International Journal of Marine Engineering Innovation and Research, Vol. 8(4), Dec. 2023. 758-770
(pISSN: 2541-5972, eISSN: 2548-1479)

The Effect of Preheat and Post Weld Heat Treatment On Welding ASTM A 516 Grade 60 Material On Destructive Test Values

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(Received: 28 November 2023 / Revised: 29 November 2023 /Accepted: 30 November 2023)

***Abstract*—In the construction of independent tanks (spherical) must be related to welding. Welding itself has a very important role in the process of connecting steel plates. The aims of the research is to determine the effect of the presence or absence of preheat and PWHT on welding and uses ASTM A 516 grade 60 steel material, where the material is commonly used for the construction of tanks or pressure vessels. The steel material is welded by the SMAW (shield metal arc welding) welding process with several different welding variables, one of which is given the preheat and post weld heat treatment (PWHT) variables and the other is not given these variables. Then the material will be tested mechanically, such as bending test, tensile test, and impact test under low temperature conditions (-20°C). The method used in this research is experimental. From the results of the tests will be known the value of tensile strength and energy absorbed. In the welding test specimen with preheat and PWHT variables, an opening of 1.68 mm was obtained, with an average tensile strength value of 523 N/mm^2, and an average energy value of 205.15 J. While in the specimen without preheat and PWHT variables, the opening was obtained. of 1.21 mm, with an average tensile strength value of 473.5 N/mm^2, and an average energy value of 46.7 J.**

Keywords—Bending Test, Impact Test, Preheat, Post Weld Heat Treatment, Tensile Test.

I. Introduction

Indonesia has a rapid industrial growth rate. In the era of the industrial revolution 4.0, all fields of production have become increasingly sophisticated and standardized. This resulted in the level of demand for energy also increasing. Which must be balanced with the ability to supply this energy. Therefore, the use of alternative energy such as energy produced from natural gas processing can help support the supply of energy needs.

Natural gas itself in the management process must be cooled to temperatures ranging from 0°C to -165°C, so that later the natural gas will undergo a process of condensation and change form to liquid (Liquefied Natural Gas), which has the aim of minimizing the volume of natural gas and can be stored and distributed easily.

This natural gas is not only found on land, but much of it is also offshore, deep under the sea. Therefore, transportation is needed to move the natural gas that has been liquefied from platforms to oil refineries, as well as from refineries to other refineries. Ships specially designed with tanks capable of storing liquefied gas are commonly known as LNG (Liquefied Natural Gas) or LNGC (Liquefied Natural Gas Carrier) ships.

To maximize the storage of liquefied natural gas, a tank that is strong and capable of storing at cold temperatures is required. Therefore, it is necessary to pay attention to the selection of the type of material as the main ingredient in the manufacture of the tank. Material ASTM A 516 grade 60 is one of the many materials that can be used as the main ingredient in the manufacture of these tanks. Material ASTM A 516 grade 60 is a carbon-manganese steel material with standard specifications for tanks and pressure vessels for medium to low service temperatures.

According to design standards, independent tank construction consists of an outer wall, an insulator wall and an inner wall. Carbon-manganese steel materials such as ASTM A 516 grade 60 are used as materials for the outer walls, whereas for the inner walls, stainless steel and polyurethane or perlite are used as wall insulator materials.

In the independent tanks fabrication process, the method used to connect steel materials is by welding. Where in the welding process there are many variables that need to be considered and these variables will greatly affect the quality of the welded joint or the strength values of the welded joint. Variables in the welding process include the type of welding electrode, amperage, volts, travel speed, heat input, heat treatment, and others.

This study intends to determine the effect of variable heat treatment on the welding process of ASTM A 516 grade 60 steel material on the quality and mechanical value of welded joints using the bending, tensile, and impact (charpy v-notch) test methods.

In the bending test, both the test specimens that used the preheat and PWHT variables and the test specimens that did not use these variables had openings or gaps, but the size of the gaps in the two test specimens still met the criteria required by the ASME section IX standard [1].

In the tensile test, the tensile strength values of the test specimens that used the preheat and PWHT variables were higher than those of the test specimens that did not

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use these variables, but the tensile strength values of the two test specimens still met the criteria required by ASTM A 516 specification standard in ASME section II part A [2].

In the impact test (charpy v-notch), the value of the potential energy that can be absorbed from the test specimens using the preheat and PWHT variables is higher compared to the test specimens that do not use these variables, but the energy values that can be absorbed from the two test specimens are still included criteria required by the standards or rules of DNV-GL part 5 chapter 7 [3].

A. Cargo Tanks

Cargo tanks or cargo spaces on ships where the design of the cargo system cannot be less than the design of the ship itself. The structural robustness of the cargo tank system must be able to withstand mode failures, but not be limited to plastic deformation, buckling, and fatigue [4].

An independent tank is one of the many types of cargo tanks for gas-laden ships, an independent tank is a type of cargo tank that does not form part of the ship's hull (separate) and also does not affect the strength of the ship's hull [5]. Figure 1 shows the spherical tank for LNG carrier.

