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The Influence of The Distance Between The SS 304 Steel Base Material And The Welding Electrode In Shilded Metal Arc Welding SMAW on Mechanical Properties

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Abstract - One of the parts of manufacturing science is Shilded Metal Arc Welding (SMAW). This type of welding is most widely used in the industrial world because almost all steel can be welded or joined using Shilded Metal Arc Welding (SMAW). Because of the importance of strong and quality welding results, it is necessary to carry out research. This research was carried out with tensile tests on welded specimens with the aim of determining the mechanical properties of SS 304 steel in Shilded Metal Arc Welding using NSN 308 electrodes, welding current of 100 Ampere, distance between seams of 2 mm and distance between the anode and the base material of 0.5 mm. , 1 mm, 1.5 mm and 2 mm. From the discussion of the data it can be concluded that welding with a distance of 0.5 to 1 mm is more perfect and the weld results are more unified in the HAZ area and can be seen in the tensile test results of 652.11 N/mm, yield stress of 854.29 N/mm and strain 27%. Meanwhile, the distance between the anode and the base material of 1.5 to 2 mm is less able to fill the weld area and can be seen from the tensile test results of 362.95 N/mm, yield stress of 563 N/mm and strain of 16%. Thus, the position of the welding distance between the base material and the electrode is very influential in determining good and tough weld results.

Keywords : SMAW Welding, Electrodes, SS304 Steel, Base Material, Stress and Strain.

1. INTRODUCTION

Welding is the joining of two or more metal materials based on the principles of the diffusion process, resulting in the joining of the parts of the materials being joined. The advantages of welded joints are that they are light in construction, can withstand high forces, are easy to implement, and are quite economical. However, the most important weakness is the change in the microstructure of the material being welded, resulting in changes in the physical and mechanical properties of the material being welded.

The development of metal welding technology makes it easier for humans to carry out their lives. Currently, scientific advances in the field of electronics through research that looks at the characteristics of atoms, have made a huge contribution to the discovery of new materials and also how to connect them. Long ago, metal joining was done by heating two pieces of metal and joining them together. The fused metals are known as fusion. Electric welding is one that uses this principle.

Nowadays, heating of the metal to be joined comes from burning gas or electric current. Several gases can be used, but the most popular is Acetylene gas, better known as carbide gas. During welding, Acetylene gas is mixed with pure Oxygen gas. The combination of this gas mixture produces the highest heat among other gas mixtures. Another method that is mainly used to heat the metal being welded is electric current. Electric current is generated by a generator and flows through a cable to a device that clamps an electrode at the end, which is a metal bar that can conduct electricity well. When an electric current is applied, the electrode is touched to the workpiece and then pulled back slightly, the electric current continues to flow through the narrow gap between the tip of the electrode and the workpiece. This flowing current is called an arc which can melt metal.

Sometimes the two metals being joined can be fused directly, but sometimes other additional materials are still needed so that the weld metal deposit forms properly, these materials are called additional materials (filler metal). Filler metal is usually in the form of rods, so it is usually called a welding rod. In the welding process, the welding rod is immersed in liquid metal which is collected in a basin called the welding pool and together they form a deposit of weld metal, this method is called Electric Welding or SMAW (Shielded metal Arch welding).

Currently, iron and steel are materials commonly used in everyday life. Thus, the steel that is most widely used by humans for their survival needs is Stel 304 stainless steel, which is one of the most commonly used types of stainless steel in the world. Its popularity is driven by its versatile, durable and corrosion-resistant properties. The chemical compositionof 304 stainless steel consists of chromium, nickel and manganese. This combination produces a material that is strong, resistant to rust and corrosion, and easy to clean. These properties make it ideal for a wide range of applications, from kitchen utensils and food equipment to building construction and industrial equipment. Stainless steel 304 also has good heat resistance so it can be used at high temperatures. Another advantage of stainless steel 304 is that it is easy to shape and process. This material can be welded, cut and bent easily, allowing for a variety of uses and functionalities. 304 stainless steel has an attractive and modern appearance, making it an ideal material for a variety of decorative applications, such as architecture, interior design and tableware. With these things, the industrial world needs to think about how to process them into finished materials that can be used directly, one of which is by welding manufacturing.

