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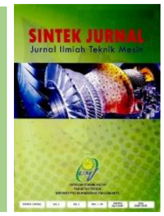

THE EFFECT OF SOLUTION HEAT TREATMENT HOLDING TIME VARIATIONS ON THE MECHANICAL PROPERTIES OF ALUMINUM A-6061 BY THE TIG WELDING PROCESS

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ABSTRACT

Aluminum and its alloys are metals that are widely used in the engineering field because its have advantages including good formability, relatively high tensile strength, corrosion resistance and a welding process for the joints. General structure, structures that have poor mechanical properties. To overcome this problem, the material that has been welded is heat treated or heat treated according to temperature and time management) which is suitable in addition to good mechanical properties as well as to reduce residual stresses. The purpose of this research is to determine the tensile strength and hardness value of welding joints of Aluminum 6061 with a variation of Holding Time 1, 2, 3 hours in the Solution Heat Treatment process with a temperature of 500^{0}C. The results showed that based on the results of the tensile test, it showed that the holding time affected the value of the tensile strength and strain of the welding joint where the highest tensile test value was at a holding time of 1 hour, while the highest strain value was at a holding time of 2 hours. Then from the hardness test data, it shows that the heating duration or holding time affects the hardness value of the material both in the weld metal, HAZ, and base metal areas. In the weld metal area, the highest hardness value is at a holding time of 3 hours. The HAZ area has the highest hardness value at a holding time of 2 hours, while the base metal region has the highest hardness value at a holding time of 1 hour

Keywords: Welding, Aluminum 6061; holding time; Solution Heat Treatment; mechanical properties.

1. INTRODUCTION

Aluminum and its alloys are metals that are widely used in engineering because they have various advantages, including light weight, good formability, relatively high tensile strength, and corrosion resistance. The mechanical properties of aluminum alloys can be improved by cold working or heat treatment, and their weldability varies depending on the type of alloy[1].

The various advantages above cause aluminum and its alloys to be widely used in the structural and machining fields, such as aircraft, ships, vehicles and the automotive industry.

Welding is an important part in an industrial process, and the need for welding is very high, therefore welding technology is increasingly developing. The use of welding technology is usually used in the fields of construction, automotive, shipping, aircraft, and other fields which in recent years have developed light material technology such as aluminum alloy.

There are many methods of joining aluminum, one of which is welding. Welding Aluminum generally uses TIG (Tugnsten Inert gas) welding. GTAW (Gas Tungsten Arc Welding) welding is an electric arc welding process that uses electrodes that are not fed or do not melt. In GTAW welding, this electrode or tungsten only functions as an electric arc generator when in contact with the workpiece, while the filler metal is a filler rod. TIG welding is used to produce high quality welds and is one of the most popular technologies for welding in the manufacturing industry[2].

The advantages of TIG welding include that the welding result does not need to be cleaned because it does not produce slag, the gas flow makes the area around the metal liquid not contain air so as to prevent contamination by nitrogen and oxygen, which can cause oxidation, the weld is stronger because it can penetrate deeply and corrosion resistance is better. high, the welding results are very clean, the welding process can be observed easily and the smoke that arises is not much, deformation is rare because the heat center is very small, does not produce spaters or welding sparks so the weld is cleaner[3].

In welding aluminum joints the strength of the material, Young's modulus, corrosion resistance and hardness of the material are mechanical properties that can be improved. One method to improve the mechanical properties is by applying heat treatment to the aluminum joint. One of the treatments with heat treatment is solution treatment and peak aging. In solution treatment and peak aging it will increase the hardness and ductility as well as the tensile strength of the aluminum plate due to the emergence of evenly distributed precipitates throughout the solid Al solution.[4].

