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Experimental Test of Tensile Strength of Barge Deck Plate Welded Joints

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Abstract

American Standard Testing and Material (ASTM) A36 is a low carbon steel, and commonly used as material of shipbuilding. Joining of steel can cause decreasing of its strength. The purpose of this study was to determine the tensile strength of joints of ASTM A36, consisting of square butt, single bevel butt, and single vee butt joints. The research methode is experimental. The specimens are made of steel for the ship's decks, which are connected using three types of joints. Each type of connection involves as many as three specimens, so there are a total of nine specimens. Before the tensile test is carried out, the specimen is subjected to a penetrant test to detect weld defects. It was detected that the specimen had broken off at the weld joint. The experiment result shows that the strongest joint from tensile strength point of view is single vee butt joint (198.80 MPa), followed by single bevel butt joint (182.19 MPa) and, square butt joint (168.51 MPa).

Keywords: Joint strength, Electrodes, Welding, Tensile strength, Experiment

1. Introduction

American standard Testing and Material (ASTM) A36 is a steel with a carbon composition ranging from 0.25% – 0.29%. ASTM A36 can also be called a type of low carbon steel [1]. In the construction or repair of a ship, welding has an important role in combining one material with another. In the shipbuilding industry, the most widely used welding method is the Shield Metal Arc Welding (SMAW) method. SMAW welding is a welding process using covered electrodes. Before welding, it is necessary to make seams of the material. The seam has an important role in welding. Based on the International Association Of Classification Societies (IACS) for plates with a thickness of ≤ 5 mm using Square butt seam type, Single bevel butt with a thickness of > 5 mm, and Single vee butt with a thickness of > 19 mm [2].

In general, the shipyards in Samarinda, East Kalimantan do not pay attention on welding-seam in ship construction and repairing process. Shipyards in Samarinda mostly use butt joints in the construction and repair of typical barges of 300 feet length [3]. Barges are detected using a 10 mm plate above the deck, which according to IACS standards should have used single vee butt welding, which has better tensile strength [4] [2]. From this problem, it is necessary to prove the strength of the welded joints commonly used in the Samarinda shipyard and which are in accordance with the standards recommended by IACS based on plate thickness [2]. Material composition and mechanical properties of ASTM A36 steel can be seen in Table 1 and Table 2.

Table 1. Material composition of tensile testing specimens. Source:[5]

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%
Phosporus (P)	0.04%
Silicon (Si)	0.4% maximum
Syifur (S) max	0.05%

Table 2. Mechanical properties of ASTM A36 steel. Source:[6]

Material Properties	Metric
Tensile Strenght, Ultimate	400-550 MPa
Tensile Strenght, Yield	250 MPa
Elongation at Break (in 200 mm)	20.00%
Elongation at Break (in 50 mm)	23.00%
Modulus of Elasticity	200 Gpa
Bulk Modulus	140 GPa
Possions Ratio	0.26
Shear Modulus	79.3 GPa

The tensile strength of ASTM A36 is greater the SS400. ASTM A36 material is tougher, so it is suitable for use as a material for structural designs that require greater tensile strength. In addition ASTM 36 steel can be also applied as girder or beam supporting with the determination the appropriate sections dimensions [7]. The weld seam is part of the base metal which will be filled with weld metal, the initial weld seam is in the form of a weld joint which is then filled with weld metal. Welded joints using seam grooves are categorized into blunt joints. A butt joint is the most efficient type of joint. Square butt or square seams can be made in closed or open seam positions. Generally this design is used on thin metals. Single bevel butt is a seam welding model used in welding with one center boundary. 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 [8]. The type of weld is shown in Figure 1.

