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# *Analysis Of The Effect Of Welding Flow Variations On The Physical Properties Of The Plate Materials*

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**Abstract – Strength is the ability of a metal to resist deformation due to external forces. Tensile ability test is performed to estimate material characteristics in the planning of a construction, and hardness is the resistance of metal to pressure penetration. The amount of hardness of a material can be known by conducting tests, so that the strength of the material is obtained. This study aims to analyze the current strength simulation system regarding the mechanical properties of plate material that undergoes a welding treatment process using electric welding and the effect of welding on strength, hardness and microstructure. The method used in this study is experimental research and literature review on the analysis of the effect of variations in current strength (65, 70, 75, 80) Amperes as an effort to determine the strength and hardness of the material. The conclusion in this study states that the main metal material is steel with the following mechanical properties Tensile strength: 43.8 Kg/mm2, Broken strain: 4.8% , Reduction of broken cross-section: 6.5%, Rockwall Hardness: 132.4 Characters fracture: Brittle fracture, then the hardness that occurs due to the influence of welding is distributed according to the distance from the center point of the weld. The farther from the center of the weld the smaller the effect, this happens because the influence of heat in this area is also smaller, the greater the current used when welding, the rougher the shape of the metal grains.**

**Keywords – Tensile strength; hardness; welding current strength; metallography; physical properties.**

## I. INTRODUCTION

The development of the times accompanied by the rapid development of science and technology (IPTEK) today creates an era of globalization and openness which requires every individual to participate in it, so that human resources must master science and technology and be able to apply it in every life. Welding is an integral part of the industry's increasing growth as it plays a major role in the engineering and repair of metal production. It is almost impossible to build a factory without involving welding elements.[1] Resistance spot welding is one of the most widely used methods of joining sheet metal in compression in the automotive industry. Welding operations are carried out in the weld shop or body shop. This is the workshop in a car manufacturing plant, where vehicles get their shape. There are about 3000 to 5000 welded joints in a typical vehicle. Every time a new car model is to be launched, a new workshop or a total overhaul of an existing workshop is needed to meet new unique needs. [2]. The fact that resistance spot welding does not require additional filler material to make the connection, makes it cheap and efficient. Processes, however, are a multifaceted engineering problem and understanding the various process-related requirements is a prerequisite for the effective planning of the power supply and distribution architecture. Welding operations are intermittent.[3] It derives high currents for periods as small as 1 to10% of the welding cycle. In the absence of interlocking welding machines, multiple welding can be performed simultaneously. Not only the supply must be able to meet the load requirements, the distribution system must also be able to support the current. But distribution systems cannot be scaled for such high currents. [4] The scope of the use of welding techniques in the field of construction is very wide, including shipping, bridges, steel frames, pipelines, and so on. Besides that, the welding process can also be used for repairs, for example to fill holes in castings, make hard coatings on tools, thicken worn parts and so on.[5] Welding is not the main objective of construction, but is a means to achieve better manufacture. Therefore the design of the weld must really pay attention to the compatibility between the properties of the weld, namely the strength of the joint and pay attention to the joint to be welded, so that the results of the welding are as expected. [6]. In choosing the welding process, the emphasis should be on the most suitable process for each welded joint in the construction. In this case the basis is high efficiency, low cost, energy savings and energy savings as far as possible. [7.] The quality of the welding results in addition depends on the welding process itself and also depends on the preparation before welding, because welding is a process of joining two or more metal parts using heat energy. In this study the welding used electric welding. This is very closely related to electric current, toughness, weld defects, and cracks which generally have a fatal effect on the safety of the welded construction. [8]. Therefore, to strive for good and quality welding results, it is necessary to pay attention to the properties of the material to be welded. For this reason, research on welding is very supportive in order to obtain good welding results. [9]. The realization of standards for welding techniques will help expand the scope of use of welded joints and increase the size of construction buildings to be welded. To be able to determine the effect of the results of electric welding on steel plates on the hardness test and tensile test of welding, it is necessary to test the test object resulting from welding. Welding is a joining process between two or more parts by using heat energy. [10]. Welding with an electric arc is a type of welding process that is often encountered because its implementation is quite simple, flexible and does not require expensive equipment.[11] In general, this type of welding process is widely used in large or small welding workshops. One of the methods in connection research is variation of the welding current to obtain the strength and hardness of the current which is suitable for accepting the load. The results of this research can be seen the percentage change in tensile strength and Rockwell hardness from a given variation of current strength.

