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THE INFLUENCE OF CURRENT STRENGTH ON THE TOUGHNESS OF JOINTS IN THE ELECTRODE ELECTRIC ARC WELDING PROCESS WRAPPED (SMAW) AISI 4340 STEEL

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ABSTRACT

The development of advanced construction technology cannot be separated from welding, as it plays an important role in constructing and repairing metal structures. At present, the construction of metal structures involves a lot of welding elements, especially in the field of good quality design. Based on the background, the problem can be formulated, namely, the effect of current strength on strength of Aisi 4340 steel joints after SMAW welding treatment. The research method used is the impact test method to see the results of the influence of strong currents in steel joints. The results of this study are the value of impact toughness at a current variation of 80 Ampere, the first specimen is 0.56080 J/mm2, the second specimen is 0.54811 J/mm2, and the third is 0.51724 J/mm2. The impact toughness value at 95 amps variation of the first sample is 0.01869 J/mm2, the second is 0.05481 J/mm2, and the third is 0.05172 J/mm2. From the test data, it can be seen that the average value of the average impact toughness in the variation of current strength of 80 Ampere and 95 Ampere is 80 Ampere current average impact toughness value of 0.54205 J/mm2 and 95 Ampere current average impact toughness value of 0.04174 J/m2. That the 80 ampere current variation is better and more efficient because it produces a higher toughness value than the 95 ampere current variation.

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1. INTRODUCTION

The development of technology in the field of construction that is increasingly advanced cannot be separated from welding because it has an important role in metal engineering and repair. The construction of construction with metal at this time involves many elements of welding, especially in the field of design because the welding connection is one of the connections that technically requires high skills for the welders to obtain a good quality connection. Welding is a metal joining technique by melting some of the parent metal and filler metal with or without metal enhancers and producing continuous metal.

The scope of use of welding techniques in construction is very broad, including shipping, bridges, steel frames, pressure vessels, transportation facilities, rails, pipelines and so on. For industries involving metal or steel, especially in the field of development using welding, various studies are needed in order to obtain high quality welding joints, because it concerns safety and service life. Along with the increasing use of steel welding joints, process technology related to changes in properties and characteristics has an equally important role.

Factors affecting welding are welding procedures, namely a plan for conducting research which includes how to make welding construction according to plans and specifications by determining all the things needed in the implementation. Welding production factors are the manufacturing schedule, manufacturing process, necessary tools and materials, sequence of implementation, welding preparation (including: selection of welding machines, appointment of welders, selection of electrodes, use of camphor types).

Welding based on the classification of work methods can be divided into three groups, namely liquid welding, press welding and soldering. Liquid welding is a welding method in which the object to be joined is heated until it melts with a heat energy source. The most widely used welding method is liquid welding with arc (electric arc welding) and gas. There are 4 types of electric arc welding, namely arc welding with wrapped electrodes, gas arc welding (TIG, MIG, CO2 arc welding), arc welding without gas, submerged arc welding. One type of wrapped electrode arc welding is SMAW welding (Shielding Metal Arc Welding).

SMAW welding machines according to the current can be divided into three types, namely Direct Current (DC) welding machines, Alternating Current (AC) welding machines and dual current welding machines which are welding machines that can be used for welding with direct current (DC) and welding with alternating current (AC). DC current welding machines can be used in two ways, namely straight polarity and reverse polarity. Straight polarity DC welding machines (DC) are used when the melting point of the parent material is high and the capacity is large, for the electrode holder is connected to the negative pole and the parent metal is connected to the positive pole, while for reverse polarity DC welding machines (DC +) are used when the melting point of the parent material is low and the capacity is small, for the electrode holder is connected to the positive pole and the parent metal is connected to the negative pole. Not all metals have good weldability. Materials that have good weldability include low carbon steel. These steels can be welded with wrapped electrode arc welding, submerged arc welding and MIG welding (precious gas metal welding). Low carbon steels are commonly used for thin plates and general construction.

In addition to construction, welding can also be used to weld metal defects in metal castings, thicken worn ones (Wiryosumarto and Okumura; 2004). In simple terms, it can be interpreted that welding is the process of joining two metals to the point of metal recrystallization, whether using added materials or not and using heat energy as a melter of welded materials. The definition of welding according to Widharto (2003) is one way to connect solid objects by melting them through heating.