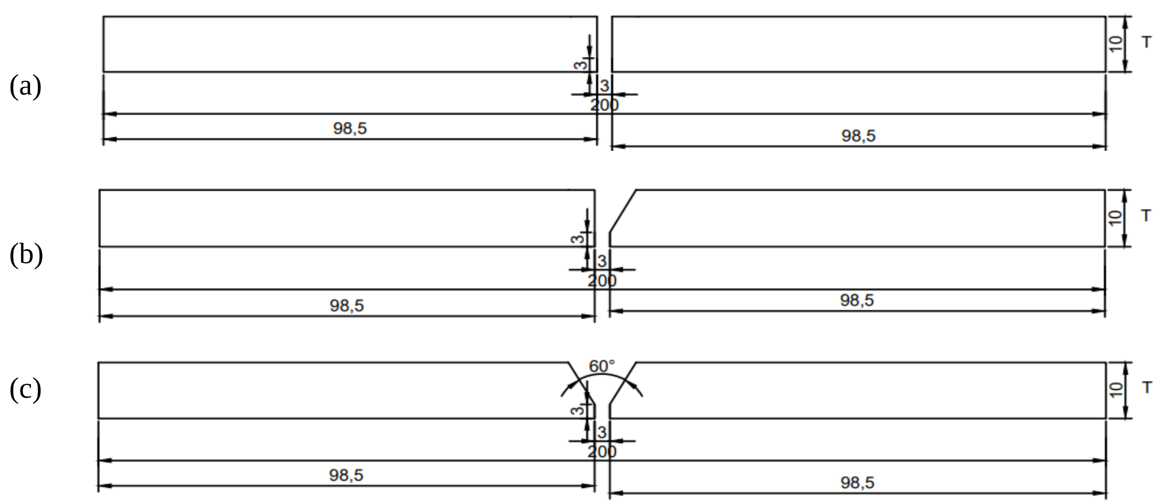


Figure 1. a. square butt; b. single bevel butt; c. single vee butt, Source: [9]

Welding is a method of joining metals by melting some of the seed metal and filler metal with or without extra metal and creating a continuous welded joint [10]. SMAW (Shielded Metal Arc Welding) welding method by melting the base material using heat from electricity between metal covers (electrodes). SMAW is manual work with equipment including power sources, electrode cables, work cables, electrode holders, work clamps, and electrodes. Electrodes and work systems are part of an electrical circuit. The circuit starts with the power supply and cables including welding, electrode holders, workpiece connections, workpieces (Weldment), and welding electrodes [11]. The principle of SMAW welding itself is that when the tip of the electrode is brought close to the seed metal, an electric arc will form which will generate heat.

This heat melts the end of the electrode (welding wire) and the local activity material, with the presence of this melting the weld seam will be filled with molten metal originating from the electrode and seed metal, forming a molten crater, which continues to solidify until weld metal and slag occur (slags)[12]. The most basic concepts in the mechanics of materials are stresses and strains. This concept can be illustrated in its most basic form by considering a prismatic rod subjected to an axial force. A prismatic member is a straight structural element having a constant cross-section throughout its length, and an axial force is a load that has the same direction as the element axis, resulting in tension or compression on the member [13]. The type of weld joint will affect the tensile strength of the welded joint [4].

2. Methods

Data collection was carried out by conducting a tensile test experiment with nine specimens, consisting of three for square butt joints, three for single bevel butt joints, and three for single vee butt joints. The dimensions and shape of the specimen are made according to the ASTM E8 standard [14]. Figure 2 and Table 3 shows the dimensions and shape of the specimen. The research was conducted in several stages. First, data were collected from various related reference sources regarding welded joints and tensile tests. Furthermore, Specimens are made of the same steel material used for barge deck plates. The connection of the plates uses three types of welded joints. Each type of welded joint was made of three specimens. Total specimens: 9 pcs. The results of the welded joints on the specimens were given a penetrant test treatment, which aims to detect welding defects that may occur. To shape the specimens, plate cutters and grinders are used to ensure proper specimen dimensions and smooth surfaces.

