Effect of variation of TIG welding current on tensile strength and hardness of aluminium A-6061

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Abstract

Aluminium is a material that is now widely used for welding because this material has good mechanical properties, is corrosion resistant, is light in weight and can be recycled. The problem that occurs in aluminium welding is the presence of a passive layer or layer of Al2O3 oxide which has a high affinity for oxygen. This oxide layer is also an insulator which can inhibit the flow of current in welding. The amount of current in the welding process greatly affects the amount of heat input, weld concentration and arc stress. The purpose of this study was to determine changes in the mechanical properties of tensile strength and hardness of welded metal joints with variations in welding current on aluminium Al-6061 using the TIG welding process. The stages of the research method carried out were to carry out the TIG welding process on aluminium material joints with variations in currents of 120A, 140A and 160A. The filler rods used were AWS A5.10/ER-5356 and argon gas with a flow volume of 15 l/m. Furthermore, the results of the weld are tested for tensile and hardness to determine changes in the mechanical properties of the weld joint. The results show that the magnitude of the welding current affects the strength of the welding joint in terms of mechanical properties, especially the value of the tensile strength and hardness of the material when receiving loads and also affects the strain or elongation of a material. The highest tensile strength value is at a current strength of 160A of 9.83 Kgf/mm^2, while the lowest tensile strength value is welding using a current strength of 120A with a value of 9.73 Kgf/mm^2. The most ductile or ductile welded joints are welding using a current of 120A. While the highest hardness value was in the 160A weld metal area of 95.17 HRE and the lowest was in the HAZ area of 160A current of 41.17 HRE.

Keywords: Aluminium 6061, ER-5356**,** TIG welding process, Welding current strength, Tensile strength test.

1. Introduction

The material that is often used in the manufacturing industry is aluminium. It is lighter than steel, corrosion resistant, and has good electrical conductivity, making this material commonly used in the manufacture of aircraft components, shipbuilding, and automotive bodies. The use of aluminium in the industrial world is increasing, therefore the development of the properties and characteristics of this material must also be improved periodically. Pure aluminium has low strength so it must be combined with other elements to improve its mechanical properties. Aluminium alloys consist of several groups based on the element that has the largest percentage composition in the alloy.

aluminium is a non-ferrous metal that is widely used in the manufacturing, automotive, and home industries. This is based on the characteristics possessed by aluminium. These properties consist of physical properties, chemical properties, and mechanical properties[1][2]

Aluminium has a light density of 2.7 g/cm^3 and a melting point of 600°C. The coefficient of thermal conductivity of aluminium is six times greater than that of steel, so the heat input for welding this non-ferrous metal must be higher and more concentrated than for welding steel. In addition, the coefficient of thermal expansion of aluminium is twice that of steel. At high temperatures, aluminium does not change color like steel, so it is difficult for the welder to determine when the material has reached its melting point.

Aluminium in its pure form has low strength with yield strength and tensile strength of 34.5 N/mm2 and 90 N/mm^2, respectively. The elastic modulus of aluminium is 69,000 MPa and is capable of absorbing energy at high impact loads. Aluminium has good formability. With the arrangement of the crystal structure in the form of Face Centered Cubic (FCC), this material is easy to form by deep drawing and extrusion processes. At the time of heating and cooling, aluminium does not change the crystal structure.

Based on its physical properties, aluminium has some properties that are not good in welding. These properties include the difficulty of melting between the base metal and the weld metal because the alumina layer formed has a high melting point. In addition, the large coefficient of expansion facilitates deformation so that it will form hot cracks when combined with alloys that have hot brittle properties. The light density of aluminium alloys will make unwanted substances form and precipitate during the welding process. However, this weakness of welding properties can be overcome by welding using noble gases such as Argon or Helium as shielding gases[4][5].

Welding is one of the metal joining techniques by partially melting the base metal and filler metal with or without pressure and with or without additional metal and produces a continuous connection. Welding of Aluminium and its alloys can be done by various types of welding. However, one of the most widely used welding methods in Aluminium welding is Gas Tungstern Arc Welding (TIG)[2][6][7].