## II. RESEARCH METHOD

The method used in this study is experimental research and literature review on the analysis of the effect of variations in current strength (65, 70, 75, 80) Amperes as an effort to determine the strength and hardness of the material. In this study, the test material used was St 42 steel plate with a size of 200 mm × 40 mm × 4 mm for a total of 8 (eight) specimens and a size of 100 mm × 40 mm × 4 mm for a total of 2 (two) specimens.

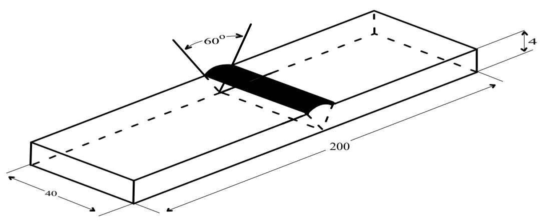



Fig. 1.Weld joint specimens

The welding machines used in this study were acetylene welding machines and electric arc welding machines with a current of 60 – 300 A Type BXI – 300 – 2 PRIM VOLTAGE 380/200 V Made in China and the hardness tester used was the KT 7001 L50 TC CH model. , Universal Testing Machine INC Taiwan.

1. The size of the material to be used for welding

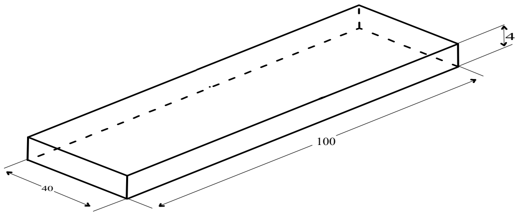



Fig. 2. Welding Material Size

2. At the ends of the specimens to be joined by welding, a V seam is made with an angle of $60^0$

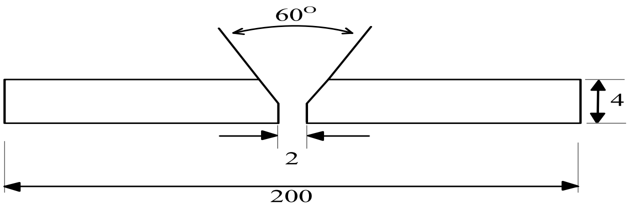



Fig. 3. The shape of the seam

The tensile test object at the forming stage was made using ZBK 22007-88 type scrap machine made in Taiwan. For the weld area, it is ground until it is flush with the base metal and then sizes are made for tensile testing.

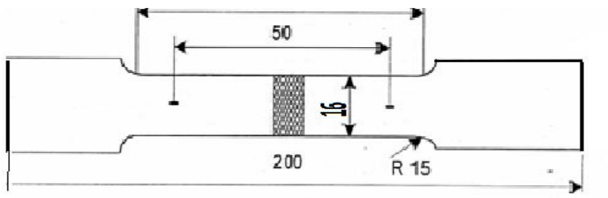



Fig. 4. Tensile test object

The Rockwell model hardness test method is to determine the hardness of the surface area of the welded area (HAS) and the base metal. This hardness test was tested using a Rockwell A hardness tester (KT 7001 L50 TC CH, Universal Testing Machine INC Taiwan), using a 120O diamond cone penetrator, with a pressing load of 60 kg, a pressing time of 5 seconds.

Hardness testing steps:

• Rub the test object using sandpaper until the test object is completely smooth and even

• Install the diamond cone penetrator to the clamp of the Rockwell hardness tester, and the penetrator.

• The pressure load used is 60 using the black A (HRA) scale

• Turn on the power by pressing the ON lever.

• Placing the work piece above the anvril and perpendicular to the penetrator.

