width 150mm, and thickness of 10mm that has been bevelled in a single v-groove with an angle of 60o will each be welding in the GMAW and FCAW methods. GMAW welding uses ER 70 S-G electrodes, and FCAW welding uses ER 71-T electrodes.

3.3 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 under 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.

3.4 Hardness Test

In this hardness test using the Vickers method and the distribution of hardness in the weld metal, HAZ (Heat Affected Zone) and the base metal will be known. The standard used in testing the hardness of the Vickers method is ASTM E92 "Standard Test Method for Vickers Hardness of Metallic Materials".

3.5 Macrostructure Test

In this metallographic test, a macrostructure photo will be taken in the weld metal, HAZ (Heated Affected Zone), and base metal (base metal) areas. Taking macro photos will be done with a 7x magnification using a DSLR camera. Before the macro photo is tested, the specimens are then polished using scrub paper with 80, 120, 240, 400, 600, 800 grit. After polishing, the etching process is carried out using a mixture of nital solution and alcohol. The etching process is carried out so that the structure of the welding specimen can be seen clearly.

3.6 Data Analysis

At this stage, the authors will 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 following relevant standards and scientifically supported. So from the results of the analysis, the author can discuss the objectives of the problem formulated.

4. RESULTS AND DISCUSSION

4.1 Welding Process

The welding process in the FCAW and GMAW methods is carried out following predetermined WPS. The average heat input from FCAW welding is 1.90 kJ / mm, and 2.30 kJ / mm, the average heat input from GMAW welding is 1.50 kJ / mm, and 2.03 kJ / mm.

4.2 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 FCAW and GMAW welding results did not have any welding defects. It can be concluded that all specimens of welding results can be continued to the next test because it meets the specified standards.

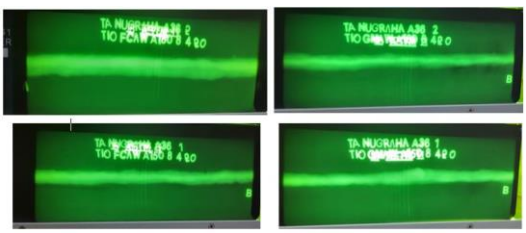

Figure 4. Radiography Test

4.3 Hardness Test

A hardness test is one form of testing to determine the hardness of a material by pressing the surface of the material using an indenter that can be known in the amount of value. In this research, the authors will use the Vickers hardness test method to get the results.

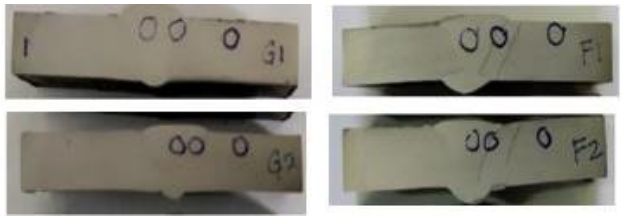

Figure 5. Specimen for Hardness Test

Vickers method hardness test results obtained from 3 test points, namely Base Metal, HAZ, and Weld Metal on each specimen. Vickers method hardness test results on the GMAW heat input 1.50 kJ/mm welding specimens get an average value on Base Metal is 145.03, HAZ 145.72, and on Weld Metal is 146.41. Vickers method hardness test results on the GMAW heat input 2.30 kJ/mm welding specimens get an average value on Base Metal is 143.55, HAZ 145.78, and on Weld Metal is 148.19. Vickers method hardness test results on the FCAW heat input 1.90 kJ/mm welding specimens get an average value on Base Metal is 141.91, HAZ 143.95, and on Weld Metal is 145.55. Vickers method hardness test results on the FCAW heat input 2.30 kJ/mm welding specimens get an average value on Base Metal is 147.09, HAZ 147.29, and on Weld Metal is 149.06.

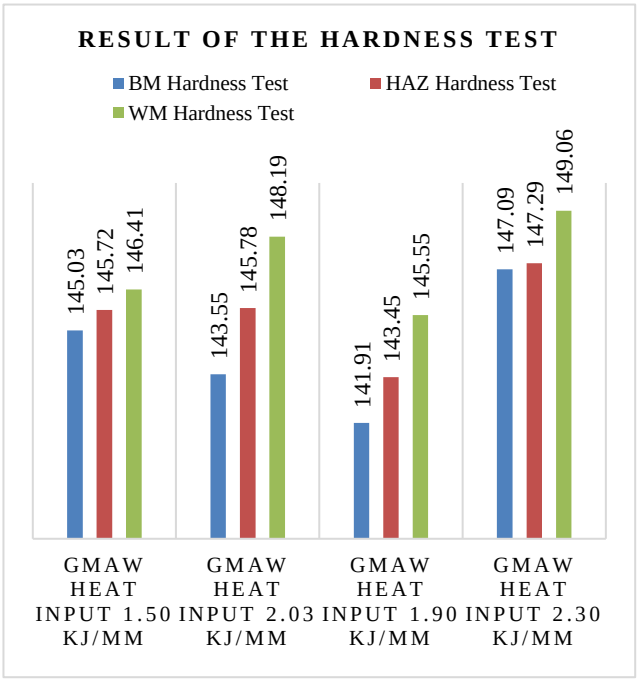

Figure 6. Hardness Test Result Graphic

It can be concluded that the highest hardness value is the hardness test on the FCAW heat input 2.30 kJ/mm welding specimens in the weld metal region with an average hardness value of 147.29 HVN as much as 2.5% compared to the FCAW heat input of 1.90 kJ/mm welding results in the weld metal area and as large as 1% compared to the GMAW heat input 2.03 kJ/mm and GMAW 1.50 kJ/mm welding results in the weld metal area, this is because the heat input received by the FCAW heat input 2.30 kJ/mm welding material is more so that the material formed in the weld metal area is more solid

4.4 Macrostructure Test

Macrostructure testing is carried out to determine the regions of the welding process, including the HAZ area, weld metal area, and base metal area. Besides, another function of macro testing is to determine the welding defects that are in the welding results. Macro testing is done by 7x magnification using a DSLR camera. The results of macro-observations on each welding result will be shown in the figure below.

