Effect of Post Weld Heat Treatment on Tensile Strength of ASTM A36 Welded Joints: Application on Hull Vessel Material

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***Abstract*—** In fact, in the welding process, there are many problems that arise. Such as cracking caused by excessive stress Residual stress can result in a decrease in the mechanical properties of a material such as brittle fracture, fatigue, and cracking. The purpose of this study was to determine the comparison of tensile strength in ASTM plate welded joints A36 with variations of single vee butt and single bevel butt and knowing the comparison of the effects ofpost-weldd heat treatment on welded joints with variations of single v butt and single bevel butt joints. The method used in this research is experimental. The results of the data obtained in this study The value of the tensile strength of the Single Bevel Butt joint without the influence of Heat Treatment is 153.87 MPa, the tensile strength of the Single Vee Butt joint without the influence of Heat Treatment is 161.75 MPa and the tensile strength of the seam Single Bevel Butt with the effect of Heat Treatment is 196,65 MPa. The tensile strength of the Single Vee Butt seam with the effect of Heat Treatment is 173,36 MPa.

Keywords—*Welding Joints, Tensile Strength, Post Heat Treatment, Single Bevel Butt, Single Vee Butt*

I. Introduction

Shipbuilding and repairs are generally carried out in a shipyard. The material used in shipbuilding is steel. The steel plate can be divided into two based on the chemical composition contained therein, namely carbon steel and alloy steel. There are various types of carbon steel, including high-carbon steel, medium-carbon, and low-carbon steel. There are several types of steel materials used in the construction of a ship, one of which is ASTM A 36 steel. This material is a type of low-carbon steel because it contains 0,25 – 0,29 % carbon [1].

In the shipbuilding project, the construction and repair of a ship requires a welding process. The welding method that is often used is Shield Metal Arc Welding (SMAW) or also known as shielded metal arc welding. The SMAW welding process uses heat energy to melt the parent material and electrodes [2]. In the connection of welded steel material has an important role in welding. Selection of the type of seam can be based on the thickness of the material used. For materials with a thickness of more than 5 mm, a single bevel butt and single vee butt can be used. This type of seam is often used in shipbuilding with a steel thickness of 12 mm.

But the fact is that in the welding process there are many problems that arise. Such as cracks caused by excessive stress. The welding process will cause an ambient heating effect with a high temperature, causing the metal to experience thermal expansion and shrinkage during cooling. This causes residual stress in the Heat Affected Zone (HAZ). Residual stress is the stress that occurs due to uneven heat energy in the weld area resulting in tensile and compressive forces. Residual stress can result in a decrease in the mechanical properties of a material such as brittle fracture, fatigue and cracking. Therefore, the effect of post weld heat treatment welding joint ASTM A36 Materials on Tensile Strength will be investigated in the present study.

A. Material Test

In the present study, American standard Testing and Material (ASTM) A 36 is a type of steel with a low carbon composition (low carbon steel). The material composition and mechanical properties of ASTM A 36 are given in Table 1 [1].

B. SMAW Welding Process

Shield Metal Arc welding (SMAW) method or also called shielded metal arc welding is a welding process using heat energy to melt the parent material and electrodes. The heat energy generated in the welding process occurs due to a jump of electric ions that occur on the surface of the material to be welded and the electrodes [2]. The welding process on a steel will cause the metal around the weld to experience a rapid thermal cycle, causing deformation, thermal stresses, and changes in properties so that it can affect the strength of the welded joint. The strength of the welded joint can be affected by: the electrodes, the welding procedure, the steel material used, and the type of seam used. SMAW welding wrapped in flux [1]. The welding process can be seen in Figure 1.

SMAW welding generates electric arc heat so that the flux that wraps around the electrode melts and then forms a slag that covers the molten metal at the

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weld joint which functions as a barrier to the oxidation reaction. The base metal that is not affected by heat and the area of the weld metal (welding zone) can be seen in Figure 2.