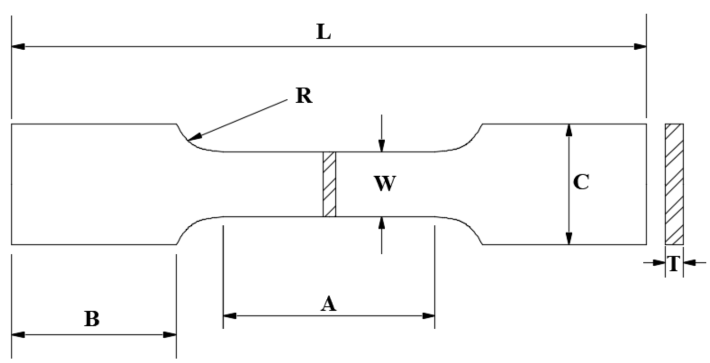


Figure 2. The specimen test of shape. source : [3]

Table 3 Dimensions of Tensile Test Specimens.

Initial	Dimension (mm)
Length of reduced section (A)	57
Width (W)	12.5
Thickness (T)	10
Radius of fillet (R)	12.5
Overall length (L)	200
Width of grip section (C)	20

Then the tensile test process is carried out on the specimen using a tensile testing machine, which is the out put of the machine is the strain for every stress till the specimen is broken. At this final stage, data processing is carried out from the values and graphs that have been obtained in the tensile test by providing conclusions and suggestions in this study. In preparing the specimens, several tools are used in the process of forming specimens. Here are same tools and materials needed: 1. ASTM A36 of sheet plate Steel; 2. Electrode E6013; 3.NDT kit (Cleaner, Developer, Penetrant); 4.grinding; 5. Cutting Tors; 6. SMAW Welding Tools 7. Frais machine; 8.Tensile Testing Machine.

Plate measurement is carried out to ensure the plate thickness matches the desired plate thickness. Forming malls using cardboard media that is adjusted to a predetermined size ASTM A36 plate pieces are placed on a flat plane before forming the bevel angle. Using a milling machine to create the bevel angleBefore forming the bevel on the milling machine, settings are made on the tool to form a 30° slope angle. Then smooth the surface of the cut using a grinding machine.

In the welding process for square butt, single bevel butt, and single vee butt joints, it is started by setting it according to the G size or the welding distance used. The distance G used is 3 mm, and the welding current is set from 115 to 140 amperes. In welding, root and arc processes are carried out. After that, the remaining welding (flug) is cleaned with a steel brush.Then do the grinding on the side that you want to do further welding on with the root and fillet welding process, and clean up the rest of the welding using the steel brush. This activity is practiced repeatedly until the workpiece is completely welded.

The penetrant test process is one of the non-destructive tests. This test is performed to determine whether there are any cracks in the welded results. Checking the results of the welds of the test object begins with cleaning the hazard area by spraying liquid cleaner on the area and then wiping it clean with a cloth. Allow the test object to stand for 5-10 minutes after being sprayed evenly with penetrant liquid on the hazardous area. Then clean the area that has been sprayed with penetrant liquid using a cloth; after that, clean the Haz area again by spraying liquid cleaner on it and then wiping it down. After cleaning, spray the developer liquid evenly on the hazard area and let it sit for about 5 minutes. If there are red spots after spraying the developer liquid, then there are welding defects or imperfect welds, so it is necessary to re-weld so that the areas with weld defects can be covered and the difference test can be continued at the stage of making the specimen form for the tensile test.

The object used in this final project is the connection of ASTM A36 steel plate with SMAW welding method and using E6013 electrode with variations of square butt, single bevel butt and single vee butt on ASTM A36 material as well as analyzing tensile test strength with tensile testing tools or machines. ASTM A36 composition based on plate thickness is shown in Table 4.

Table 4: Steel composition. source : [15]

