



Comparative analysis of mechanical strength in aluminum welding joints of AA 5052 and AA 6061 plates

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ABSTRACT

Oxy-Acetylene welding is a commonly used manual welding method due to its affordability and portability, as it does not require electricity. This process joins metal surfaces by heating them with a flame from burning a mixture of acetylene (C_2H_2) and oxygen (O_2), with or without filler metal, and without applying pressure. Aluminum, known for its lightweight, corrosion resistance, and good conductivity, is often alloyed with elements like Cu, Mg, Si, Mn, Zn, and Ni to enhance its mechanical properties. This study analyzes the mechanical properties and microstructure of Oxy-Acetylene welded aluminum alloys AA 5052 and AA 6061. Tests conducted include tensile, flexural (bending), and hardness tests. The tensile test showed AA 6061 had a higher tensile strength of 78.4 MPa, though still considered brittle due to the presence of weld defects. These defects were linked to the uneven melting and poor adhesion of the welding wire, resulting in gaps. The highest bending strength was also recorded by AA 6061 at 70.44 MPa with no fractures, while AA 5052 had the lowest at 50.1 MPa with fractures in the weld metal. Overall, Oxy-Acetylene welding on both materials showed imperfections due to inconsistent weld quality.

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1. INTRODUCTION

The development of technology in the increasingly advanced construction sector cannot be separated from welding because it has an important role in metal engineering and repair (Ardiansah, 2019). The construction of metal construction today involves many welding elements, especially in the field of design and construction because welding joints are one of the joints that technically require high skills for the welder to obtain good quality joints (Pereira & de Melo, 2020). 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. More than 40 types of welding have been known to people and are used in metal joining practices. One of the welding methods used is the Oxygen Acetylene Welding (OAW) method.

Welding using Oxy-Acetylene gas welding as a heat source is one of the welding methods that is widely used in the field (Setiawan, 2017). This is because Oxy-Acetylene gas welding is relatively cheaper (Orkforce, 2016), can be done anywhere, namely it does not require electric current like welding using electrodes or electric current (Murugan & Sathiya, 2024). OxyAcetylene welding (acetylene welding) is a manual welding process (Singh *et al.*, 2020), where the surfaces to be joined are heated until melted by the acetylene gas flame (i.e. combustion of C_2H_2 with O_2), with

or without filler metal, where the joining process is without pressure. In the application, the results are very satisfactory for welding carbon steel, especially sheet metal, tanks and thin-walled pipes. According to Wisnujati & Nurhuda, 2017, almost all types of ferrous and non-ferrous metals can be welded with gas welding, either with or without additional materials (filler metal).

In the world of engineering and design construction, connecting one material to another requires the use of the right method (Januar & Suwito, 2016). According to Sugito *et al.*, (2022), in the world of manufacturing industry today we often encounter the manufacture of products or components that require material connection in the automotive, aviation, shipping and other fields. And welding is one of the connection methods that is often used for connecting materials (Haghshenas & Gerlich, 2018). In modern times, many manufacturing industries are developing welding techniques to improve product quality and cut production costs. Welding based on the definition of Deutsche Industri Normen (DIN) is a metallurgical bond at the joint of metal or alloy metals carried out in a melted or liquid state (Siswanto *et al.*, 2020).

Aluminum is a light metal that has good corrosion resistance and electrical conductivity and other good properties as metal properties (Anderson *et al.*, 2018). The addition of Cu, Mg, Si, Mn, Zn, Ni, and so on will increase the mechanical strength of Aluminum (Haghshenas & Gerlich, 2018). This alloy contains a number of other elements that vary, thus providing mechanical properties that adapt it to different applications. For example, AA 5052 aluminum plate is easier to shape and bend without cracking.

AA 6061 aluminum sheet is readily extruded into shapes such as channels, angles, and tees, and can be heat treated, providing superior strength and hardness (Di Bella *et al.*, 2023). However, both types of aluminum share certain similarities, including their ability to be anodized, which increases corrosion resistance or, if desired, add a colored finish. Each grade of aluminum alloy offers unique advantages and disadvantages, depending on the specific application needs (Czerwinski, 2020). Common beneficial features of 6061 and 5052 aluminum alloys include advanced corrosion resistance, lightweight, and high tensile strength (Wu *et al.*, 2022). 6061 aluminum is a metal that contains some alloying of aluminum with magnesium-silicon (Al-rawashdeh, 2023); it is a ductile, malleable, non-corrosive, and weldable material that is well suited for use in construction framing, especially in the marine industry. Aluminum is a material that is difficult to join, especially with the welding process. In the shipping technology industry, this type of aluminum is widely used in construction frames such as stiffener frames and offshore building construction (Chen *et al.*, 2024).