TABLE 1.
CHEMICAL COMPOSITION OF ASTM A36

Element	Content
Carbon (C) max	0.25 – 0.29% (depending on thickness)
Copper (Cu) min	0.2%
Iron (Fe)	98%
Manganese (Mn) max	1.03%
Phosphorus (P)	0.04%
Silicon (Si)	0.4% max
Sulphur (S) max	0.05%

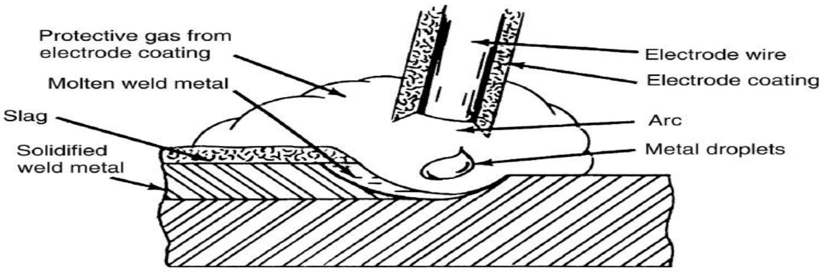

Figure 1. Shielded Metal Arc welding (SMAW) Process [3]

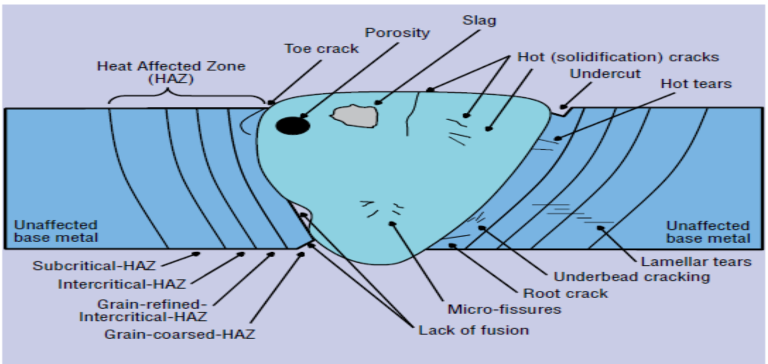

Figure 2. Welding Zone [4]

C. Post Weld Heat Treatment (PWHT)

Post Weld Heat Treatment (PWHT) is a process of applying heat to metal after the welding process. As a result of welding the material undergoes changes in structure and grain caused by uneven heating and cooling. Thus forming a residual stress in a material. So that the material has high hardness but low toughness. So to eliminate residual stress on the material, heat treatment must be carried out with a certain temperature and a certain period of time. Temperature and heating time are determined based on the type of material used. There are several general reasons PWHT is carried out including [2]:

• Reduce residual stresses.
• Reduced hardness in the HAZ and weld areas
• Increase the toughness of the material.
• Removing the hydron from the weld metal.
• Increase tenacity.
•Increase resistance to cracking caused by environmental factors and corrosion.
• Improved dimensional stability during machining.

The steps for the PWHT process are as follows: 1. Prepare the steel material used in the PWHT Process or specimen test objects. 2. Prepare the oven with a certain temperature required by the material (temperature used according to the type of material). 3. Put the material into the oven during the holding time (holding time is used according to the type of material) 4. Once in the oven, cool the material using room temperature. The purpose of PWHT is to obtain the properties needed in construction such as strength, softness, hardness, and toughness and reduce the size of crystal grains [5].

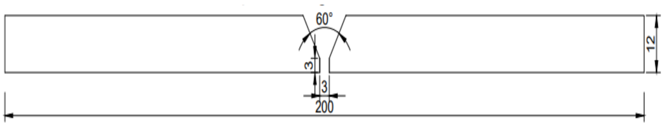

Figure 3. Single Bevel Butt

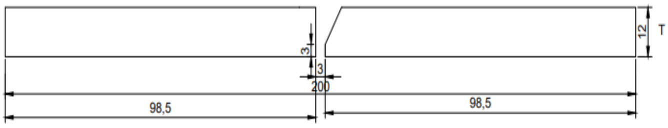

Figure 4. Single Vee But

D. Tensile Test

In the present study, Tensile test is a method used to determine the strength of a material by providing an axial force load. The results obtained in the tensile test are in the form of strength data from the material. Tensile tests are carried out to measure the resistance of a material to a statically applied force slowly. The tensile testing machine consists of a frame, measuring system, pulling system and mechanics.

E.Tensile Test

The weld seam is the base metal to be filled by the weld metal. In selecting the shape of the seam, it is necessary to consider reducing the weld metal to the lowest price and not reducing the quality of the weld joint [6]. Single Vee butt or single V seam is a type of seam that is stronger than square seam. This type of seam can accept large compressive forces and has resistance to static loads [6]. The Single Vee Butt can be seen in Figure 3. Single bevel butt is a welding model single bevel butt is a seam model used in welding with one center line. The Single Bevel Butt can be seen in Figure 4.