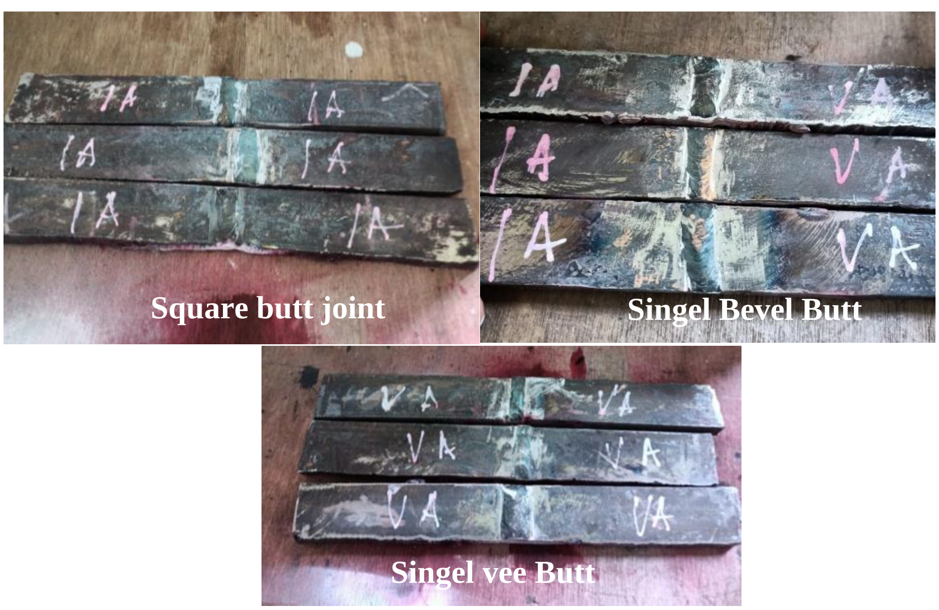
Composition (%)	Plate thickness(mm)				
	20	20 - 40	40 - 65	65 – 100	> 100
carbon (C), max	0.25	0.25	0.26	0.27	0.29
Manganese (Mn)	…	…	0.18-1.20	0.08-1.20	0.08-1.20
Phosphorus (P), max	0.04	0.04	0.04	0.04	0.04
Sulfur (S), max	0.05	0.05	0.05	0.05	0.05
Silicon (Si)	0.04 max	0.04 max	0.15 – 0.40	0.15 – 0.40	0.15 – 0.40
Copper (Cu), if specified	0.2	0.2	0.2	0.2	0.2

The following is the welding data made according to the standard Welding Procedure Specification (WPS) [2] which is the parameter for the welder: a. material specification ASTM A36 with plate thickness 10 mm; b. welding position is 1G; c. welding corner is 30°. Tensile testing was carried out for 9 samples with 3 samples each for each variation of the type of seam. The welded joints on the specimens were given a penetrant test treatment, in order to detect welding defects that may occur so it is necessary to re-weld so that the areas with weld defects can be covered and the difference test can be continued at the stage of making the specimen form for the tensile test. To shape the specimens, plate cutters and grinders are used to ensure proper specimen dimensions and smooth surfaces. The dimensions of the specimen are then dissected using calipers to conform to ASTM E8 standards. If there are deviations in the form of excess dimensions, they will be refined using sandpaper and a grinder. Conversely, when a lack of dimensions is found, the specimen is made from scratch again.