Solution heat treatment is a controlled reheating and cooling process carried out on the welding results of a component, with the aim of changing the physical and mechanical properties of a material or metal as desired. This process is carried out by preheating to rapid cooling by heating the alloy to above the solvus line. The purpose of solution heat treatment is to obtain a solid solution that is nearly homogeneous. However, there are problems during the welding process, the microstructure and mechanical properties of aluminum alloy 6061 will change during the welding process due to the melting process of the base material. In addition, the welding area and the heat affected area (HAZ) have a lower energy impact and lower ductility than the base metal.[5].

In general, welded structures have less good mechanical properties than the base metal. To overcome this, the welded material is heat treated according to the appropriate temperature and holding time, in addition to obtaining good mechanical properties as well as reducing residual stress. Solution heat treatment is one of the processes that can improve the mechanical properties of the welded material. However, this process requires an appropriate holding time during the heating process to increase the strength of the 6061 Aluminum welding joint. Another important aspect of this heat treatment process is the prevention of the material from brittle fracture and to soften the hard zone so as to make the machining process easier and can eliminate residual stress due to heat absorbed by the material will make the metal particles move and prevent dislocation in the metal microstructure.

Previously, various studies have been carried out on aluminum welding to obtain suitable welding parameters with a variety of parameters so as to increase the strength of aluminum welding joints[1], [5]–[9]. Natawiguna et al, in their research found that with increasing solution heat treatment temperature and dwell time, the shear tensile strength of the welded object will decrease. The hardness value of the welded object will decrease and the grain size in the SZ, HAZ, TMAZ areas will increase with increasing solution heat treatment temperature and dwell time[1].

Based on this description, it is necessary to carry out further research with the aim of knowing the tensile strength and hardness value of 6061 Aluminum welding joints with variations in

Holding Time 1, 2,3 hours in the Solution Heat Treatment process with a temperature of 500^{0}C.

2. METHODS

The data analysis technique used in this research is analysis with comparative descriptive method. The data obtained in this study were in the form of tensile strength and hardness data as well as from observations and then analyzed descriptively. The material used is Aluminum type 6061.

The research method begins with material preparation, namely material preparation with dimensions of 300 x 150 x 6mm, 30^0 groove angle. Furthermore, the preparation of equipment includes a TI welding machine, welding wire used ER 5356 with a diameter of 2.4 mm with a protective weld using argon gas. The parameters used in this welding are GTAW welding machine, Tungsten Electrode diameter: 2.4 mm, Filler rod: ER 5356 diameter: 2.4 mm, Shelding gas: Argon, Gas flow: 15 l/min.

Then, the aluminum connection of the 6061 series was welded with a current of 140A. The material that has been welded is done visually. Visual inspections carried out include inspection of connection preparation, welding process, size and type of electrode, weld defects on the surface after welding. The welding process is carried out in the 1G position or the underhand position.

Figure 1. Aluminum welding process using TIG welding with 1G position

Furthermore, the welding results that have passed the test are given solution heat treatment at a temperature of 500^{0}C with variations in holding time for 1 hour, 2 hours and 3 hours.

Figure 2. Solution heat treatment process with holding time variations of 1, 2, 3 hours

Cooling is done by queching or rapid cooling using water as a medium with a water temperature of about 25^{0}C.

After the solution heat treatment, an artificial aging process was carried out for 7 hours at a temperature of 170^{0}C with normalizing or air cooling.

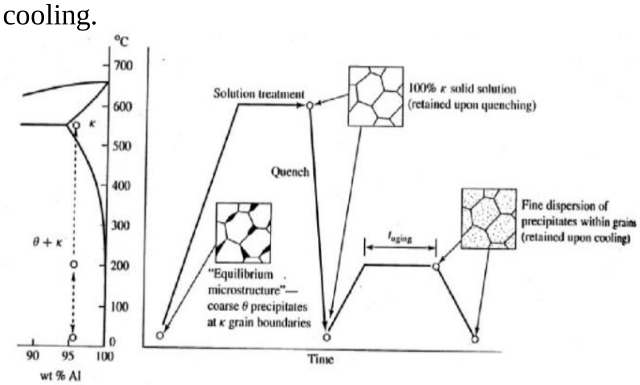


Figure 3. Solution heat treatment process scheme

After heat treatment, the mechanical properties will be tested in the form of tensile tests and hardness tests.