In Aluminium welding there are welding process requirements that must be met so that the welds have good quality such as intense and localized heat input to overcome high thermal conductivity, specific heat, and latent heat of Aluminium alloys, an oxide layer on the surface which has a melting point. must be destructible and trapped to form inclusions in the weld bead, the coefficient of thermal expansion of Aluminium is relatively high so that distortion appears which can be reduced by the use of high welding speeds, and porosity in the weld bead after solidification should be avoided by reducing the hydrogen gas content. which is included in the Aluminium welding process because of its high solubility in molten Aluminium.

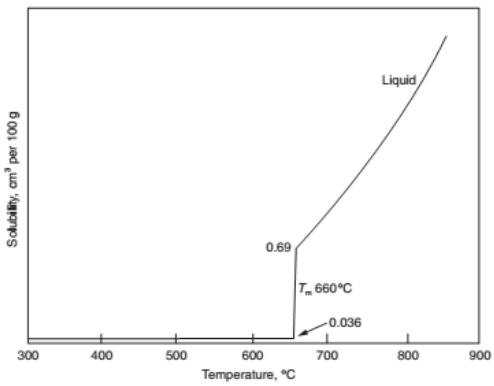


Figure 1. Solubility of Hydrogen in Aluminium [1].

The principle of Gas Tungsten Arc Welding (TIG) welding is to use Tungsten as the non-feeding electrode and noble gas to protect the electrode. The noble gas used is Argon or Helium gas which is sprayed through the torch to prevent oxygen or nitrogen from entering the welding fluid which can cause porosity.

Materials that are welded using TIG generally require direct current (Direct Current) with a negative charge on the Tungsten and the weld metal is connected with a positive charge. However, in Aluminium welding, the current source used is alternating current. In welding with AC current, the arc will work when the electrode is positively charged and the weld metal is negatively charged so that it can damage the oxide layer formed on the Aluminium surface to facilitate the welding process.[2].

The advantages of TIG when compared to other welding processes are a clean welding process due to minimal oxidation, easy control of heat input, no welding spark, and very low distortion.

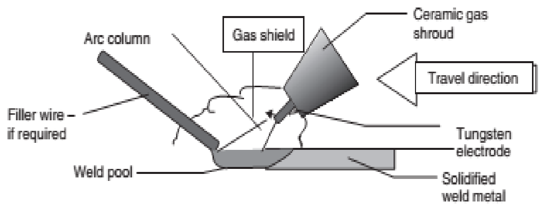


Figure 2. TIG Welding Scheme [8].

The success of the TIG welding process is largely determined by the welding parameters, including current strength, arc voltage, speed, and shielding gas. The amount of energy produced by the arc is proportional to the current and voltage, the amount of weld material deposited per unit length is inversely proportional to the welding speed. The arc produced with Helium shield gas is deeper than with Argon gas.

Welding current is one of the parameters in the welding process that will determine weld penetration. Weld penetration will have an effect on the mechanical properties of the weld. The use of low currents will result in low weld penetration, but too high currents will also produce weld beads that are too wide, causing weld deformation.

TIG welding can use direct current (DC) and alternating current (AC). This current selection depends on the type of material to be welded. Direct current with the electrode on the negative side can result in deep penetration and higher welding speeds.

Shielding gases (noble gases) are gases that do not react with metals or other gases. This gas is used as arc protection and hot metal during the welding process. The shielding gases commonly used in TIG welding include Argon and Helium gases.

In the weld area there will be a thermal cycle due to the heating and cooling process. The welded area that has a thermal cycle is divided into three parts, namely:

1. Welded area (weld metal)
   The area of the metal that melts during welding, and mixing occurs and then solidifies. The special area that delimits the weld area and the heat-affected area is called the fusion line.
2. Heat Affected Zone
   Areas of metal that undergo microstructure changes due to rapid thermal cycles of heating and cooling.

3. The base metal region (base metal)
The area on the metal that does not change its properties and microstructure due to welding temperature.

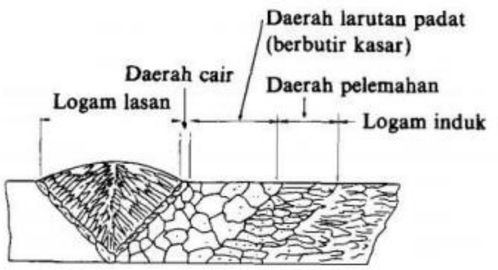


Figure 3. Microstructure of Heat-treatable Aluminium Alloy Welding Area [4].