Based on the definition of Deutche Industrie Normen (DIN), welding is a metallurgical bond in metal or metal alloy joints carried out in a molten or liquid state. Wiryosumarto and Okumura (2004) state that welding is the local connection of several metal rods using heat energy. The joining of two metals together is done by heating or melting, where the two ends of the metal to be joined are made molten or melted with a flame arc or heat obtained from an electric arc flame (gas burner) so that the two ends or metal fields are strong and not easily separated. Of all the types of welding, only two types are the most popular in Indonesia, namely welding using Carbide Welding (Oxyfuel gas welding) and electric arc welding.

The welding electrode, which is covered with flux, melts during the welding process after receiving electrical input. This is what causes the formation of gas and slag that protects the welding arc and molten weld pool from the surrounding air impurities (referred to as arc flame). The flux will also provide advantages such as functioning as a deoxidizer while also providing an alloying effect on the weld metal thus strengthening the weld metal. Electric arc is a continuous current of electrons flowing through a short medium between two electrodes (+ and -) known by the occurrence of heat energy and radiation of air or gas between the electrodes will be ionized by electrons emitted by the cathode. Two factors affect the emission of electrons:

1. Temperature
2. Electric field strength

To cause an arc, the two electrodes are short-circuited by touching first (arc starting) and on the part in contact this will occur heating (temperature rises), this encourages an arc. The electric arc that occurs between the ends of the electrodes is the multiplication of the electric voltage (E) with the current strength (I) and time (t) expressed in units of joule heat, or calories as the formula below:

$$\boldsymbol{H = ExIxt}$$

Welding current is the amount of flow or electric current coming out of the welding machine. The size of the welding current can be adjusted with the tools on the welding machine. Welding current must be adjusted to the type of material and the diameter of the electrode used in welding. The use of a current that is too small

will result in low penetration or penetration of the weld, while a current that is too large will result in the formation of a weld bead that is too wide and deformation in welding.
Welding using electric arc welding requires a welding wire (electrode) consisting of a core made of a metal coated by a layer made of a mixture of chemicals, in addition to functioning as a generator, the electrode is also an added material.
The electrode consists of two types of parts, namely the coated (flux) and uncoated parts which are the base for clipping the welding pliers. The function of flux or electrode coating in welding is to protect molten metal from the air environment to produce protective gas, stabilize the arc, source of alloy elements. Basically, when viewed from the metal being welded, the electrode wire can be divided into electrodes for soft steel, high carbon steel, alloy steel, cast iron, and non-ferrous metals. Electrode material must have similar properties to metal.

Electrode selection in welding medium carbon steel and high carbon steel must be carefully considered if the weld strength is required to be equal to the strength of the material. The classification of electrodes is based on the AWS (American Welding Society) and ASTM (American Society Testing Material) standard systems. E6013 electrodes can be used in all welding positions with AC and DC welding currents. Electrodes with the E6013 code for each letter and each number have their respective meanings, namely:
E = Electrode for electric arc welding.
60 = Stating the minimum tensile stress value of the welding result multiplied by 1000 Psi (60,000 Ib/in2) or 42 kg/mm2.
1 = States the welding position, 1 means it can be used for welding all positions.
3 = Rutile-Calium electrode membrane type and welding with AC or DC current.
The metal will experience the effect of heating due to welding and experience changes in the microstructure around the weld area. The shape of the microstructure depends on the highest temperature reached during welding, the welding speed and the cooling rate of the weld area. The area of metal that undergoes changes in microstructure due to heating due to welding is called the heat affected zone (DPP), or Heat Affected Zone.
To produce good quality welding joints, one of the factors that must be considered is the weld seam. This welding camp is useful for accommodating filler material so that more of it adheres to the workpiece, thus the strength of the weld will be guaranteed. The factors that must be considered in choosing the type of camphor are:
1. Workpiece thickness.
2. Type of workpiece.
3. Desired strength.
4. Welding position.

Before starting the welding process, first determine the type of welding joint to be selected. Things that must be considered that the connection made will be able to accept loads (static loads, dynamic loads, or both).

With the possibility of providing several welding joint loads, there are several types of welding joints, namely as follows:

1. Single V Seam. This connection is also stronger than a square connection, and can be used to receive large compressive forces, and is more resistant to static and dynamic load conditions. In plates 5mm-20 mm thick, 100% penetration can be achieved.
2. Square Gap. This connection can be made into 2 possibilities, namely closed connection and open connection. This connection is strong for static loads but not strong for bending loads.
3. Double V Seam. This connection is stronger than a single V, is very good for static and dynamic load conditions and can keep changes in the shape of the curve as small as possible. used in thicknesses of 18 mm-30 mm.
4. Single Tapered Seam. This joint is used for large compressive loads. It is better than a square joint, but not better than a V joint. It is recommended to be open and used in plate thicknesses of 6 mm-20 mm.
5. Single U Seam. This joint is stronger to accept static loads and is required for high quality joints. It is used in thicknesses of 12 mm-25 mm.