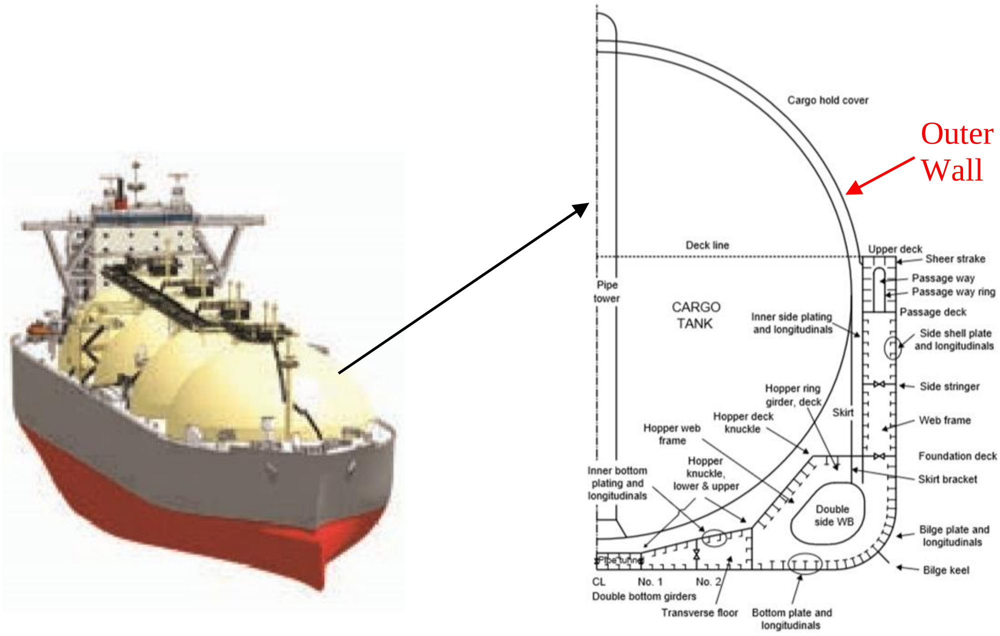

Figure. 1. Spherical Tank

B. Material ASTM A 516 Grade 60

ASTM A 516 grade 60 is a steel material that is commonly applied to environments with lower temperatures than normal, has good notch toughness and is suitable for use as a material in fabrication such as pressure vessels, boilers, and tanks. This steel material has good yield stress and tensile stress [2].

C. Welding

Welding is a local connection of several metals using heat energy. And there are 3 (three) areas or areas of welding results, namely the area of welds, heat affected zone (HAZ) and the base metal [6].

There are many kinds of welding processes, one of which is shielded metal arc welding (SMAW). Shielded metal arc welding is a type of electric arc welding where in welding using an electric arc flame as a heat source for melting metal. This type of welding is the most chosen or used for all welding purposes [7].

D. Preheating

Preheating is an activity in the form of heating before the start of welding which is carried out at a temperature below the recrystallization temperature. Preheat is done by using a gas burner, oxy-gas flame, electric blanket, induction heating or heating with a furnace [8].

The purpose of doing preheat is to slow down the cooling rate on metal weld and base metal, which allows hydrogen to diffuse out and reduces the potential for the cracking and can also increase the toughness of the metal [9].

E. Post Weld Heat Treatment

The release of residual stress or stress relief may be one of the reasons for conducting post-weld heat treatment, which aims to reduce residual welding stress in welded joints that experience heavy restraint or are sensitive to cracking [10].

F. Visual Inspection

Visual inspection is a very simple non-destructive testing method. This method is used to detect defects or cracks on the surface. In that case the detected defects are those that can be seen by the naked eye or with the help of a magnifying lens [11].

G. Liquid Penetrant Test

The liquid penetrant test is a non-destructive test method used to determine fine discontinuities on the surface of the test object, such as cracks or holes.or leakage. The principle of this test is to utilize capillary power.

With this method, discontinuities detected are not limited to size, shape, direction, material structure or composition. Penetrant liquid is able to seep into small gaps. This test is widely used to determine surface cracks, porosity, and others [12].

H. Bending Test

Bending test aims to determine the flexural strength of a material. This test can also be used to visually determine the quality of the weld as a result of the buckling loading that occurs.

Based on the position of taking in the manufacture of test specimens, the bending test is divided into 2 (two), namely the transverse bending test and the longitudinal bending test. Meanwhile, based on the location of observation and loading, the transverse buckling test is classified into 3 (three), namely face bend, root bend and side bend [13].

I. Tensile Test

Tensile test on metal materials aims to determine the nature of the tensile strength of the metal. The principle is to apply a continuous uniaxial tensile load to the test specimen [14].

Tensile testing in the weld area intends to determine whether the weld strength value is lower, the same or higher than the strength value of the raw material [12].

J. Impact Test (Charpy V-Notch)

The impact test is a test for the resistance of a material in receiving shock loads. This test aims to determine the toughness of a material. The principle of this test is the material's ability to absorb potential energy from a pendulum swinging from a height. Prior to testing, the test specimen is notched in advance in an area parallel to the load pendulum. The function of the notch for localize the fracture which will later occur in the notch area [15].