However, the results of aluminium welding with the TIG process are still often found welding defects and mismatches in the selection of welding parameters which result in lowering of mechanical properties such as tensile strength and hardness of welds. Several factors that affect the mechanical properties of welds are the determination of parameters in the welding process, namely current strength, voltage, selection of filler metal. Previously, several studies have been carried out by researchers to obtain the appropriate welding parameters so that the maximum or desired weld joint strength can be obtained[9]–[13].

Based on this, a study was conducted with the aim of knowing the effect of the strong current of the TIG welding process on the mechanical properties of 6061 Aluminium material. The mechanical properties to be analyzed are tensile strength and hardness.

2. Research Methodology

The material used in this research is Aluminium series AA 6061 with filler metal ER 5356. The current strength is varied 120 A, 140 A, 160 A. In the welding process, the welding voltage and speed are considered constant. Argon gas used in the TIG welding process is 15 l/m. The type of connection used is a single V-butt joint.

The initial method is the formation of material for the welding process with the dimensions of the material being welded 200x150x5 mm. The inclination of the seam angle is 300. Welding of material joints uses the TIG welding process with filler metal ER 5356. Welded material as many as 3 specimens with variations in current strength of 120 A, 140 A, 160 A.

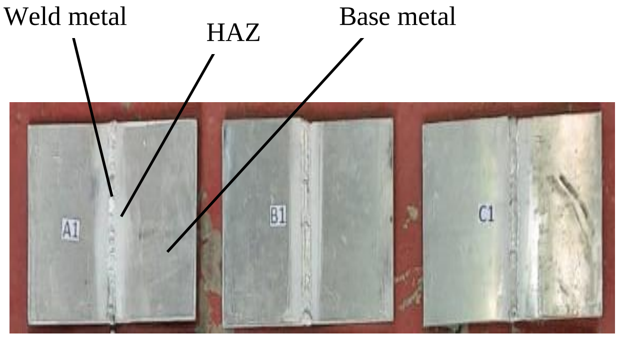
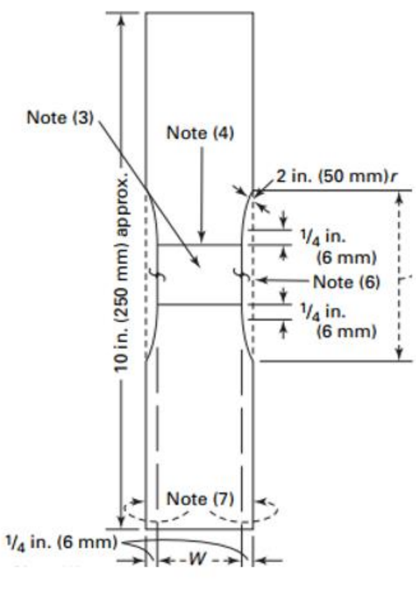


Figure 4. TIG-welded aluminium. (A1) Current 120A. (B1) Current 140A. (C1) Current 160A.

Table 1. Composition of Al 6061 [7]

Component	amount (%)
Aluminium	97,32
Magnesium (Mg)	0.8-1.2
Silicon (Si)	0.4-0.8
Iron (Fe)	Max. 0,7
Copper (Cu)	0.15-0.4
Zinc (Zn)	Max. 0.25
Titanium (Ti)	Max. 0.15
Manganese (Mn)	Max. 0.15
Chromium (Cr)	0.04-0.05
Other Ingredients	0.02

After welding, the tensile and hardness tests were carried out using the Rockwell E or HRE method. Prior to the tensile test, the tensile test specimen was first made using the ASME standard as shown below.