Tensile testing is carried out to measure the resistance of a material to a slowly applied static force[10][11]. The manufacture of tensile test specimens refers to ASME IX 2015.

Hardness test is carried out to determine the ability of a material to withstand indentation or penetration loads[11]. Hardness tests were carried out in the base metal, HAZ and weld metal areas.

Hardness testing using the *Hardness Rockwell* E atau HRE method.

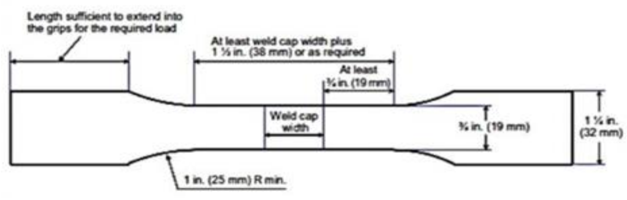


Figure 4. Tensile test specimen.

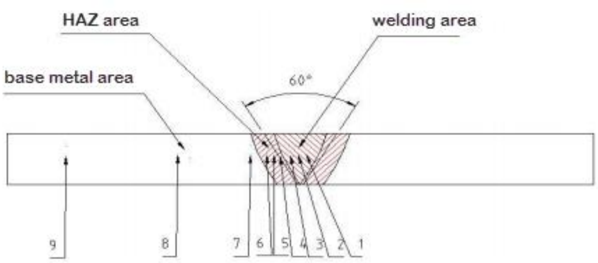


Figure 5. Hardness testing point location

3. RESULTS AND DISCUSSION

The result of welding aluminum is as shown figure 6.

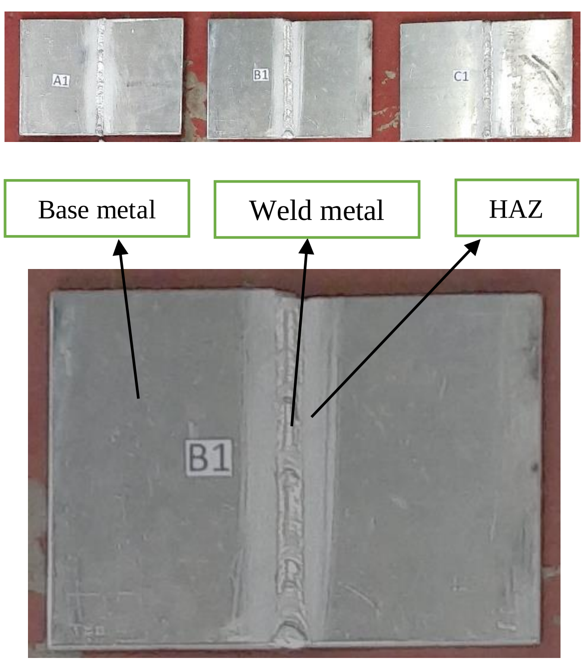
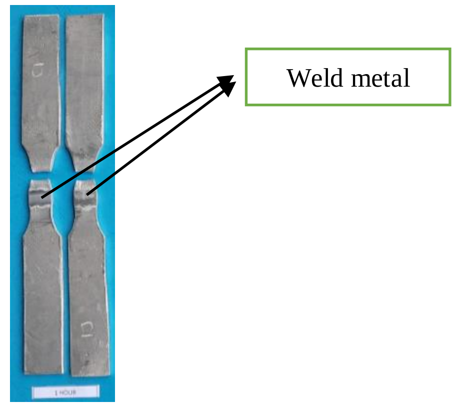
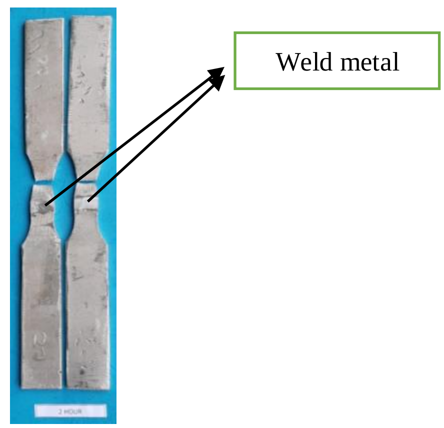