II. METHOD

A. Research Methods

The method used in this study is an experimental and analytical method, which aims to determine the effect of preheat and post weld heat treatment on the mechanical properties of ASTM A 516 grade 60 steel material welded joints. This experimental method is in the form of observations under artificial conditions that are deliberately arranged and planned. This research was conducted by manipulating the object of the research accompanied by a control variable.

B. Study of Literature

The literature study was carried out aiming to gain knowledge in the form of theory in completing this final project. Among other things, journals and international standards as references related to the discussion.

C. Welding Process

1. Preliminary Welding Procedure Specifications

Preliminary welding procedure specifications (pWPS) are useful as a reference or guide in making qualification procedures, namely welding procedure specifications (WPS), in which the pWPS is designed by a welding engineer. In this study, there were 2 (two) pWPS, each of which was designed with the same variables, but there were several distinguished variables, namely the preheat and post weld heat treatment variables. And the two pWPS refer to the ASME section IX standard.

The following details the variables from the two preliminary welding procedure specifications (pWPS):

a) pWPS 01

Material Specification	:	ASTM A 516 Grade 60
Welding Process	:	SMAW
Joint Design	:	Single – V Groove
Angle Groove	:	60 – 65^{o}
Root Face	:	3 mm
Root Spacing (Gap)	:	1.6 – 3.2 mm
Filler Metal	:	E7016 & E7018
Size of Filler Metal	:	Ø 2.6 & 3.2 mm
Welding Position	:	3G (Uphill)
Amperage	:	75 – 150 A
Polarity	:	DCEN & DCEP
Volts	:	18 – 30 V
Travel Speed	:	58 – 110 mm/minute
Technique	:	String & Weave
Interpass Cleaning	:	Brushing & Grinding
Preheat Temperature	:	65 – 100 ^{o}C
Interpass Temperature	:	250 ^{o}C
PWHT Temperature	:	620 ^{o}C
Heating Rate	:	108 ^{o}C/hour
PWHT Holding Time	:	60 minutes

b) pWPS 02

Material Specification	:	ASTM A 516 Grade 60
Welding Process	:	SMAW
Joint Design	:	Single – V Groove
Angle Groove	:	60 – 65^{o}
Root Face	:	3 mm
Root Spacing (Gap)	:	1.6 – 3.2 mm
Filler Metal	:	E7016 & E7018
Size of Filler Metal	:	Ø 2.6 & 3.2 mm
Welding Position	:	3G (Uphill)
Amperage	:	75 – 150 A
Polarity	:	DCEN & DCEP
Volts	:	18 – 30 V
Travel Speed	:	58 – 110 mm/minute
Technique	:	String & Weave
Interpass Cleaning	:	Brushing & Grinding
Preheat Temperature	:	Ambient Temperature
Interpass Temperature	:	250 ^{o}C
PWHT Temperature	:	N/A
Heating Rate	:	N/A
PWHT Holding Time	:	N/A

2. Material Preparation

The material used in this study was ASTM A 516 grade 60, with test coupons dimensions of 345 mm in length, 140 mm in width and 25 mm in thickness. And formed a welding seam of 60^{o}.

3. Preheating

Preheating is carried out only for the test coupon which refers to pWPS 01, which is 65 to 100ºC. As for the test coupon which refers to pWPS 02, preheating is not carried out, but only follows the room temperature (ambient temperature).

4. Welding Implementation

Welding in this study was carried out in a workshop and was carried out by a certified welder with appropriate qualifications. And supervised directly by a welding inspector.

D. Visual Inspection

Visual testing is carried out after the welding process for the two test coupons is completed by a welding inspector with acceptance criteria referring to the ASME section IX standard.

E. Penetrant Test

Penetrant testing in this study were carried out in the same workshop as welding operations and were carried out by certified level II penetrant test operators. The two test coupons were tested alternately. And the results of interpretation are carried out by level II penetrant operators with acceptance criteria referring to the ASME section IX standard.

F. Post Weld Heat Treatment

Post weld heat treatment (PWHT) in this study was carried out in the same workshop as welding and was carried out by qualified and competent operators. The implementation of PWHT is carried out according to the procedure and after the visual and penetrant testing stages have been declared feasible or accepted.

PWHT is carried out on a test coupon that refers to pWPS 01 only, while a test coupon that refers to pWPS 02 is not carried out by PWHT.

G. Bending Test

The bending test in this study was carried out in the laboratory of PT. Bintang Inspeksindo Indonesia with qualified operators and calibrated test equipment.

In this test, the two test coupons were cut and formed into 2 (two) test specimens with the configuration and orientation required by the ASME section IX standard, namely the length of the test specimen is 150 mm, the thickness of the test specimen corresponds to the thickness of the test coupon, which is 25 mm and the width of the test specimen for material P-Number 1 is at least 10 mm. Because the thickness of the test coupon in this study is 25 mm, the required bending position is side bend.