• Raise the anvril by rotating the handle clockwise until it touches the penetrator, then raise it continuously until the small needle on the indicator dial touches the red dot and press the test button, wait a few moments (5 seconds) until the long needle points to the hardness number.

• Record the test results (hardness number)

• Lowering the anvril by turning the handle counterclockwise.

- This test is carried out as many as 3 (three) emphases for three test areas on each specimen, namely the emphasis on the weld area.

The machine used in this test is a universal tensile testing machine with the UPHG 20 model, the TARNOGROCKI brand made in Germany.

Tensile Testing Steps

- Marking acetylene welding work pieces and electric welding.
- Determine the load used, namely 10000 Newton, then determine the total length and width of the object.
- Turn on the main power switch so that the indicator light is on.
- Make sure the handle load control is in the stop position.
- Place the tool on the surface of the test tool and the retaining plate.
- Make sure the pointer is in the zero position.
- Make sure the clamp is on the lower crosshead and raise the lower crosshead by pressing the up crosshead button so that it can grip the tensile test object properly.
- Set loading speed.
- The load indicator needle continues to move until it reaches the max load point of the test object being tested and then decreases and breaks the work piece.
- Record loading and elongation.
- Then remove the test object from the gripper.

## III. Result And Discussion

Tensile Strength Testing, Properties of metals in tensile testing: Tensile testing is a way to determine the mechanical properties of a material. Tensile testing is carried out using specimens, equipment and tensile machines. The results of the tensile test, which can be in the form of a curve or stress diagram, are obtained by dividing the tensile strength or the initial area, and the stress is obtained from the change in the length of the initial specimen. The relationship between stress and strain can show the limit where Hooke's law still applies and is called the proportional limit and point E shows the limit where if the load is reduced to zero again there will be a permanent extension of the test specimen and is called the elastic limit. Point E is difficult to determine precisely because it is usually determined by an elastic limit with a fixed extension of 0.005% to 0.01%. Point S1 is called the upper yield point and point S2 is called the lower yield point. The highest stress is the highest tensile strength of the specimen and the stress that occurs at fracture is called the fracture stress.

In the tensile testing process, the specimen is loaded gradually, increasing in size little by little. As a result of this loading, there is a change in length to the magnitude of the load by the pulling machine so that a diagrammatic relationship occurs. In this diagram it can be seen that there are proportional limit points which identify the stress limit is proportional to strain. The tensile test carried out will experience a condition known as the proportional limit, if the stress and strain are proportional, then the graph will show a straight line. When it reaches the elastic limit, the stress is no longer proportional to the strain. When the load is removed, the rod length returns to its original state. It should be noted that the elastic limit and the proportionality limit are not different. In the static testing process where the load acting on the test rod is continued until beyond the elastic limit there will be a sudden permanent extension of a test rod, this is called the Yield point (melting limit), where the strain increases even though there is no increase in stress. This working load is equal to Fy.

The hardness test uses the Rockwell method by directly reading the depth of pressure generated by the test equipment. This test is a very practical and easy test and is widely used by industry, especially in metal construction. In the hardness measurement according to Rockwell as a sign of pressure, a hard steel bullet with a predetermined size is used. The pressing object is first pressed with an initial force Fo into the material. This is the initial position of the hardness measurement, where the gauge needle with the surface of the plate shows 130 (for steel bullets) or 100 (for diamond bullets). Furthermore, after that the pressing object is pressed with the main force or F1 into the material. The gauge needle reaches the division of the scale. Once the main force of F1 is released the material will spring back and finally stop which will show Rockwell hardness. This figure represents the difference from the initial position (130 or 100) and the magnification into the compression former. Rockwell's results depend on the shape of the pressure body and the main force of F1.

Hardness Test, Carbon steel is a material that is still widely used in the construction, automotive, shipping and other industries. Because of its wide use, various treatments are experienced by the steel. Steels that are used undergo various special ingredients to produce welded products that meet safety requirements. Low carbon steel (C<0.2%) has good weld ability properties, but with increasing carbon content such as medium carbon steel (0.2%<C<0.5% and high carbon steel (0.5%<C<0.7% higher effort is required to weld the material, because the increased carbon content makes it more likely to form martensitic phases on the weld metal and HAZ. For this reason, the welding process will affect the mechanical properties that occur in the weld metal or HAZ.