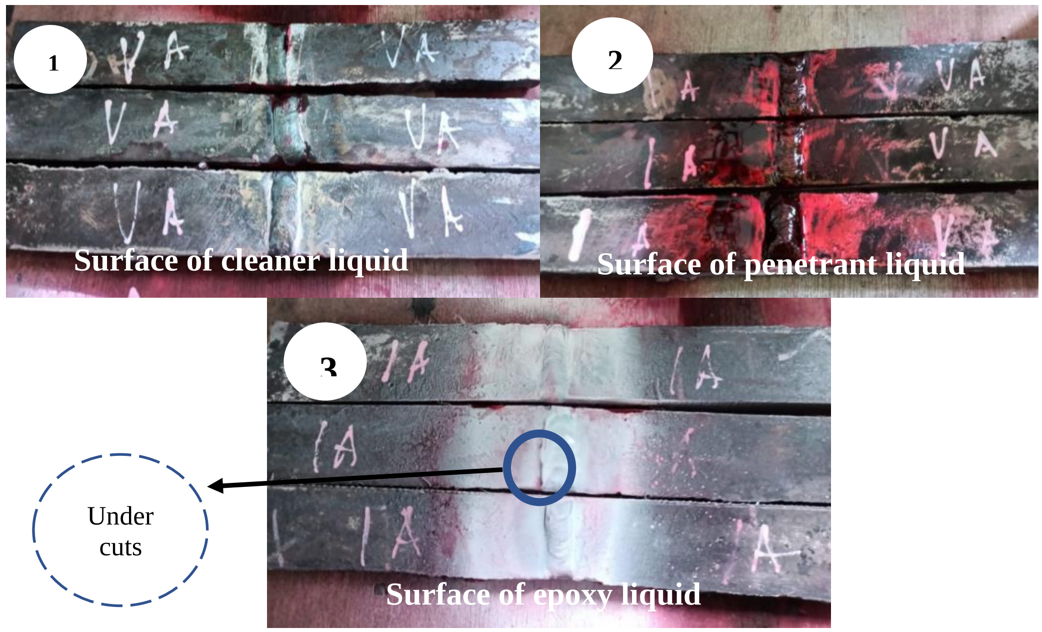
3. Results and Discussion

3.1. Specimen Tensile Test

The test object that was previously made according to the design in the image above is subjected to a tensile test. Tensile testing is carried out to obtain the value of the stress-strain relationship of the test object. Specimens of the test material before and after finishing are shown in Figure 3.



(a)



(b)

Figure 3 a. All types of weld joints; b. penetrant test proccess of specimen

The process of forming specimens using a milling machine cutting on important parts so that they can match the dimensions of the specimen, which refer to the ASTM E8 standard. The cutting process in the Width of Grip section (C) is carried out by means of a milling cutter touching the surface of the specimen bit by bit. The cutting process in the area of the length of the reduced section (A) is carried out with the direction of the worktable in the vertical direction. The cutting process in the Radius of Fillet (R) area begins with measuring the angle of inclination using a bow, then making a line according to the direction of the angle of inclination on the arc, and then setting the lathe according to the angle of inclination required. In Area R, the incision is made using a lathe. The final step is to use a milling machine to cut in the overall length (L) area. 10 mm cuts were made on each side. The tensile test specimens for each of the welded joints. Three specimens were made for each type of welded joint. All specimens have been adjusted to the standard size used as a reference in testing. Checking is done by measuring the specimen using a vernier caliper. The surface of the specimen is smoothed with sandpaper and grinding. The specimen has undergone a penetrant test to detect welding defects that may occur.

3.2. Tensile Test Results

In this tensile test, the results obtained in the form of raw data in the form of soft files to be processed into graphics. This test was carried out on 3 types of seam variations with 3 samples each. The results of testing each variation can be seen in comparison through the existing graph. The stress-strain curve of the variation of the square butt seam can be seen in the following this figure the results of the average yield strength value of 183.34 MPa, ultimate strength average value of 259.54 MPa, fracture strength average value of 187.36 MPa, and Young's modulus average value of 165.20 MPa. This value is obtained from the results of testing in the laboratory using a tensile testing machine connected to a computer.

The data obtained in the sample with variations of Single Bevel Butt can be seen in the results of the Single Bevel Butt tensile test data. From the data obtained, a graph of the relationship between stress and strain can be made for the Single Bevel Butt variation sample. The results obtained in the form of a yield strength average value of 202.80 MPa, average ultimate strength 265.94 MPa, average fracture strength 212.48 MPa, and average of modulus young 181.53 MPa.

The data obtained in the sample with variations of Single Vee Butt can be seen in the results of the tensile test data of Single Vee Butt. From the data obtained, a graph of the relationship between stress and strain for the Single Vee Butt variation sample can be made. The results of the single vee butt tensile test value, the results are obtained in the form of a average yield strength value of 227.38 MPa, average ultimate strength 296.35 MPa, average fracture strength 197.26 MPa, and average modulus young 212.39 MPa. From the test results it was found that the single vee butt joint is the strongest connection compared to the square butt joint and single bevel. This can happen because the single vee butt has a welded joint that allows deep penetration or penetration of the weld. From the graph of the relationship between stress and strain with variations of Square Butt, Single Bevel Butt and Single Vee Butt. Then a combined graph can be made from the three graphs, the purpose of making the combined graph is to compare the stress and strain values of the three variations of Square Butt, Single Bevel Butt and Single Vee Butt joints. The combined stress-strain graph of the three variations of Square Butt, Single Bevel Butt and Single Vee Butt can be seen in Figure 4.