6. Double U Seam. Double U joints can also be made closed and open, this joint is stronger to accept static and dynamic loads with a plate thickness of 12 mm-25 mm, 100% penetration can be achieved.
7. Double J Seam. Double J joints are used for the same purposes as double V joints, but are no better for receiving loads. This joint can be made closed or open.

Steel is one of the ferrous metals that is widely used in engineering and industry. Steel consists of iron and carbon content, where the iron (Fe) content in steel is around 97% and carbon (C) is around 0.2% to 2.1% by weight according to the grade. The carbon content in steel is generally not more than 1% carbon (C). In addition to iron (Fe) and carbon (C), steel also contains other mixed elements such as manganese (Mn) with a maximum content of 1.65%, silicon (Si) with a maximum content of 0.6%, copper (Cu) with a maximum content of 0.6%, sulfur (S), phosphorus (P) and others with limited and different amounts.

The impact testing machine is used to determine the impact price of a material caused by a shock force on the test material. The types and forms of construction of impact testing machines range from conventional types to more advanced digital systems. In static loading there can also be a high rate of deformation if the material is notched, the sharper the notch the greater the deformation concentrated at the notch, which allows increasing the strain rate several times, brittle fracture becomes an important problem in steel and iron.

Charpy impact testing is widely used to determine the quality of materials. V-shaped notch test specimens that have 2 mm notches are widely used. The surface of the test specimen in charpy impact is done smoothly on all surfaces. The charpy impact testing machine is shown in the figure below. In this test, the test rod is notched or grooved and disconnected with one blow (cracking speed and shape change speed).

2. RESEARCH METHOD

This research was conducted at the Mechanical Engineering Laboratory of Medan State Polytechnic. At this stage, the materials and tools needed for testing were prepared. The specimens used in this study were AISI 4340 steel plates with considerations:

1. AISI 4340 steel material is widely used in industries today.
2. The welding process of AISI 4340 steel material requires special skills in the weld process,

Before testing each specimen is cut and formed using a scrap machine so that it complies with the impact test standard, ASTM E-8M. The steps of the specimen forming process:

1. The specimen is cut into 6 parts whose size corresponds to the test requirements

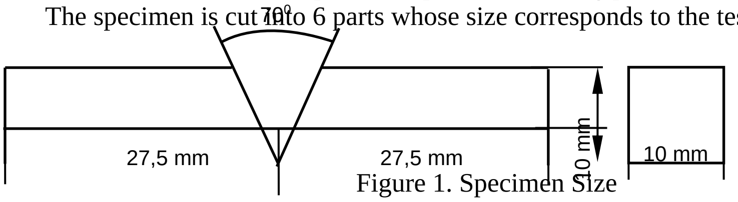


Figure 1. Specimen Size

2. After cutting, the corners are formed and the electrodes are applied. Welding is carried out at the angle of the formed seam using the electric welding process.
3. Cleaning of the specimen from the welding residue was carried out.

Data Collection Techniques with literature studies in the form of literature studies by studying books, journals, articles and related scientific works, both sourced from print, electronic and internet media. Then Interactive Discussion by conducting discussions in the form of questions and answers between students and supervisors regarding matters relating to the manufacturing and testing process and solving problems faced together.

Then Making Test Objects by carrying out the process of making test objects, namely welding on AISI 4340 steel plates. Testing and Data Collection with testing carried out several times and data collection which includes toughness values. After that, the final evaluation is carried out in the form of conclusions and suggestions and revisions of the results of the research process that has been carried out.

3. RESULTS AND DISCUSSIONS

The test results of the material used AISI 4340 steel in the form of plates have the following chemical composition:

Elements	Levels (%)

Carbon ©	0,41
Silikon (Si)	0,24
Sulfur (S)	0,10
Fospor (P)	0,154
Mangan (Mn)	0,78
Nikel (Ni)	1,632
Kromium (Cr)	0,810
Molibdenum (Mo)	0,203
Tembaga (Cu)	0,199
Wolfram (W)	0,009
Timah (Sn)	0,010
Kobalt (Co)	0,012
Alumunium (Al)	0,013
Besi (Fe)	Balance

Tabel 1. Chemical Composition of AISI 4340

In this impact test aims to measure the ductility of a material against a sudden load by measuring the change in potential energy of a pendulum dropped at a certain height. The difference in the height of the pendulum swing is a measure of the energy absorbed by the test object. The amount of energy absorbed is determined by the ductility of a test object. If the impact value is large, it means that the material used is classified as ductile and can experience brittle fracture.