In this study, the same carbon steel welding process was carried out, namely carbon steel. The welding process was carried out by varying the current, namely 65 A, 75 A and 85 A, constant speed and voltage. From the results of the welding for each parameter the mechanical properties were tested, namely the hardness test on the weld metal area and the HAZ as well as the tensile strength test.

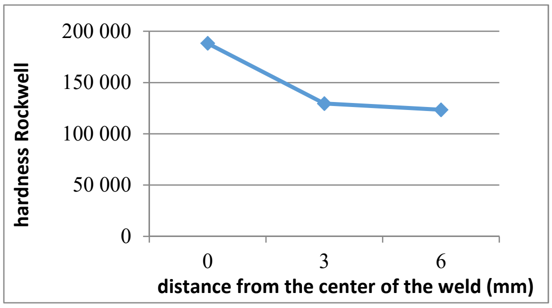



Fig. 5. Graph of the distribution of hardness due to welding with a current of 65 A

Based on the results of testing the hardness of the 65 A carbon steel welding specimens, it shows that:

- The highest hardness of welded joints in both the HAZ and weld metal areas occurs at the zero point position (welding metal area) with an average hardness of the three samples of 186.260 HR
- The lowest hardness in the HAZ area occurs at position -6 of 123.424 HR,
- The highest hardness in the HAZ area occurs at position -3, namely 153.102 HR

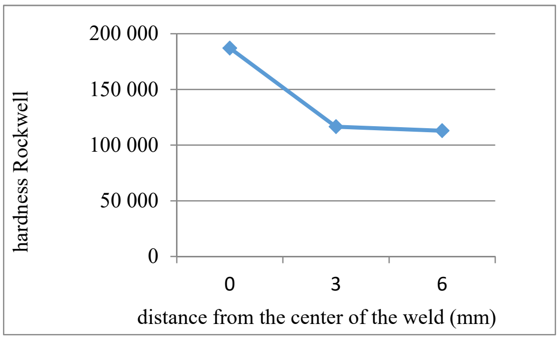



Fig.6. Graph of distribution of hardness due to welding with a current of 75 A.

Based on the results of the hardness test of dissimilar carbon steel welding specimens with a current of 75 A shows that:

- The highest hardness of welded joints in both the HAZ and weld metal areas occurs at the zero point position (welding metal area) with an average hardness of the three samples of 187.085 HR

- The highest hardness is in the HAZ area, occurring at position -3, namely 160,494
- The lowest hardness in the HAZ area occurs at position -6 which is equal to 112,892 HR

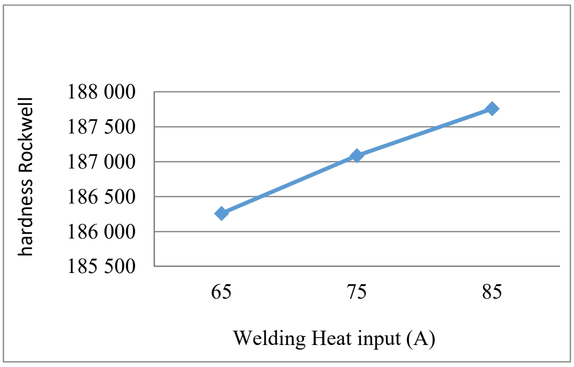



Fig. 7. Graph of hardness distribution due to welding with a current of 85 A

Based on the results of the hardness test of dissimilar carbon steel welding specimens with a current of 85 A in the tables and graphs it shows that:

- The highest hardness of welded joints in both the HAZ and weld metal areas occurs at the zero point position (welding metal area) with an average hardness of the three samples of 199.907.
- The lowest hardness in the HAZ area occurs at position -6, namely 147.102HR.
- The highest hardness in the HAZ area occurs at position -3, namely 162,333 HR.