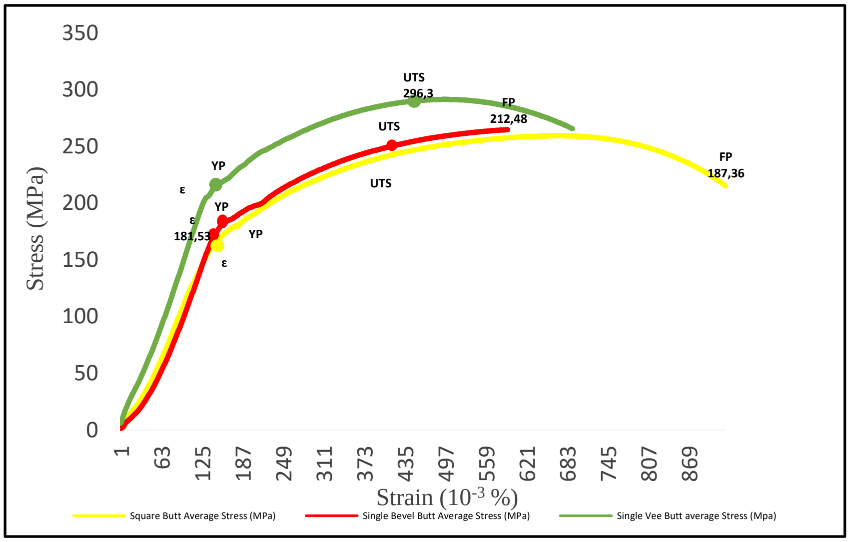


Figure 4. The combined stress-strain graph of each variation of the seam.

Figure 4 shows that the strongest connection in terms of tensile strength is the single vee butt joint (198.80 MPa), followed by the single bevel butt joint (182.19 MPa), and the square butt joint (168.51 MPa). The tensile test result curve also shows very interesting information, which detects that a square butt joint is more ductile than a single bevel joint. This could be related to the amount of heat absorbed by each type of connection. Square-butt joints have a higher heat absorption, which has implications for the ductility of the joints. This is in line with previous research that shows heat treatment of welded joints will increase ductility [16][17]. The test results also show that the value of the mechanical properties of the test specimen is very far from the strength of the base material. This is because the specimen breaks at the weld joint and does not break at the base material. There is a significant difference between the test results and the inherent mechanical properties of the base material.

Another result found in the tensile test was that the yield strength decreased significantly (about 22%) compared to the base metal. The use of proper current strength during the welding process will significantly affect the increase in yield strength [18]. so that the reduction in yield strength in the test results is thought to be due to inappropriate welding current strength. Likewise, the ultimate strength is significantly reduced (around 26%) compared to the base metal, and this is directly proportional to the reduction in the yield strength of the specimen [10]. This phenomenon can occur allegedly because the welding is not so perfect; visually, it looks fine, but when the penetrant test is carried out, there are several undercuts that make it difficult to do the welding. Even when using SMAW welding, the skill of the operator also determines the results of the welding. If the specimen breaks during the welding, the weld joint test is declared failed.

Successful tests should ideally degrade to the base material. In future research, the use of the appropriate welding current will be adjusted, the addition of the NDT procedure will be added to the penetrant test, and a radiographic test will also be carried out before the test so that the results obtained are more valid, which has implications for the study's conclusions.

4. Conclusions

The type of joint affects the tensile strength caused by the amount of filler metal in each joint. The strongest connection in terms of tensile strength is the single vee butt joint, followed by the single bevel butt joint and the square butt joint. It has been demonstrated that the type of connection can also affect the ductility of the material, which is influenced by the heat absorption capacity of each joint. Square butt joints show a higher ductility value than other joints. This shows that the square butt joint has a high heat absorption capacity compared to other types of joints. It was detected that the specimen had broken off at the weld joint.

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