The results of this test are used to determine the qualifications of the welder's performance in welding the two test coupons with reference to the criteria of the ASME section IX standard. Figure 2 shows the bending test specimen.

Figure. 2. Bending Test Specimen Configuration and Orientations

H. Tensile Test

The tensile test in this study was carried out in the same laboratory as the bending test.

In this test, the two test coupons were cut and formed into 2 (two) test specimens with the configuration and orientation required by the ASME section IX standard, namely the length of the test specimen is 250 mm, the thickness of the test specimen corresponds to the thickness of the test coupon, which is 25 mm and the minimum gage width of the test specimen is 19 mm.

The results of this test are useful for knowing the qualifications of the preliminary welding procedure specifications (pWPS) for the two test coupons, especially for the variable filler material (filler metal) and also for knowing the comparison of the tensile strength values between the two different test coupons for pWPS with reference to ASTM A 516 criteria. specifications (raw material) in standard ASME section II part A.

Figure. 3. Tensile Test Specimen Configuration and Orientations

I. Impact Test (Charpy V-Notch)

The impact test (charpy v-notch) in this study was carried out in the same laboratory as the bending and tensile test.

In this test, the two test coupons were cut and formed into 4 (four) test specimens with the configuration and orientation required by the ASTM E23 standard, namely the length of the test specimen is 55 mm with a tolerance of less than -2.5 mm, the width of the cross-section of the test specimen 10 mm x 10 mm with a tolerance of ± 0.075 mm, notch angle of 45^{o} with a tolerance of $\pm 1^{o}$ and for a notch radius of 0.25 mm with a tolerance of ± 0.025 mm.

In this study, 4 (four) test specimens from each test coupon were divided into 2 (two) test specimens at ambient temperature conditions and 2 (two) other test specimens at -20°C.

The results of this test are useful in knowing the comparison of energy values that can be absorbed between the two different pWPS test coupons with reference to the criteria of the DNV-GL standard part 5 chapter 7. Figure 3 shows the tensile test specimen.

Figure. 4. Impact Test (Charpy V-Notch) Specimen Configuration and Orientations

III. Results and Discussion

A. *Bending Test Results*

Each test coupon from both pWPS 01 and pWPS 02 consists of 2 (two) test specimens, where each test specimen has an identification.

In this test, the identification of the test specimens from the pWPS 01 test coupon is RJA1-SB.1 and RJA1-SB.2. While the identification of test specimens from the pWPS 02 test coupon is RJA2-SB.1 and RJA2-SB.2. Figure 3 shows Impact Test (Charpy V-Notch) Specimen

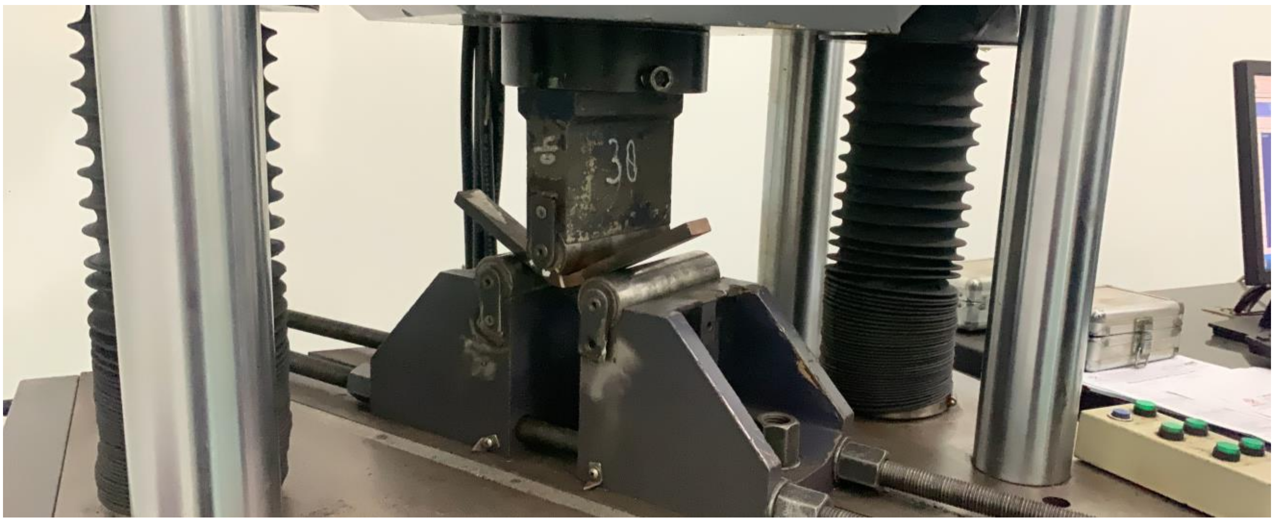

Figure. 5. Bending Test

1. Test Coupon from Preliminary Welding Procedure Specifications (pWPS) 01

TABLE 1.
THE RESULT OF THE BENDING TEST OF THE TEST SPECIMEN FROM THE PWPS 01 TEST COUPON

Specimens No.	Side Bend (RJA1-SB.1)	Side Bend (RJA1-SB.2)
Observation	1.68 mm	-
Result	Accepted	Accepted