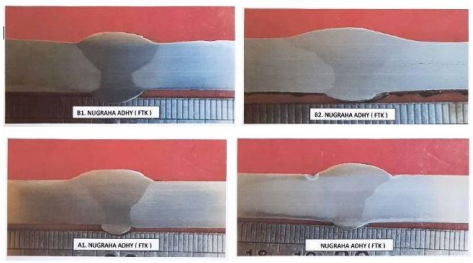

Figure 7. Macrostructure Photo Results for SMAW

Table 1. Results of Macrostructure Test

Welding	Area	wide
GMAW 1.50 kJ/mm	HAZ	16 mm
GMAW 2.03 kJ/mm	HAZ	19 mm
GMAW 1.90 kJ/mm	HAZ	18 mm
GMAW 2.30 kJ/mm	HAZ	20 mm

5. CONCLUSION

1. The best hardness test results are the results of FCAW heat input 2.30 kJ/mm welding in weld metal areas with an average of 147.29 HVN, having a difference of 0.87 HVN with GMAW heat input of 2.03 kJ/mm and a difference of 2.65 HVN with GMAW heat input 1.50 kJ/mm and a difference of 3.51 HVN with FCAW heat input 1.90 kJ/mm. This is because in FCAW 2.30 kJ/mm welding the heat input received by the material is greater than other welding methods, the higher the heat input received by the material, the more heat-receiving parts will be more solid.
2. The results of macrostructure testing show that the results of FCAW heat input 2.30 kJ/mm welding with the widest HAZ area compared to FCAW 1.90 kJ/mm, GMAW 2.03 kJ/mm, and GMAW 1.50 kJ/mm welding show that the wider HAZ area, the greater the results of tensile and hardness tests.

ACKNOWLEDGEMENTS

The author thanks employees and technicians from the Welding Laboratory, Surabaya State Polytechnic, employees and technicians from the Material Testing Laboratory, Surabaya State Polytechnic, and technicians from the DT and NDT Laboratories of the Madura State Polytechnic who have helped and directed the authors in carrying out this research. The author also does not forget to thank all those who have helped in completing this final project directly or indirectly.

REFERENCES

[1] Jaya, Danang Baskara. *2018. "Analisis Pengaruh Sudut Groove pada Pengelasan SMAW terhadap Sifat Mekanis dan Prediksi Laju Korosi ASTM A131 AG36 di Lingkungan Laut".* Surabaya: Tugas Akhir Teknik Kelautan FTK, Insititut Teknologi Sepuluh Nopember.

[2] Setyawan, Agus. 2002. *"Analisa Perbandingan Proses Pengelasan SMAW dan FCAW Terhadap Kekerasan dan Ketangguhan Untuk Tebal Plat Pipa 10mm dan 15mm".* Surabaya: Tugas Akhir Teknik Kelautan FTK, Institut Teknologi Sepuluh Nopember.

[3] Parekke, Simon. 2017. *"Pengaruh Variasi Arus pada Pengelasan GTAW terhadap Sifat Mekanis dan Fisis pada Logam Berbeda Baja Karbon Sedang Dengan Baja Tahan Karat Austenit".* Jurnal Ilmiah Teknik Mesin, Vol. 9, No. 1, November.

[4] Kumar, S dan A.S. Shahi. 2011. Effect of heat input on the microstructure and mechanical properties of gas tungsten arc welded AISI 304 stainless steel joints. *Journal of Materials and Design*. 32: 3617-3623

[5] Ghazvinloo, H.R, and Raouf, A.H. 2010. "Effected of Gas-Shielded Flux Cored Arc Welding Parameters on Weld Width and Tensile Properties of Weld Metal in a Low Carbon Steel*". Journal of Applied Sciences,Vol: 10, Pages 658-663*

[6] Saha, K. M., J. Mondal., A. Mondal., dan S. Das. 2018. Influence of Heat Input on Corrosion Resistance of Duplex Stainless Steel Cladding Using Flux Cored Arc Welding on Low Alloy Steel Flats. *Indian Welding Journal*. 51: 66 – 72

[7] Sidhu, G.S and Chatha, S.S. 2012. "Role of Shielded Metal Arc Welding Consumables on Pipe Weld Joint". *International Journal of Emerging Technology and Advanced Engineering, Vol: 2, Pages 746-750*

[8] Indiarsa, A.B. 2018. "Analisis Sifat Mekanik Pada Sambungan Pelat Baja AH 36 dan ASTM A 53 Mengunakan Pengelasan Flux Core Arc Welding (FCAW) Dengan Variasi Heat Input dan Jenis Elektrode". Surabaya: Tugas Akhir Teknik Kelautan FTK, Institut Teknologi Sepuluh Nopember