Figure 6. Welding results and welding terminology

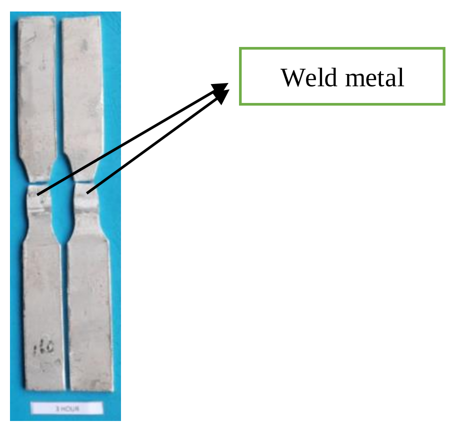
Based on the visual tests carried out that the welding results are not defective so that these results can be continued with tensile testing as shown Figure 7.



(a)



(b)



(c)

Figure 7. Tensile test results. (a) 1 hour. (b) 2 hour. (c) 3 hour

Based on the Figure 7, all specimens break are not in the weld metal or weld metal area, so it can be concluded that the selection of electrodes, filler rods, welding currents and other welding parameters is correct. If the break is in the weld metal area, the joining process is considered a failure because the electrode selection is not compatible with the material being welded or other factors so that it does not have the strength of the welding connection. Then the welding process must be repeated by adjusting other appropriate parameters and a tensile test is carried out again until the welded joint is stronger than the base material. Because basically the welding joint must be stronger than the base material or base metal.

The results of the tensile test are as shown in the following figure 8.

Based on the figure 8, it shows that the holding time affects the value of the tensile strength of the welding joint where the highest tensile test value is at a holding time of 1 hour at 9.46 kgf/mm^2, followed by a holding time of 2 hours with a tensile test value of 9.37 kgf/mm^2, while the lowest tensile test value is at a holding time of 2 hours with a value of 9.25 kgf/mm^2.

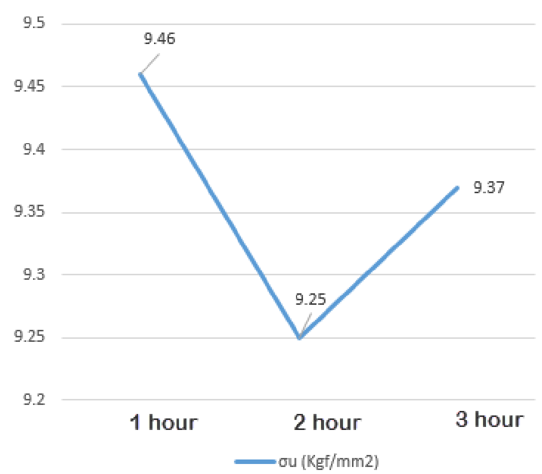


Figure 8. Tensile test chart, σu (kgf/mm2)

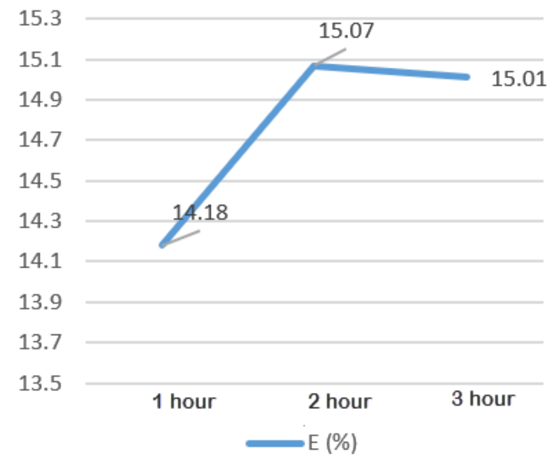


Figure 9. Strain value graph, E (%)