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2. LITERATURE REVIEW

2.1 Welding

Welding is a technique for joining metals by partially melting the base metal and filler metal with or without pressure. Welding is defined by DIN (*Deutsche IndustrieNormen*) as metallurgical bonding in metal or metal alloy joints which is carried out in a melted or liquid state. In other words, welding is a process of joining metals together due to heat or without the influence of pressure or it can also be defined as a metallurgical bond created by the attractive forces between metals. Welding is an activity of joining two or more parts of an object by heating or pressing or a combination of the two in such a way that they come together like a complete object. Connections can be made with or without additional materials (*filler metal*) with the same or different melting point and structure.

The welding procedure seems very simple, but actually there are many problems that must be overcome, the solution of which requires a variety of knowledge. Therefore, in welding, knowledge must accompany practice, in more detail it can be said that the design of building construction and machines with welded joints, must also be planned regarding welding methods. This method examines the welding material and type of welding that will be used, based on the function of the parts of the building or machine being designed.

2.2 SMAW (Shilded Metal Arc Welding)

The welding process is one of the material joining processes. As for the definition of the welding process which refers to the AWS (*American Welding Society*), the welding process is the process of joining metal or non-metal which produces one unified part, by heating the material to be joined to a certain welding temperature, with or without pressure. , and with or without filler metal. Although the welding process method is not only a joining process, but can also be a cutting and brazing process. Welding processes are divided into several types, and SMAW is one of the welding processes that is commonly used, especially for short welding in production, maintenance and repair, and for the construction sector. SMAW (*Shielded Metal Arc Welding*) is a welding process by melting the base material using heat from electricity between metal covers (*electrodes*).

The SMAW welding process, which is generally called electric welding, is a welding process that can use heat to melt the base material and electrode. This heat is generated by electrical ion jumps that occur between the cathode and anode (the tip of the electrode and the surface of the plate to be welded). The heat that arises from this electric ion jump can reach 4000°C. There are two types of voltage sources used, namely AC electrical welding current (*alternating current*) and DC electric current (*direct current*). The process of welding occurs due to contact between the tip of the electrode and the base material so that a short circuit occurs and when the short circuit occurs the welder must pull the electrode so that an electric arc is formed, namely ion jumps that generate heat. The heat will melt the electrode and base material so that the electrode liquid and base material will combine to form weld metal. To produce a good and constant welding arc, the welder must keep the distance between the tip of the electrode and the surface of the base material the same. The best distance is the same as the diameter of the electrode used. The amount of heat or temperature (H) that can melt some materials is the product of the electric voltage (E) with the current strength (I) and time (t) which is expressed in joule heat units as in the formula below:

$$H = \mathrm{E} \times \mathrm{I} \times \mathrm{t}$$

Where :
H: Heat (*Joules*)
E: Electrical Voltage (*Volts*)
I: Current Strength (*Ampere*)
t: Time (*Seconds*)

2.3 Welding Electrodes

Electrodes and fillers are two important materials used in welding. The electrode is the material used to create an electric arc, while the filler is the material used to fill the gap between the two metals being welded. The function of the electrode is to create an electric arc, channel electric current and add weld metal while filler is to fill the gap between the two metals being welded, increasing the strength of the weld and improving the properties of the weld.

The selection of welding electrodes is very important for the welding process because it determines the strength, weld results, and also spatter production. Electrodes or welding wire are not only a technical element, but also a critical aspect in achieving optimal welding results. Electrodes should be stored in a dry place and removed carefully from their packaging. If the electrode is wet and not good, dry it first with a drying oven to maintain the quality of the electrode.

Type NSN 308-16 electrode is an electrode used specifically for welding stainless steel materials with specifications:

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Table 1. Specifications

CODE	DESCRIPTION
E	Arc Electrode
30	Minimum Tensile Strength 13 Tons
8	Stainless Steel Friends
16	TiO and K2O Flux Content and DCRP/AC Current

2.3 Welding Area

The weld area consists of 3 parts, namely the weld metal, the Heat Affected Zone (*HAZ*) heat influence area, and the base metal which is not affected. Weld metal is a part of the metal that melts and then solidifies during welding. HAZ is the base metal adjacent to the weld metal which during the welding process experiences a rapid heating and cooling thermal cycle. Unaffected base metal is the part of the base metal where the heat and welding temperature do not cause changes in structure and properties. Apart from these three main divisions, there is still one special area that delimits the weld metal and the area affected by heat, which is called the weld boundary. In discussing the thermal cycle of the weld area, things that need to be discussed include the freezing process, the reactions that occur and the microstructure that is formed, each of which is discussed separately.