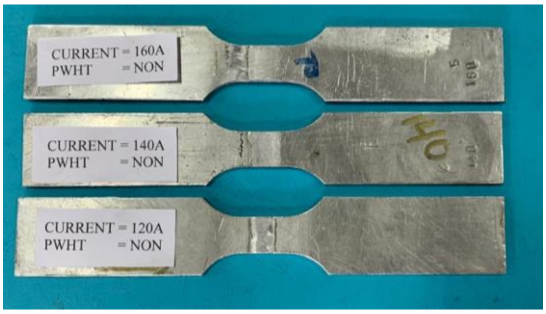


Figure 5. Tensile Test Specimen

3. Results and Discussion

The results of welding aluminium material using a current of 120 A, 140 A, 160 A TIG welding process with 5356 added material can be seen visually that there is a perfect connection process where there are no defects on the surface of the material connection. Thus these three currents can be used to weld the Aluminium material. The results of the Aluminium welding process as shown below.

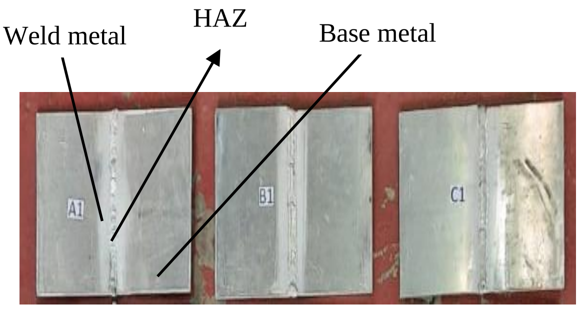


Figure 6. TIG-welded Aluminium. (A1) Current 120A. (B1) Current 140A. (C1) Current 160A.

After welding, a tensile test is carried out with the test results as shown below:

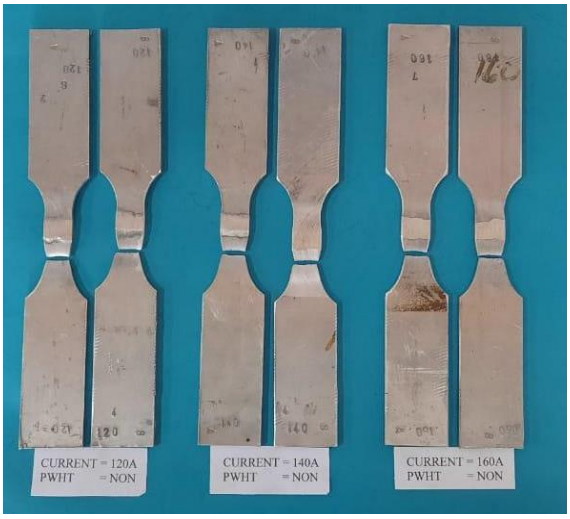


Figure 7. Tensile Test specimen drawing spesimen

Based on the picture above, it shows that all specimens break outside the welding area or weld metal, this shows that the welding parameters are correct and the three currents can be used for splicing Alumnium 6061 material using a filler rod 6061. However, research is needed with tensile testing to get one the best current to obtain a high weld joint strength.

3.1 Tensile Test Results

Based on the results of the tensile tests that have been carried out, the tensile strength data obtained from each weld with different currents, namely 120 A, 140 A, 160 A.

Table 2. Tensile test data

Current	σ_u (Kgf/mm^2)	e (%)
120 A	9.77	11.79
120 A	9.68	11.83
Average	9.73	11.81
140 A	9.98	10.56
140 A	9.62	10.30
Average	9.80	10.43
160 A	9.92	9.03
160 A	9.74	9.67
Average	9.83	9.35

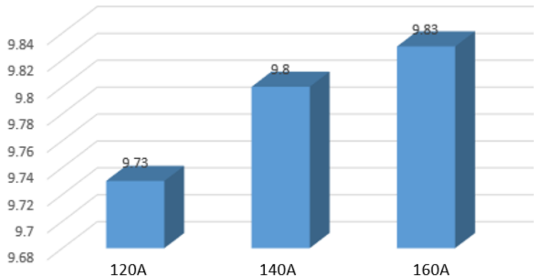


Figure 8. Graph of the tensile strength of the welded material of Aluminium 6061 against the welding current.