Based on Table 1. In the RJA1-SB.1 test specimen, a crack or opening of 1.68 mm was found, while in the RJA1-SB.2 test specimen there were no cracks or openings, with the results of the two test specimens being declared to have passed the acceptance criteria of the ASME standard section IX because the opening does not exceed 3 mm. Tabel 1 shows the result of the bending test *pWPS 01*. Meanwhile table 2 shows the result of the bending test *pWPS 02.*

2. Test Coupon from Preliminary Welding Procedure Specifications (pWPS) 02

TABLE 2.
THE RESULT OF THE BENDING TEST OF THE TEST SPECIMEN FROM THE PWPS 02 TEST COUPON

Specimens No.	Side Bend (RJA2-SB.1)	Side Bend (RJA2-SB.2)
Observation	-	1.21 mm
Result	Accepted	Accepted

Based on Table 2. No cracks or openings were found in the RJA2-SB.1 test specimen, while in the RJA2-SB.2 test specimen a 1.21 mm crack or opening was found, with the results of the two test specimens being declared to have passed the acceptance criteria of the ASME standard section IX because the opening does not exceed 3 mm. Figure 6 shows the tensile test at laboratory. Table 3 shows the result of the tensile test.

B. Tensile Test Results

Each test coupon from both pWPS 01 and pWPS 02 consists of 2 (two) test specimens, where each test specimen has an identification.

In this test, the identification of the test specimens from the pWPS 01 test coupon is RJA1-T.1 and RJA1-T.2. While the identification of test specimens from the pWPS 02 test coupon is RJA2-T.1 and RJA2-T.2.

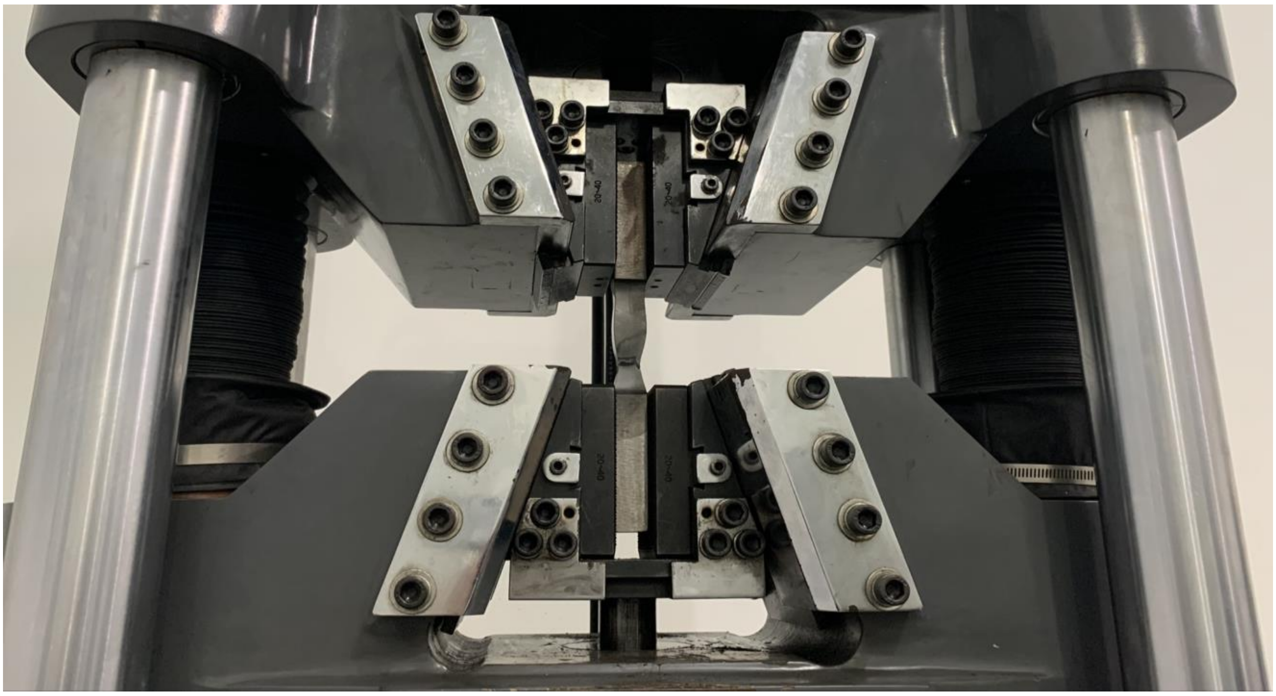

Figure. 6. Tensile Test

1. Test Coupon from Preliminary Welding Procedure Specifications (pWPS) 01

TABLE 3.
THE RESULT OF THE TENSILE TEST OF THE TEST SPECIMEN FROM THE PWPS 01 TEST COUPON

Specimens No.	Tensile 1 (RJA1-T.1)	Tensile 2 (RJA1-T.2)
Measured Thickness (mm)	25.14	25.00
Measure Width (mm)	19.14	19.16
Effective Area (mm^2)	481.18	479.00
Ultimate Tensile Load (kN)	251.86	250.50
Ultimate Tensile Strength (N/mm^2)	523	523
Location Failure	Base Metal	Base Metal
Type of Failure	Ductile	Ductile