Figure 5. ASTM A 36 Plate

Figure. 6. Process of Cutting to Form a Bevel

II. MATERIAL AND METHOD

A. Material Thickness Selection and Measurement

Material selection is done by taking sample plates in the form of pieces of leftover plates in shipbuilding. Plate measurements are carried out to ensure the size of the plate thickness is in accordance with the desired plate thickness in the study. The ASTM A 36 material can be seen in Figure 5.

B. Material Process of Forming Bevel Angle Used for Welding Process

ASTM A36 plate pieces are placed on a flat plane before the bevel angle is formed. Formation of the bevel angle using the Semi-Automatic Cutting Torch tool. Before the bevel formation is carried out on the semi-automatic cutting torch machine, do the settings on the tool to form an angle of 30°. After that, turn on the semi-automatic cutting torch machine until it finishes forming a 30° tilt angle. Then smooth the surface of the cut using a grinding machine. The process of bevel formation can be seen in Figure 6.

C. Single Vee Butt Welding Process

In the single vee butt welding process, it begins with an adjustment according to the G size or the welding distance used. The distance G used is 3 mm. then the welding current is set to 119-140 amperes. The welding process is carried out by root and viler. Then do the cleaning on the rest of the welding (Flug). Then do the grinding on the side that you want to do the next welding with the Root and Viler welding process and clean the rest of the welding by refinishing. Do this method repeatedly until the workpiece is completely welded. The Single Vee Butt welding results can be seen in Figure 7.

Figure. 7. Single Vee Butt Welding Results

Figure. 8. Single Bevel Butt Welding Results

D. Single Bevel Butt Welding Process

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E. NDT Process (Penetrant Test)

The penetrant test process is a non-destructive test. This test is carried out to see cracks in the welding results that have been carried out. Checking on the welding results of the test object begins with cleaning the Haz area by spraying cleaner on the Haz area and then wiping it with a cloth until it is clean. After the test object is cleaned, spray the penetrant evenly on the Haz area and let sit for 5 to 10 minutes. Then clean the area that has been sprayed with penetrant liquid using a cloth, after being wiped clean the Haz area again by spraying cleaner liquid and then wiping. After cleaning, spray the developer liquid evenly on the Haz area and let it sit for about 5 minutes. If there is a red rickshaw after spraying the developer liquid, then there is a crack or the results of the welds that have been done are less than perfect, so it is necessary to re-weld so that the area that has cracks can be covered and the test object can be continued at the stage of making the specimen shape for a tensile test. The spraying process of penetrant test can be seen in Figure 9.

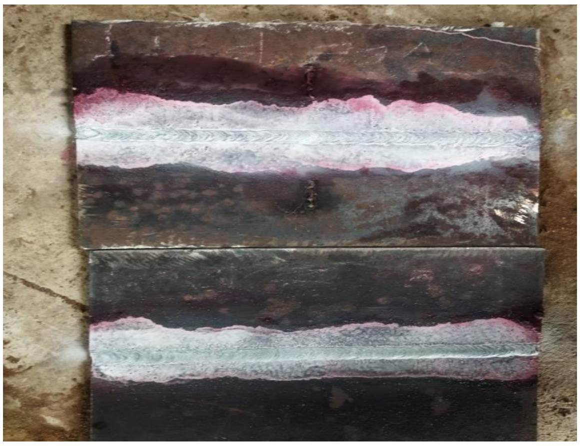

Figure. 9. Spraying Process Using Developer

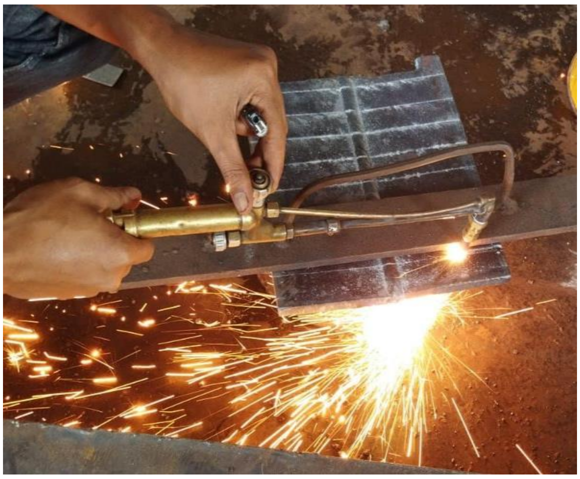

Figure. 10. Workpiece Cutting Process

F. Cutting Test Item

Before making the specimen, the plate that has been done with NDT is cut using a cutting tourch with a length of 220 mm and a width of 26 mm. while for the main sizes needed in the manufacture of test specimens using length (L) 200 mm, area A 50 mm, area B 57 mm, width (C) 20 mm, thickness (T) 12 mm and a radius of 12.5 mm. The process of cutting the test object can be seen in Figure 10.