Based on the histogram, the highest tensile strength value is at 160 A current of 9.83 Kgf/mm^2, then followed by a current of 140 A with a tensile strength value of 9.80 Kgf/mm^2, while the lowest tensile strength value is welding using strong current is 120 A with a value of 9.73 Kgf/mm^2. From the tensile test data, it shows that the higher the current, the higher the tensile strength value of the 6061 type aluminium welding joint, this is due to the higher the electric current in the welding process, the greater the heat input, so the higher the tensile strength value is also This tensile strength value is also influenced by the type of filler rod used and the cooling method used, where the filler rod used is type 5356 with the normalizing cooling method or cooling in free air.

In addition to testing the tensile strength value, a strain test is also carried out on the welding results of aluminium 6061. It is also important to do a strain test to show the ductility or ductility of the material which is usually expressed in percentage terms. This data shows the amount of elongation that can be given by the material until it breaks. Strain graph data as follows

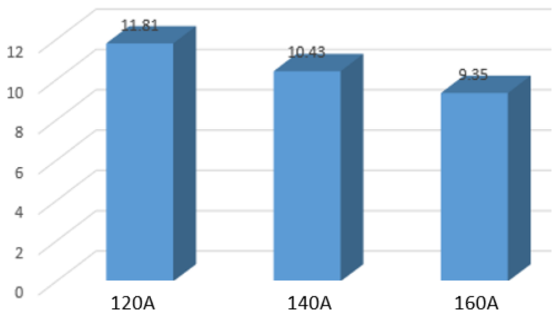


Figure 9. Graph of strain (elongation) value. (1=120A, 2=140A, 3=160A).

Based on the histogram above, the highest strain value is at 120 A current of 11.81%, followed by 140 A current with a tensile strength value of 10.43%, while the lowest strain value is welding using 160 A current with a value of 9.35%. From the tensile test data, it shows that the higher the current, the lower the strain value of the 6061 type Aluminium welding joint. Based on these data, it shows that the most ductile or ductile welding connection is welding using a current of 120A, this is strongly influenced by the current strength used because it describes the amount of heat input given during the welding process and is also influenced by the cooling process carried out using the normalizing method which can affect the microstructure of the material so that the grain size of the material changes during natural cooling.

3.2 Hardness Test Results

The results of the HRE hardness test can be seen in the following picture

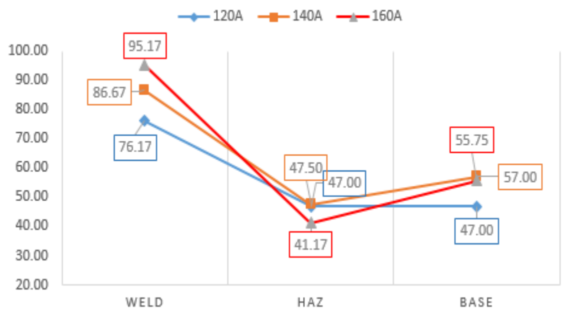


Figure 10. Hardness value

Based on the graph above, the highest hardness value is in the 160A current weld metal area of 95.17 HRE and the lowest is in the 160A current HAZ area of 41.17 HRE. From the test results, it can be explained that there is an increase in the value of hardness in the weld metal area compared to the base metal in all welding currents, both 120A, 140A and 160A, so that the strength of the weld joint is very good because the hardness value is higher than the strength of the base metal, this is influenced by the use appropriate current and filler. While in the HAZ area there is a decrease in material hardness compared to the hardness of the base metal area, so that further treatment is needed such as heat treatment or PWHT (post weld heat treatment) with a certain temperature so that the hardness value in the HAZ area can increase or as desired.

4. Conclusion

Based on the research on the effect of current strength on the mechanical properties of Aluminium 6061 welds, it can be concluded that the welding current affects the tensile strength and tensile strength of the material as well as the hardness of the material. The highest tensile strength value is at 160 A current of 9.83 Kgf/mm^2, followed by by a current of 140 A with a tensile strength value of 9.80 Kgf/mm^2, while the lowest tensile strength value is welding using a current of 120 A with a value of 9.73 Kgf/mm^2. Based on the data shows that the most ductile or ductile welding connection is welding using a current of 120A. While the highest hardness value is in the weld metal area with a current of 160A of 95.17 HRE and the lowest is in the HAZ area of 160A of 41.17 HRE.

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