Then based on the figure 9 of the stretch value (Elongation) above, it shows that the holding time affects the strain value where the highest strain value is at a holding time of 2 hours at 15.07%, followed by a holding time of 3 hours with a strain value of 15.07%, while the lowest strain test value was at a holding time of 1 hour with a value of 14.18%.

After the tensile test is carried out, the next is hardness testing with the test results of the average test values in the weld metal, HAZ, and base metal areas as follows.

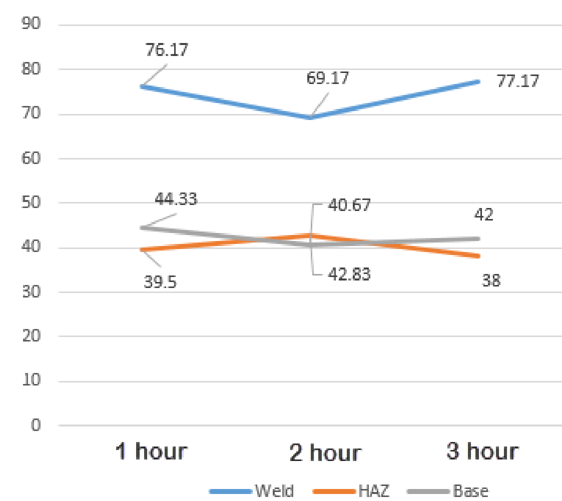


Figure 10. Hardness test results

Based on the figure 10, the highest hardness value in the weld metal area is at a holding time of 3 hours at 77.17 HRE, then followed by a holding time of 1 hour with a hardness value of 76.17 HRE, while the lowest hardness value is at a holding time of 2 hours with a value of 69.17 HRE.

Then the highest hardness value in the HAZ area is at a holding time of 2 hours at 42.83 HRE, then followed by a holding time of 1 hour with a hardness value of 39.5 HRE, while the lowest hardness value is at a holding time of 3 hours with a value of 38. HRE.

Furthermore, the highest hardness value in the base metal area is at a holding time of 1 hour of 44.33 HRE, then followed by a holding time of 3 hours with a hardness value of 42 HRE, while the lowest hardness value is at a holding time of 3 hours with a value of 40, 67 HRE.

The hardness test data shows that the heating duration or holding time affects the hardness value of the material both in the weld metal, HAZ, and base metal areas. In the weld metal area, the highest hardness value is at a holding time of 3 hours. The HAZ area has the highest hardness value at a holding time of 2 hours, while the base metal region has the highest hardness value at a holding time of 1 hour.

4. CONCLUSION

Based on the test results, it can be concluded that all tensile test specimens for the three variations of holding time 1, 2, 3 hours are broken not in the weld metal or weld metal area, so it can be stated that the selection of electrodes, filler rods, welding currents and other welding parameters is correct and meet the welding criteria. Based on the results of the tensile test, it shows that the holding time affects the value of the tensile strength and strain of the welding joint where the highest tensile test value is at a holding time of 1 hour of 9.46 Kgf/mm2, while the highest value of strain is at a holding time of 2 hours of 15. 07%. The lowest tensile test value was at a holding time of 2 hours with a value of 9.25 Kgf/mm2, while the lowest value of the strain test was at a holding time of 1 hour with a value of 14.18%. Then from the hardness test data, it shows that the heating duration or holding time affects the hardness value of the material both in the weld metal, HAZ, and base metal areas. In the weld metal area, the highest hardness value is at a holding time of 3 hours. The HAZ area has the highest hardness value at a holding time of 2 hours, while the base metal region has the highest hardness value at a holding time of 1 hour.

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