From the results of data analysis, the welding specimens of carbon steel with a current of 85 A as well as currents of 65 A and 75 A, the highest hardness occurs in the metal area of the weld metal compared to the HAZ area and the parent metal. For base metal and HAZ . But the parent metal hardness & HAZ for each material are well distributed. The graphs and tables show that the higher the current, the greater the hardness of the weld metal and HAZ, both in welding. This shows that a lower current (65 A) has a better quality of welding results because it has better ductility and is not susceptible to cracking.

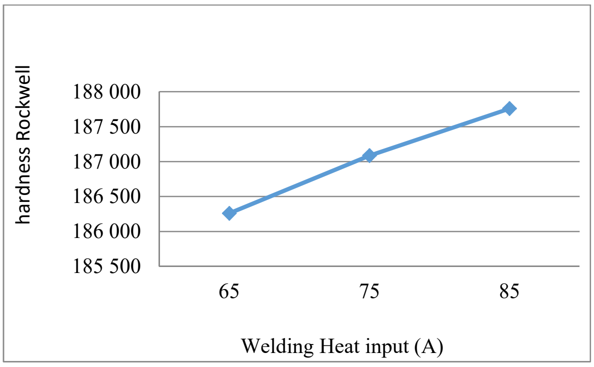



Fig. 8. Graph of the relationship between the hardness value of the weld area and the amperage

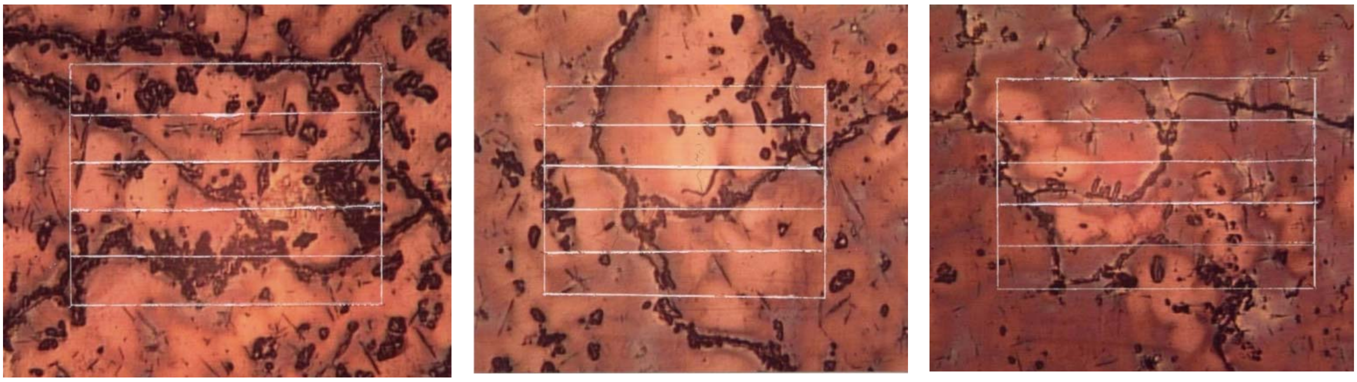
Thus, the results obtained from the study showed that welding steel with a current of 65 A, 75 A, 85 A all had the highest hardness properties in the weld metal area compared to the hardness of the base metal and HAZ, also the distribution of hardness was relatively even in the area of the base metal and HAZ. This shows that the hardness of the weld metal is quite good. However, in the area of the base metal, HAZ and weld metal for each current variation, namely: 65 A, 75 A, 85 A, all steel welding has better hardness properties. Based on the results of the tensile test, the results of carbon steel welding show that the difference in hardness at the -3 and -6 sides of the weld center occurs due to the influence of temperature on the welding point where the area close to the weld center will certainly get high heat compared to areas that are wider. far. This allows the recrystallization temperature to be reached which will result in a phase change during heating.

For samples with 65 A having tensile strength (σu) = 42,548 – 47,157 kgf with an average of 44,911 kgf, the percentage reduction in cross-sectional area (r) = 5.41 – 8.80 with an average of 7.28 %,/elongation (ε) = 0.17 – 0.5 with an average of 0.39 %, the position of the fracture at the HAZ and the fracture that occurs is brittle fracture.