Things that can include the presence of notches, high loading speeds that can cause high strains as well. This impact test was carried out using the Charpy method with an initial beating angle of 140.2º. The results can be seen below.

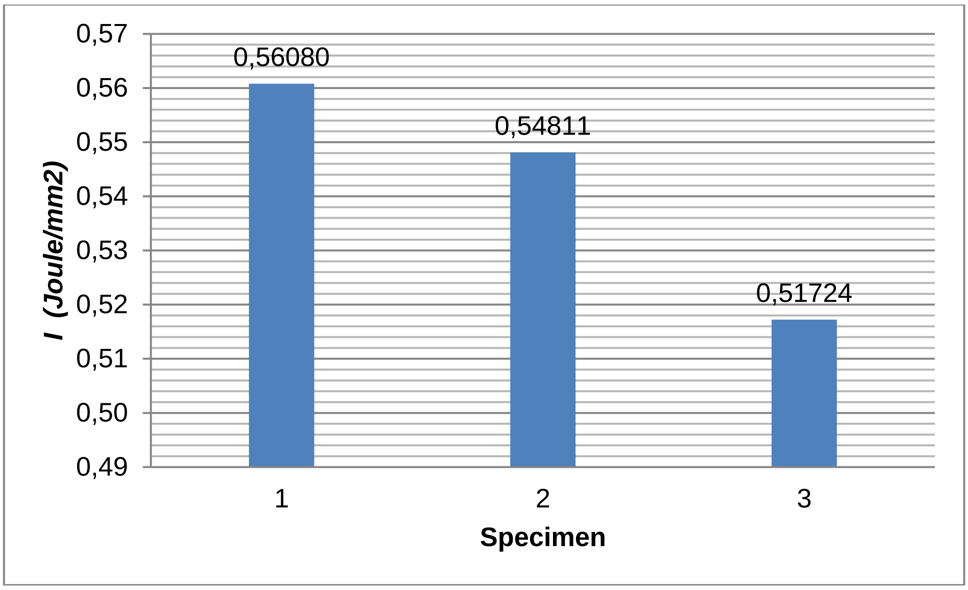
Specimen	Angle α (^{0})	Angle β (^{0})	A (mm)
1	140,2	125	30
2	140,2	125,1	30
3	140,2	126,7	30

Tabel 2. Impact Testing Results With a Current Strength of 80 A

Specimen	Diameter Electrode (mm)	A (mm^2)	h2 (m/s)	v2 (m/s)	E Joule	I (J /mm^2)	Ïavg (J /mm^2)
1	2,6	100	1,1775	2,6491	56,0805	0,56080	0.54205
2			1,1812	2,6532	54,8114	0,54811	
3			1,1902	2,6633	51,7244	0,51724	

Tabel 3. Impact Calculation Result 80 Ampere

From the table above, it can be seen that the impact toughness value in the first specimen is 0.56080 J/mm2, the impact toughness value in the second specimen is 0.54811 J/mm2, and the impact toughness value in the third specimen is 0.51724 J/mm2. While the average impact toughness value of the specimens is 0.54205 J/mm2.



Graphic 1. Graph of Impact Test Result Value with 80 Ampere Current Strength

From the graph above, it can be seen that the highest impact toughness value is found in the first specimen which is 0.560805J/mm2 and the smallest in the second specimen which is 0.51724J/mm2.

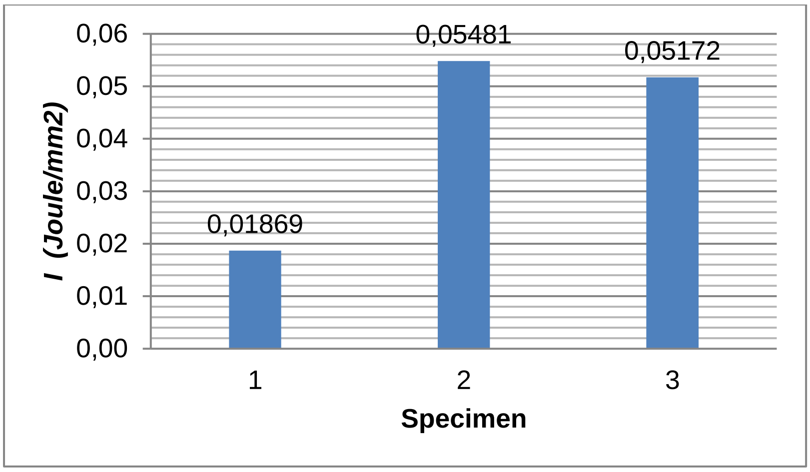
Specimen	Angle α (^{0})	Angle β (^{0})	A (mm)
1	140,2	128,2	100
2	140,2	125,7	100
3	140,2	124,4	100