Based on Table 3. In the RJA1-T.1 test specimen the ultimate tensile strength value was 523 N/mm^2, whereas in the RJA1-T.2 test specimen the ultimate tensile strength value was 523 N/mm^2, with the results of the two test specimens being passed because the tensile strength values of the two test specimens were not less than the criteria in the ASTM A 516 grade 60 standard, that is 415 – 550 MPa. Table shows 4 the results of the tensile test pWPS 02.

2. Test Coupon from Preliminary Welding Procedure Specifications (pWPS) 02

TABLE 4.
THE RESULT OF THE TENSILE TEST OF THE TEST SPECIMEN FROM THE PWPS 02 TEST COUPON

Specimens No.	Tensile 1 (RJA2-T.1)	Tensile 2 (RJA2-T.2)
Measured Thickness (mm)	25.03	25.03
Measure Width (mm)	19.19	19.17
Effective Area (mm^2)	480.33	479.83
Ultimate Tensile Load (kN)	226.82	227.76
Ultimate Tensile Strength (N/mm^2)	472	475
Location Failure	Base Metal	Base Metal
Type of Failure	Ductile	Ductile

Based on Table 4. In the RJA2-T.1 test specimen the ultimate tensile strength value was 472 N/mm^2, whereas in the RJA2-T.2 test specimen the ultimate tensile strength value was 475 N/mm^2, with the results of the two test specimens being passed because the tensile strength values of the two test specimens were not less than the criteria in the ASTM A 516 grade 60 standard, that is 415 – 550 MPa.

C. Impact Test (Charpy V-Notch) Results

Each test coupon from both pWPS 01 and pWPS 02 consists of 4 (four) test specimens, of which 2 (two) test specimens from each pWPS are tested at ambient temperature conditions and 2 (two) other test specimens are tested at low temperature conditions of $-20^{\circ}C$. And each test specimen has an identification.

In this test, the identification of the test specimens tested at room temperature conditions from the pWPS 01 test coupon is RJA1-W.1 and RJA1-W.2. While the identification of test specimens from the pWPS 02 test coupon is RJA2-W.1 and RJA2-W.2.

And for the identification of test specimens tested at low temperature conditions ($-20^{\circ}C$) from the test coupon pWPS 01 is RJA1-W.3 and RJA1-W.4. While the identification of the test specimen from the pWPS 02 coupon test is RJA2-W.3 and RJA2-W.4. Figure 4 shows the impact test or Charpy test.

Figure. 7. Impact Test (Charpy V-Notch)

1. Ambient Temperature

a) Test Coupon from Preliminary Welding Procedure Specifications (pWPS) 01

TABLE 5.
THE RESULT OF THE IMPACT (CHARPY V-NOTCH) TEST OF THE TEST SPECIMEN FROM THE PWPS 01 TEST COUPON

Standard	ASTM-E23	Batch No.	RJA1
Type	V	Deep (mm)	2
Sn	Area (mm^2)	Toughness (J/mm^2)	Energy (J)
a-001-WCL	80	3.39	270.91
a-002-WCL	80	3.43	274.16
Min. Value	80.00	3	271
Max. Value	80.00	3	274
Mean Value	80.00	3	273
Standard Deviation	0.00	0	2

Based on Table 5. In the RJA1-W.1 test specimen the energy value that can be absorbed is 270.91 J, while in the RJA1-W.2 test specimen the energy value that can be absorbed is 274.16 J. Table 5 shows the result of the impact or Charpy test pWPS 01. In Table 6 shows the result of the impact or Charpy test pWPS 02.

b) Test Coupon from Preliminary Welding Procedure Specifications (pWPS) 02

TABLE 6.
THE RESULT OF THE IMPACT (CHARPY V-NOTCH) TEST OF THE TEST SPECIMEN FROM THE PWPS 02 TEST COUPON

Standard	ASTM-E23	Batch No.	RJA2
Type	V	Deep (mm)	2
Sn	Area (mm^2)	Toughness (J/mm^2)	Energy (J)
a-001-WCL	80	3.30	263.98
a-002-WCL	80	3.45	275.77
Min. Value	80.00	3	264
Max. Value	80.00	3	276
Mean Value	80.00	3	270
Standard Deviation	0.00	0	7

Based on Table 6. In the RJA2-W.1 test specimen the energy value that can be absorbed is 263.98 J, while in the RJA2-W.2 test specimen the energy value that can be absorbed is 275.77 J.