2.3 Steel

Steel is an alloy of iron (Fe) and carbon (C) with a maximum carbon content of 1.7%. An alloy of iron and carbon with a carbon content of 1.7% to 3.5% is called cast iron. Cast iron is steel that has low carbon content (Indiyanto, 2005). Iron and steel are the materials most widely used in industry.

Carbon steel consists of iron and carbon. Based on carbon content, this steel is divided into three types, namely:

a. Mild Carbon Steel
   Mild carbon steel is steel that contains 0.10 – 0.25%C. This steel has high toughness and ductility, is easy to shape and weld, so it can be used as raw material for making car body components, building structures, gas pedals, brakes, fences and so on. Mild carbon steel is steel that contains 0.10 – 0.25%C. This steel has high toughness and ductility, is easy to shape and weld, so it can be used as raw material for making car body components, building structures, gas pedals, brakes, fences and so on.
b. Medium carbon steel
   Medium carbon steel is steel that contains 0.20 – 0.50% C. Medium carbon steel has higher hardness and tensile strength than mild carbon steel. This type of steel is usually used as raw material for making agricultural tools such as hoes, shovels and forks.
c. High carbon steel
   High carbon steel contains 0.5 – 1.7%C. High carbon steel has low ductility, heat resistance and high tensile strength so it is widely used as a material for equipment or mechanical equipment (Fox, 1979).
d. Stainless steel (StainleesStell)
   Stainless steel is a high alloy steel with a chromium element content of at least 10%, so it has corrosion resistant properties. Apart from the element chromium, there are other additional elements, namely Ni, Mo, Mn, Al, Cu, Ti, C, and Nb (Yunaidi, 2016). Each element has an influence in the high temperature oxidation process. The oxidation process will produce FeO, Fe3O4, Fe2O3, Cr2O3, and CrO compounds (Bandriyana et al., 2004).
e. Stainless steel SS 304
   Austenitic stainless steel type 304 is an alloy steel with a Cr content of 18 – 20%, and Ni 8 – 10.5% (Roberge, 2000). This type of steel is commonly used as the main construction material in several industries such as the nuclear, chemical and food industries. This steel has good corrosion resistance because there is a layer of chromium oxide on its surface (Riszki and Harmami, 2015). The corrosion resistance of SS-304 will decrease if it is continuously immersed in acid solutions or sea water. The longer the steel is immersed in a corrosive medium, the corrosion rate will decrease (Iliyasu et al., 2012). SS-304 is a steel that has a low hardness level of around 123 HB and a tensile strength of 505 N/mm2 (Nasir, 2014). Table 2.2 shows the chemical element composition of SS-304 steel.

2.6 Tensile test

Welded metal can be subjected to destructive testing and non-destructive testing. Destructive testing can be carried out with mechanical tests to determine the strength of the welded metal joints, one of which can be a standardized tensile test. The tensile strength of welded joints is greatly influenced by the nature of the parent metal, the HAZ area, the properties of the weld metal, and the geometry and stress distribution in the joint. To carry out a tensile test, a tensile rod is needed. Tensile bars, with normalized sizes, are machined from the specimen to be tested. The tensile test is one of several tests that are commonly used to determine the mechanical properties of a material. In its simplest form, the tensile test is carried out by clamping both ends of the tensile test specimen to the tensile test load frame. The tensile force on the tensile test specimen is applied by a tensile testing machine

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(Universal Testing Machine) which causes the test specimen to elongate and fracture. In testing, the test specimen is loaded with increasing load little by little until the test specimen breaks, then the tensile properties can be calculated using the equation:

$$\sigma_1 = \frac{F}{A_0}$$

Where :
σ_1 : Voltage(N/mm^2)
F : Force (N)
A_0 : Initial area(mm^2)

$$\varepsilon = \frac{L - L_0}{L_0} \times 100\%$$

Where :
ε : Strain
L : Initial length of test rod(mm)
L_0 : Length of Test Bar under load(mm)

Tensile testing of a material can be carried out using a universal testing machine. The test specimen is clamped in a tensile testing machine, then the static load is increased gradually until the specimen breaks. The magnitude of the load and the increase in length are connected directly with the plotter, so that stress (Mpa) and strain (%) graphs are obtained which provide data information in the form of yield stress (σys), ultimate stress (σult), modulus of elasticity of the material (E), toughness and ductility of the welded joint. tensile tested.