Tabel 4. Impact Testing Results with a Current Strength of 95 Amperes

Spesi-men	Diameter Elektroda (mm)	A (mm^2)	h2 (m/s)	v2 (m/s)	E Joule	I (J/mm^2)	$\bar{I}_{rata-rata}$ (J/mm^2)
1			1,1105	4,6653	56,0805	0,01869	
2	2,6	100	0,0677	1,1519	54,8114	0,05481	0,04174
3			0,8676	4,1237	51,7244	0,05172	

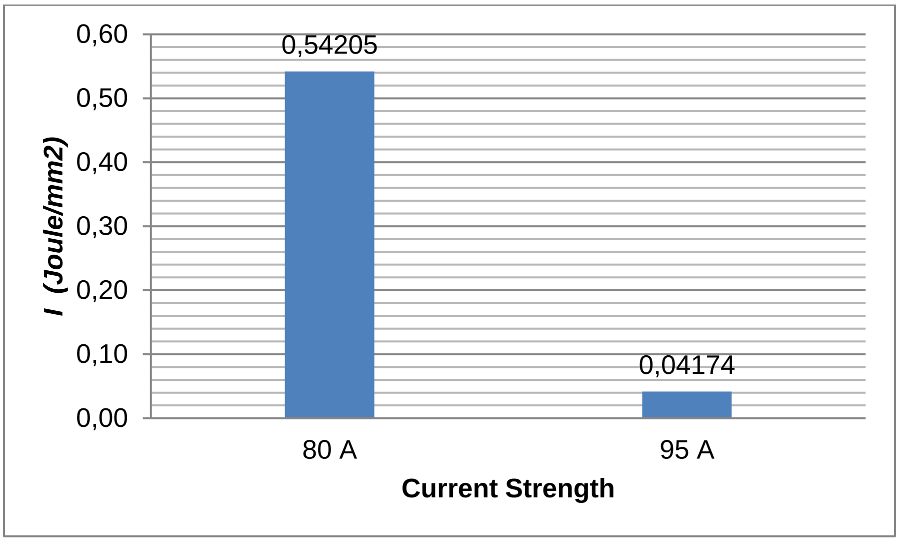
Tabel 5. Impact Data Calculation Results Strong Current 95 Ampere

From the table above, it can be seen that the impact toughness value in the first specimen is 0.01869 J/mm2, the impact toughness value in the second specimen is 0.05481 J/mm2, and the impact toughness value in the third specimen is 0.05172 J/mm2. While the average impact toughness value of the specimens was 0.04174 J/mm2. The average impact toughness value at a current of 95 Ampere can be seen in the following graph



Graphic 2. Graph of Impact Test Result Value95 Ampere

From the graph above, it can be seen that the highest impact toughness value is found in the second specimen which is 0.05481J/mm2 and the smallest in the first specimen which is 0.01869 J/mm2.



Graphic 3. Average Impact Toughness Value of Current Strength 80 Ampere and 95 Ampere

From the test data it can be seen that the average value of the average impact toughness on the variation of current strength of 80 Ampere and 95 Ampere is 80 Ampere current impact toughness value of 0.54205 J/mm2 and 95 Ampere current impact toughness value is 0.04174 J/mm2.

This shows that the 80 Ampere current variation is better and more efficient because it produces a higher toughness value than the 95 Ampere current.

So that in this test shows the value of 80 Ampere current with RB 26 type wrapped electrode electric welding the welding connection process is good and produces higher tensile toughness than the 95 Ampere electric current variation on AISI 4340 steel.

4. CONCLUSION

The results of this study are the value of impact toughness at a current variation of 80 Ampere, the first specimen is 0.56080 J/mm2, the second specimen is 0.54811 J/mm2, and the third is 0.51724 J/mm2. The impact toughness value at 95 amps variation of the first sample is 0.01869 J/mm2, the second is 0.05481 J/mm2, and the third is 0.05172 J/mm2. From the test data, it can be seen that the average value of the average impact toughness in the variation of current strength of 80 Ampere and 95 Ampere is 80 Ampere current average impact toughness value of 0.54205 J/mm2 and 95 Ampere current average impact toughness value of 0.04174 J/m2. That the 80 ampere current variation is better and more efficient because it produces a higher toughness value than the 95 ampere current variation.

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