2. Low Temperature (-20^{o}C)

a) Test Coupon from Preliminary Welding Procedure Specifications (pWPS) 01

TABLE 7.
THE RESULT OF THE IMPACT (CHARPY V-NOTCH) TEST OF THE TEST SPECIMEN FROM THE PWPS 01 TEST COUPON

Standard	ASTM-E23	Batch No.	RJA1
Type	V	Deep (mm)	2
Sn	Area (mm^2)	Toughness (J/mm^2)	Energy (J)
a-001-WCL	80	2.60	208.14
a-002-WCL	80	2.50	200.15
Min. Value	80.00	2	200
Max. Value	80.00	2	208
Mean Value	80.00	2	204
Standard Deviation	0.00	0	5

Based on Table 7. In the RJA1-W.3 test specimen the energy value that can be absorbed is 208.14 J, while in the RJA1-W.4 test specimen the energy value that can be absorbed is 200.15 J. With an average value of energy that can be absorbed is 204.15 J, where the average value is greater than the required average value or criteria in the DNV-GL standard part 5 chapter 7, which is 27 J.

b) Test Coupon from Preliminary Welding Procedure Specifications (pWPS) 02

TABLE 8.
THE RESULT OF THE IMPACT (CHARPY V-NOTCH) TEST OF THE TEST SPECIMEN FROM THE PWPS 02 TEST COUPON

Standard	ASTM-E23	Batch No.	RJA2
Type	V	Deep (mm)	2
Sn	Area (mm^2)	Toughness (J/mm^2)	Energy (J)
a-001-WCL	80	0.37	29.71
a-002-WCL	80	0.80	63.69
Min. Value	80.00	2	29
Max. Value	80.00	2	63
Mean Value	80.00	2	46
Standard Deviation	0.00	0	24

Based on Table 8. In the RJA2-W.3 test specimen the energy value that can be absorbed is 29.71 J, while in the RJA2-W.4 test specimen the energy value that can be absorbed is 63.69 J. With an average value of energy that can be absorbed is 46.7 J, where the average value is greater than the required average value or criteria in the DNV-GL standard part 5 chapter 7, which is 27 J.

D. Discussion

From the tests that have been carried out, such as the bending test, tensile test and impact test (charpy v-notch) on the test specimens from the two test coupons, the results of comparisons and decisions are obtained from the criteria for each test. Figure 8 shows the bending test specimen. In the Figure 9 shows the bending test results.

1. Correction from Bending Test

Figure. 8. Bending Test Specimens

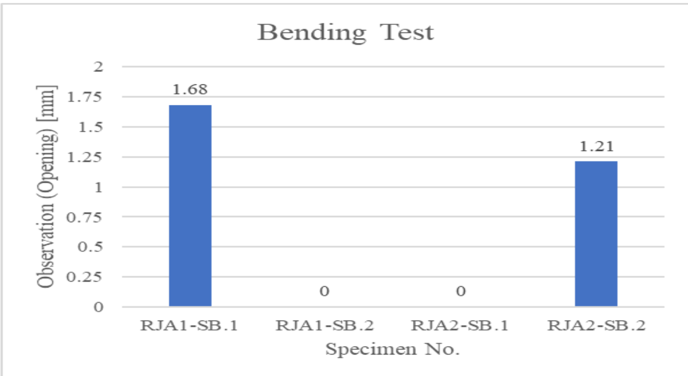

Figure. 9. Bending Test Results

TABLE 9.
CORRECTION RESULT FROM BENDING TEST

Specimens No.	Observations (Opening) [mm]	ASME Sec. IX (Max. Opening) [mm]	Results
RJA1-SB.1	1.68	3.00	Accepted
RJA1-SB.2	-	3.00	Accepted
RJA2-SB.1	-	3.00	Accepted
RJA2-SB.2	1.21	3.00	Accepted

Based on Table 9. All test specimens from the pWPS 01 test coupon and pWPS 02 test coupon were declared to have passed the acceptance criteria of the ASME section IX standard because the openings or gaps in all test specimens did not exceed 3 mm.

The decided that the welder who welded the two test coupons was competent and qualified in performing welding with the same variable qualifications as the welding procedure in this study, namely preliminary welding procedure specifications. Figure 10 shows the tensile test specimen. In the Figure 11 shows the tensile test results.

2. Correction from Tensile Test

Figure. 10. Tensile Test Specimens

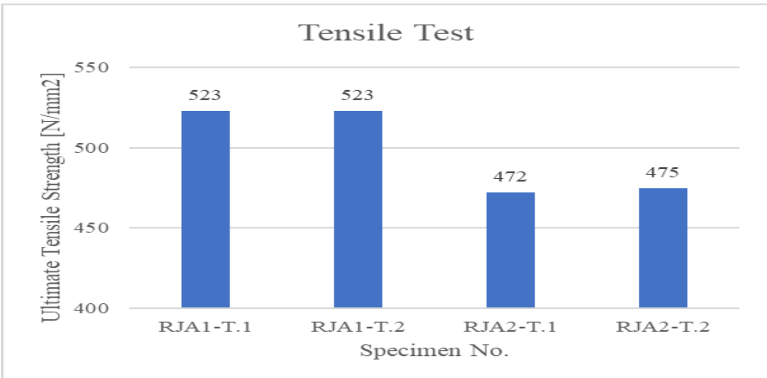

Figure. 11. Graph of Tensile Test Results

TABLE 10.
CORRECTION RESULT FROM TENSILE TEST

Specimens No.	Ultimate Tensile Strength [N/mm^2]	Tensile Strength Criteria [MPa]	Results
RJA1-T.1	523	415 – 550	Accepted
RJA1-T.2	523	415 – 550	Accepted
RJA2-T.1	472	415 – 550	Accepted
RJA2-T.2	475	415 – 550	Accepted