G. Process of Post Weld Heat Treatment

The initial process carried out in the Heat Treatment process is by setting up the furnace or furnace. The settings made are by turning on the on button then setting the preheating temperature to 30° with a holding time of 60 minutes after that set the heating temperature to 660° with a holding time of 60 minutes. Then put the specimen into the furnace and then close the furnace. After clicking the start button. Then wait for the heating to finish. After heating is complete, turn off the furnace by pressing the off button then remove the specimen from the combustion furnace using tongs to go to the next process stage, namely the cooling process. The post weld heat treatment process is shown in Figure 11.

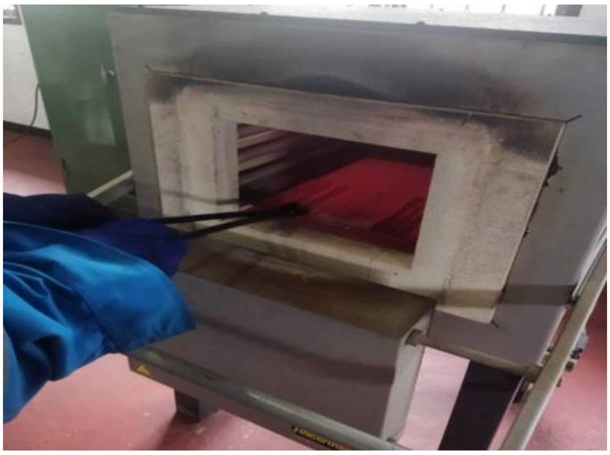

Figure. 11. Process of Post Weld Heat Treatment

a. without heat treatment   b. with heat treatment

Figure.12. Specimen Test

Figure. 13. Specimen Mounting and Tensile Test

a. without heat treatment

b. with heat treatment

Figure. 14. Final Results of Tensile Test

H. Tensile Test

Tensile testing is carried out on the specimen to obtain the value of the tensile strength on the specimen that has been tested. There are 12 test specimens were prepared. The test specimens can be seen in Figure 12.

Attach the test specimen to the two-clamping vise on the tensile tester and tighten the specimen on the two vises until it is firmly clamped. The process of installing specimens and tensile tests can be seen in Figure 13, and the results of the tensile test is shown in Figure 14, the All specimens were tested on a regular basis experimentally does not break in the weld area as it was shown in the previous studies [7][8][2].

III. RESULTS AND DISCUSSION

A. Tensile Strength Result of Single Bevel Butt

The Tensile testing was carried out at the Integrated Latest samples. Tensile testing was carried out in the Integrated Lab Building of the Kalimantan Institute of Technology with a total of 12 tensile test samples. The results of this test data are obtained in the form of a softfile sent via email which is processed into a graph. The data obtained on the Single Bevel Butt tensile test sample without the influence of Heat Treatment after the tensile test is carried out. From the data that has been obtained, a graph of the relationship between stress and strain is made on the Single Bevel Butt sample without the influence of Heat Treatment. The graph of the relationship between stress and strain on the Single Bevel Butt sample without the influence of Heat Treatment can be seen in Figure 15.

The data obtained on the sample with a variation of Single Bevel Butt with the influence of Heat Treatment from the tensile test data. From the tensile test data obtained, the graph of the relationship between stress and strain for the Single Bevel Butt sample was processed with the influence of Heat Treatment. The graph of the relationship between stress and strain Single Bevel Butt with the influence of Heat Treatment can be seen in Figure 16.

B. Tensile Strength Result of Vee Butt

From the tensile test data obtained, the graph of the relationship between stress and strain was processed for the Single Vee Butt variation sample without the influence of Heat Treatment. The graph of the relationship between stress and strain variations of Single Vee Butt without the influence of Heat Treatment can be seen in Figure 17.