For samples with 75 A having tensile strength (σu) = 43.576 – 45.118 kgf with an average tensile strength of 44.498kgf, percentage reduction in cross-sectional area (r) = 2.00 – 7.34 % with an average of 5.28 %, strain/elongation (ε ) = 0.33 – 0.67 % with an average of 0.50 %, the position of the fracture at HAZ (St 80 & St 42) and the fracture that occurs is brittle fracture.

For samples with 85 A having tensile strength (σu) = 40.952 – 43.079 kgf with an average of 41.998 kgf, percentage reduction in cross-sectional area (r) = 5.41–8.45 % with an average of 6.79%, strain/elongation (ε) = 0.33–0.83 % with an average of 0.56 %, the position of the fracture at the HAZ and the fracture that occurs is brittle fracture.

Microstructure, With metallographic testing, it will be seen that the grain structure of the metal is limited by grain boundaries. Usually the grains formed in the metal have irregular shapes and the sizes seen in the metal are not the same, so to estimate the metal grains it can be done by measuring the average size of the grains or measuring the nominal diameter seen on a microscope. This test does not measure surface area, but measures the average diameter of crystal grains. In this test, 5-10 parallel lines are needed, which are drawn directly on the grain image of the research results. Each of these lines has a length (L) mm. Then get the number of grains cut by the lines mentioned above (2) pieces. The number of lines that have been drawn is (p) fruit, with the enlargement of the image (V) times.



(a) (b) (c)

Fig. 9. Struktur Mikro hasil pengelasan baja ST42 dengan arus (a) 65 A. (b) 75A. (c) 85 A.

## IV. Discussion

The heat treatment process is defined as the process of changing the mechanical properties of the material/metal by changing the microstructure through heat regulation and cooling rate. Heating and cooling of welded products occurs under certain conditions. The existence of heating and cooling of the welded product is an indication that the welding process actually occurs heat treatment process. The difference in grain size of the microstructure obtained from the study of ST 42 steel welds is an example of a welding heat treatment product. In addition to heating and cooling, the grain size of the microstructure is affected by heat input, which means that it is also affected by the welding current. The effect of welding current on the grain size of the microstructure in the HAZ is shown in Figure 4.3, meaning that the higher the welding current used during welding, the coarser the microstructure grains. With coarse grain, the strength and toughness of the HAZ is low, while in Figure 4.1 it can be seen that with a low welding current, the heat input is not too large, it can be seen from the large grain that occurs, thus the area of influence of the HAZ is also not too wide, so that the toughness pretty good metal.

Each metal occurs in it an orderly growth of atoms and from the growth of atoms form crystals which then form dedenrites. If these dedenrite growths touch each other, metal grains and grain boundaries are formed. Of the two kinds of things, namely grain and grain boundaries will affect; hardness, strength, impact value (brittleness), magnetic properties, machinability, deep drawing capability, resilience, hardness, and fatigue capability. If the heat applied to the metal exceeds the recrystallization temperature of the metal, the new crystals will grow larger by eliminating the old crystals (cannibal fashion). By continuing to increase the heating temperature, new crystals continue to grow and enlarge so that large crystal grains will be obtained. This is undesirable in this process, because with large (coarse) grains the ductility of the metal is lower than what it would be if the metal had fine grains. Thus the results of this microstructure test show that the results of welding gray cast iron with preheat at a welding current of 65 A have finer metal grains than the results of welding ST 42 steel with currents of 75 A and 85 A.

## V. Conclusions

The main metal material is ST 42 steel with the following mechanical properties Tensile strength: 43.802 Kg/mm2, Fracture strain: 4.833 %, Reduction of fracture cross-section: 6.45 %, Rockwall hardness: 132.424 Brittle fracture character.

The violence that occurs due to the influence of welding is distributed according to the distance from the center point of the weld. The farther from the center of the weld the smaller the effect, this happens because the influence of heat in this area is also smaller, the greater the current used when welding, the rougher the shape of the metal grains

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