Based on Table 10. The tensile strength value of the test specimen from the pWPS 01 test coupon is higher than the tensile strength value of the test specimen from the pWPS 02 test coupon, where the pWPS 01 test coupon in the working process uses variable preheat and post weld heat treatment (PWHT), so it can be it was decided that pWPS 01 which used preheat and PWHT variables was better than pWPS 02 which did not use preheat and PWHT variables.

However, all test specimens from the pWPS 01 test coupon and pWPS 02 test coupon were declared to have passed the ASTM A 516 grade 60 specifications in the ASME section II part A standard because the tensile strength values of all test specimens were within the scope or range of the tensile strength criteria, namely 415 – 550 MPa.

This also indicates that all the essential variables in pWPS 01 and pWPS 02 have been accepted and can be used as welding procedure specifications (WPS).

3. Correction from Impact Test (Charpy V-Notch)

Because the thickness of the material (test coupon) in this study was 25 mm, according to the requirements in the DNV-GL standard part 5 chapter 7, for materials that have a thickness exceeding 20 mm it is required to carry out a impact testing (charpy v-notch) with the condition of the test specimen at -20°C. Figure 12 shows the impact test specimen. In the Figure 13 shows the impact test results.

Figure. 12. Impact (Charpy V-Notch) Test Specimens

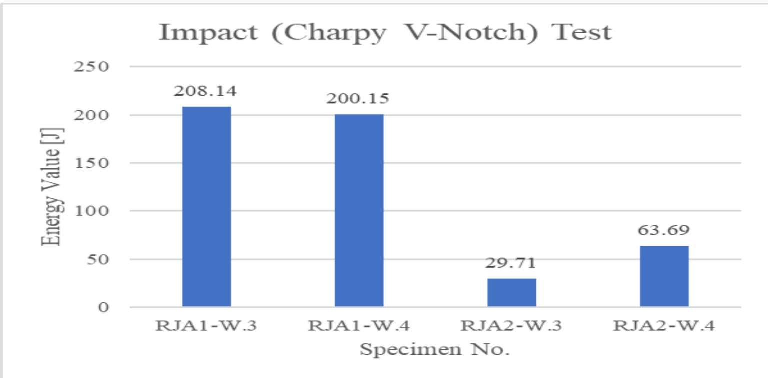

Figure. 13. Graph of Impact (Charpy V-Notch) Test Results

TABLE 11.
CORRECTION RESULT FROM IMPACT TEST (CHARPY V-NOTCH)

Specimens No.	Energy Value [J]	Mean Value [J]	Min. Value Criteria [J]	Results
RJA1-W.3	208.14	205.15	27	Accepted
RJA1-W.4	200.15		27	Accepted
RJA2-W.3	29.71	46.7	27	Accepted
RJA2-W.4	63.69		27	Accepted

Based on Table 11. The energy value that is able to be absorbed by the test specimens from the pWPS 01 test coupon is higher than the energy value that is able to be absorbed by the test specimens from the pWPS 02 test coupon, where the pWPS 01 test coupon in the work process uses variable preheat and post weld heat treatment (PWHT), it can be concluded that pWPS 01 which uses preheat and PWHT variables is better than pWPS 02 which does not use preheat and PWHT variables.

However, all test specimens from the pWPS 01 test coupon and the pWPS 02 test coupon were declared to have passed the criteria in the DNV-GL standard part 5 chapter 7, because the average value of energy that can be absorbed by all test specimens exceeds the average energy value required by standard criteria i.e. 27 J.

This also indicates that ASTM A 516 grade 60 material is worthy of being used as a choice of the many materials in tank construction needs.

IV. CONCLUSION

From the results of the research conducted, the following conclusions were obtained:

1. The results of the bending test showed that welding with the presence of preheat and post weld heat treatment (PWHT) variables or without the presence of preheat and PWHT variables had no effect, because the results of observations from all test specimens of the two test coupons passed (accepted) the criteria. This shows that the welder is competent and qualified.
2. The results of the tensile test show that welding in the presence of preheat and post weld heat treatment (PWHT) variables greatly influences the results of the tensile strength value. Where this value is greater or better than welding without the presence of preheat and PWHT variables.
3. The results of the impact test (charpy impact test) at temperature conditions -20°C as a material requirement rather than an independent tank (spherical) shows that the best energy value is in welding with the presence of preheat and post weld heat treatment (PWHT) variables compared to welding without the presence of preheat and PWHT variables.

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