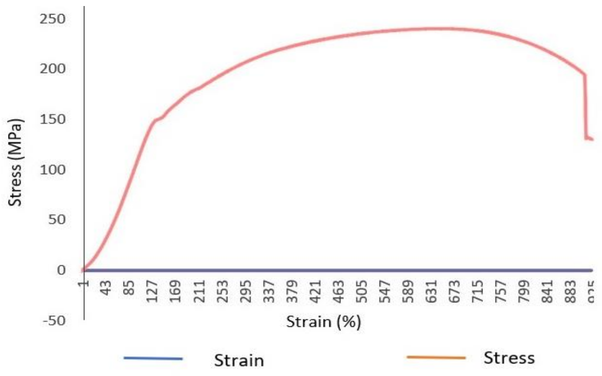

Figure 15. Single Bevel Butt Stress and Strain Without Heat Treatment

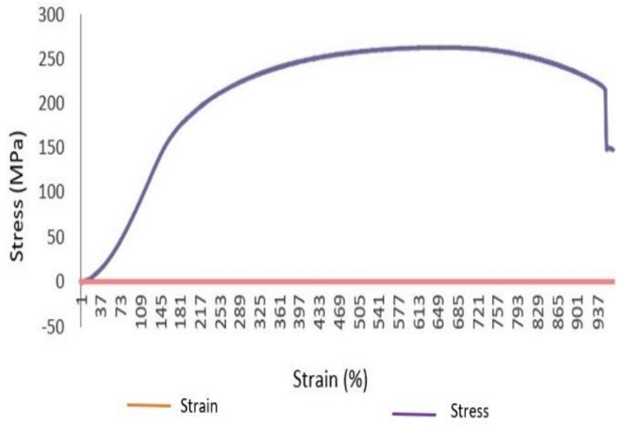

Figure 16. Single Bevel Butt Stress and Strain with Heat Treatment

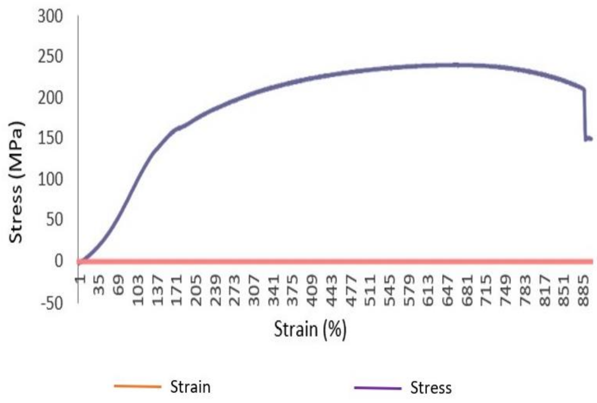

Figure 17. Single Vee Butt Stress and Strain Without Heat Treatment

The data obtained on the sample with the variation of Single Vee Butt with the influence of Heat Treatment from the tensile test data. From the tensile test data obtained, a graph of the relationship between stress and strain was processed for the Single Vee Butt variation sample with the influence of Heat Treatment. The graph of the relationship between stress and strain variation of Single Vee Butt with the influence of Heat Treatment can be seen in Figure 4.38 below:

From the figure of the relationship between stress and strain in the Single Bevel Butt variation with the effect of heat treatment and without the effect of heat treatment, a composite graph can be made from the graph. The purpose of making the composite graph is to compare the stress and strain values of the four graphs. The graph of the combined relationship between stress and strain in the Single Bevel Butt variation without the influence of Heat Treatment and with the influence of Heat Treatment can be seen in Figure 19 and Figure 20.

From Figure 19 and 20, it can be seen that the average strain value of the Single Bevel Butt without the influence of Heat Treatment is 0.0152947 %, the Single Vee Butt without the influence of Heat Treatment is 0.017295767%, and in the Single Bevel Butt seam with Heat Treatment is 0.0216907 %, on Single Vee Butt with Heat treatment it is 0.016496667.