3. RESULTS AND DISCUSSION

This research begins with the preparation of materials and tools as well as the formation of new specimens through welding and tensile tests.

a. Making specimen shapes according to ASTW E8 standards

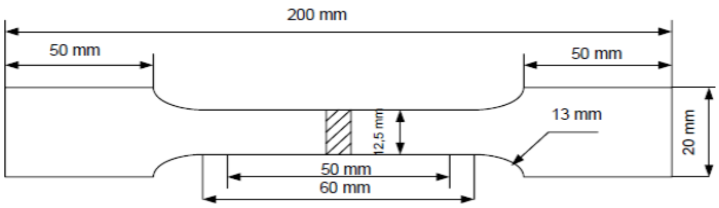
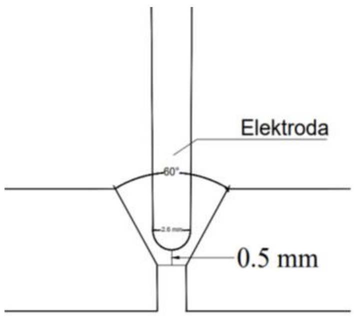


Figure 1. :Standard Specimen ASTM E8

b. Welding method
The welding method used in making specimens is as follows:
1. Welding in a flat position.
2. The type of electrode used is NSN 308-16.
3. The electric current used is 100 A.
4. The seam used is a V seam with a distance between specimens of 2 mm and a seam angle of 60°.
5. Determine the distance for specimen one starting from 0.5 mm – 2 mm.



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c. Welding process
1. Prepare the SMAW welding machine according to installation.
2. Set the ammeter used to measure current to the position where the needle is at zero, then clip one of the clamps to the cable used to clamp the electrode. The welding machine is turned on and the electrode is moved until the needle on the ammeter shows 100 A.
3. Prepare the workpiece to be welded on the welding table. Welding position using a horizontal position or under the hand, according to the research variables the electrode position must be above the material as far as 0.5 mm, 1 mm, 1.5 mm, 2 m

d. Tensile test process
The strength and elasticity values of the test material can be seen from the tensile test curve. In tensile testing, the test rod is loaded with increasing load little by little until the test rod breaks. The series of testing processes are as follows:
1. Measure the diameter and area of the specimen.
2. Enter the measured specimen data into the computer.
3. Turn on the tensile testing machine.
4. Open the clamping head and position the specimen.
5. Clamp the specimen into the clamping head.
6. Turn on the tensile testing machine.
7. Long withdrawal until the specimen breaks.
8. The drawing curve will appear on the tensile stress and strain monitor screen.
9. Turn off the tensile testing machine.
10. Remove the specimen that has been tested from the clamp (Clamping Head).
11. Record the change in Length after the Tensile test
12. Continue to the next specimen

4. RESULTS AND DISCUSSION

a.* Tensile Stress *(Tensile Streght).

Test data was obtained in four test variations, namely welding with a distance of 0.5 mm, welding with a distance of 1 mm, welding with a distance of 01.5 mm, welding with a distance of 2 mm. The results of this test can be seen in the following table:

Table.2.Tensile Stress Value (σ_u)

Number	Specimen	Tensile Stress (σ_u)
1	Distance 0,5 mm	652,11 N/mm^2
2	Distance1 mm	598,07 N/mm^2
3	Distance 1,5 mm	588,96 N/mm^2
4	Distance 2 mm	362,95 N/mm^2

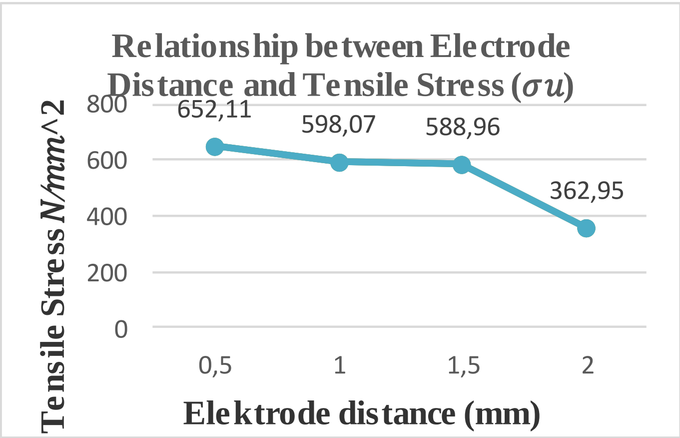

Figure 2.Tensile Stress Graph (σu)

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b. Yield Streght

Test data was obtained in four test variations, namely welding with a distance of 0.5 mm, welding with a distance of 1 mm, welding with a distance of 01.5 mm, welding with a distance of 2 mm. The results of this test can be seen in the following table:

Table.3.Yield Stress Value(σ_y)

Number	Specimen	Yield Stress(σ_y)
1	Distance 0,5 mm	854,29 N/mm^2
2	Distance 1 mm	956,51 N/mm^2
3	Distance 1,5 mm	890,50 N/mm^2
4	Distance 2 mm	563,01 N/mm^2

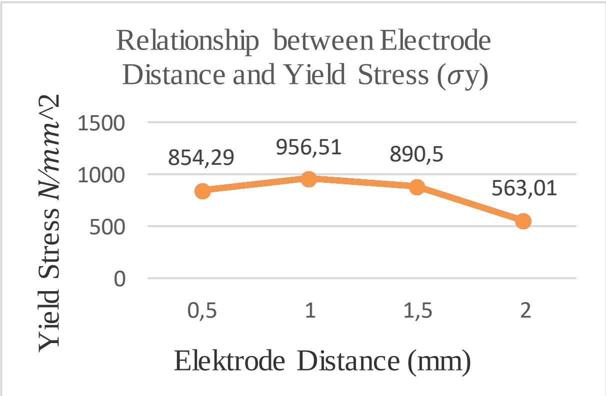

Figure.3..Yield Stress Graph(σ_y)

c. Strain (Elongation)

Test data was obtained in four test variations, namely welding with a distance of 0.5 mm, welding with a distance of 1 mm, welding with a distance of 01.5 mm, welding with a distance of 2 mm. The results of this test can be seen in the following table:

Table.4.. Strain Value (e)

Number	Specimen	Strain (e)
1	Distance 0,5 mm	27,61%
2	Distance 1 mm	43,71%
3	Distance 1,5 mm	33,57%
4	Distance 2 mm	16,24%

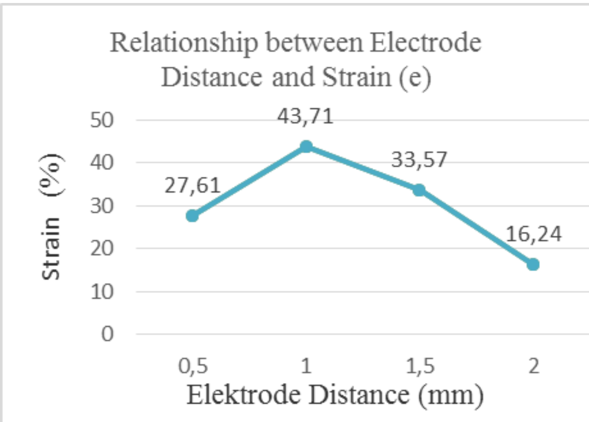

Figure.4..Strain Graph (e)

The first test is a tensile test for a distance variation of 0.5. The tensile strength, yield stress and elongation values for stainless steel quality have the greatest values among the variations in welding distance. At 100 Amperes, the current that occurs is enough to turn on the welding arc and melt the material. The heat generated is sufficient to melt the electrode and material and maximum penetration occurs. In tensile testing for weld quality, this group has

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the highest tensile strength value among other variation groups. The largest yield stress value in welding varies with a distance of 1 mm compared to other variables. for the largest strain value in welding with a distance of 1 mm, for variable distances of 1.5 mm and 2 mm, it appears that there is still an empty gap in the weld area because at the fracture resulting from the tensile test there is a cavity in the weld, unlike the variable distance of 0.5 mm and 1mm .

5. CONCLUSION

From the results of research conducted on Shilded Metal Arc Welding (SMAW) welding on SS 304 steel with a welding current of 100 Ampere using NSN 308 electrodes with a welding distance between the electrode and the base material of 0.5 mm, 1 mm, 1.5 mm and 2 mm After carrying out the tensile test it was concluded that:

1. Welding with a distance of 0.5 – 1 mm is very effective where the bond between the filler metal and the base material is more unified in the HAZ area, with a tensile stress value of 652.11 N/mm, yield stress of 854.29 N/mm and strain: 27 %.
2. Meanwhile, welding with a distance of 1.5 – 2 mm is less effective where the bond between the filler metal and the base material is less unified in the HAZ area, with tensile stress values of 362.95 N/mm, yield stress of 563.01 N/mm, and strain 16%.

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