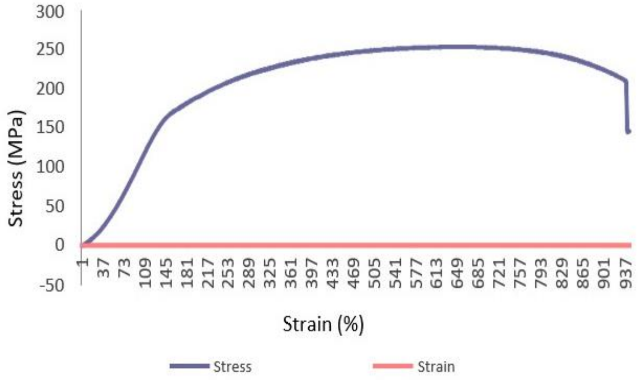

Figure 18. Single Vee Butt Stress and Strain With Heat Treatment

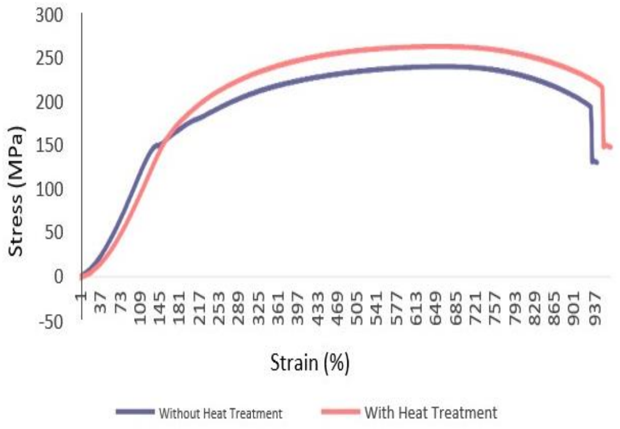

Figure 19. Combined Stress and Strain of Single Bevel Butt with and without the effect of heat treatment

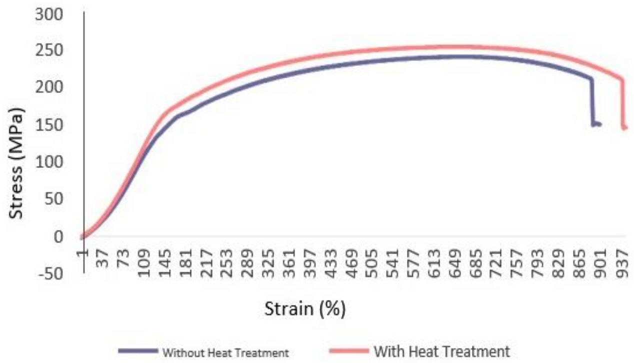

Figure 20. Combined Stress and Strain Single Vee Butt with and without the effect of heat treatment

The average stress value on the Single Bevel Butt seam without the influence of Heat Treatment is 153.8687978 MPa, the Single Vee Butt seam without the influence of Heat Treatment is 161.7463474 MPa, and the Single Bevel Butt with the effect of Heat Treatment is 196, 6502738 Mpa, in Kampuh Single Vee Butt with the influence of Heat Treatment is 173.3618009 MPa.

From the tensile test data that has been obtained, it shows that the yield strength value of the welded joint does not exist because the welding process is good, causing the sample in the HAZ area to not break. This can happen because the Haz area has high strength than the base metal area. From the elongation data that has been obtained from the test results, it is known that there is no significant change in the weld joint area. This is due to the good value of the strength of the welded joints so that the test sample does not break in the weld area.

IV. CONCLUSIONS

The value of the tensile strength of the Single Bevel Butt without the influence of Heat Treatment is 153.8687978 MPa, the tensile strength of the Single Vee Butt seam without the influence of Heat Treatment is 161.7463474 MPa The effect on the strength of the welded joint of Single Bevel Butt and Single Vee Butt can be seen from the strain value. The value of the tensile strain on the Single Bevel Butt seam without the influence of Heat Treatment is 0.0152947 %. The break area in the test sample occurs in the base metal region. This is due to a good weld joint so that the strength value of the weld joint is higher than the base metal area. the tensile strength of the Single Bevel Butt seam with the effect of Heat Treatment is 196,6502738 Mpa. The tensile strength of the Single Vee Butt joint with the effect of Heat Treatment is 173,3618009 MPa. The effect on the strength of Single Bevel Butt and Single Vee Butt welded joints can be seen from the strain value. The value of the strain in tension on the Single Bevel Butt seam with the effect of Heat Treatment is 0.02169067%, the value of the strain on the tension on the Single Vee Butt seam with the effect of Heat Treatment is 0.016496667 %. The break area in the test sample occurs in the base metal region. This is because the weld joint.

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