Based on the background above, the author considers it necessary to conduct research so that the process of joining different types of materials (dissimilar) between aluminum AA 5052 and aluminum AA 6061 becomes more efficient and becomes a method of joining different materials (dissimilar) according to industrial needs. So on this occasion the author will raise the theme of research with the title "Comparative Analysis of the Strength of Mechanical Properties of Aluminum Welding Joints with Variations of AA 5052 and AA 6061 Plates".

2. RESEARCH METHOD

The research method is a way to scientifically account for the implementation and results of research (McNulty *et al.*, 2019). In this study, the experimental method was used, namely a method used to find the relationship between two or more influential factors (Aithal & Aithal, 2020). The experiment was carried out in a laboratory with conditions and equipment that were adjusted to obtain data on the effect of the comparison of the strength of the mechanical properties of aluminum welding joints with AA 5052 and AA 6061 plate variations.

The research was conducted at the Medan State Polytechnic campus in the material testing laboratory and mechanical workshop of Mechanical Engineering. The research implementation period starts from February - August 2024.

Cutting of materials and making of aluminum 5083 welds were carried out at Harapan Jaya Welding Workshop, Medan. Then the TIG (Tungsten Inert Gas) welding process was carried out at Sinaga Steel Welding Workshop, Medan. After the welding process, bending and tensile tests were carried out at the Medan State Polytechnic Laboratory.

The tools and materials used in this research are as follows :

a) Tool :

1. Grinding machine.

Machine grinder used for cutting aluminum plate specimens.



Figure 1. Machine grinder

Source: Personal Documentation (2025)

2. Oxy Acetylene welding machine



Figure 2. Oxy acetylene welding machine

Source: Personal Documentation (2025)

3. Universal Testing Machine



Figure 3. Tensile testing machine

Source: Personal Documentation (2025)

4. Vise

5. Graph paper

6. *Whiteboard marker*
- b) Material :
1. 6061 aluminum alloy plate
 2. 5052 aluminum alloy plate

This research was conducted in several stages, including the following:

Preparation of tools and materials

- a. The tools and materials prepared are as previously mentioned in this research.
- b. Preparation of AA 6061 and AA 5052 specimens for welding workpieces. The workpieces used in this research are a pair of aluminum alloy 5052 and aluminum alloy 6061 with the shape and size as shown in the following picture:

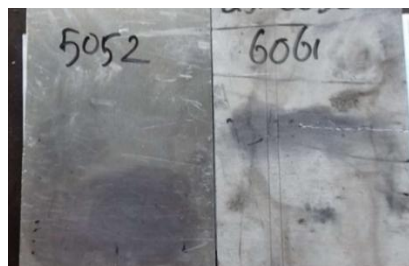


Figure 4. AA 5052 and AA 6061 plate specimens
Source: Personal Documentation (2025)

- c. Workpiece welding process

The connection stage is carried out by skilled workers who have experience in the connection stage of *Oxy Acetylene welding* aluminum plates. The connection stage uses an ER 5356 type *electrode* which has a diameter of 3.2 mm with a gas pressure condition on oxygen of 1 - 2 bar then for oxygen gas pressure of 0.5 bar. The connection condition used is 1G (*Down hand*). The welding process can be seen in Figure 5. Below.



Figure 5. Welding specimen a). specimen before welding b). welding process at the joint specimen
Source: Personal Documentation (2025)

3. RESULTS AND DISCUSSIONS

3.1 Mechanical Properties of Aluminum Base Metal Material

To ensure that the parent metal used in Friction stir welding (FSW) is aluminum alloy material AA 5052 and AA 6061 by considering its chemical composition and mechanical properties. The following table 1 shows the results of testing the chemical composition and mechanical properties.

Table 1. Chemical composition of aluminum AA 5052 and aluminum AA6061

Element	Chemical Composition (%)									
	Si	Fe	Cu	M N	Mg	Cr	This	Zn	You	Zr
AA5052	0.35	0.40	0.10	0.10	2.2-2.8	0.15 – 0.35	-	0.10	-	-
AA6061	0.64	0.2	0.19	0.06	1.0	0.15	-	0.05	0.07	

From table 1, the main element composition of the dominant parent metal aluminum alloy is obtained, which consists of Magnesium (Mg), Silica (Si) which corresponds to the main aluminum alloy series 6xxx (Al-Mg-Si) and Series 5xxx which consists of Magnesium (2.2-2.8%).

3.2. Results of the Testing Process of AA 5052 Aluminum and AA 6061 Aluminum Specimens

After the welding process is complete, the results of *the oxy acetylene welding are then tested*, the next stage is the mechanical properties testing of the material, namely Tensile testing and bending testing. The process and results of mechanical properties testing of tensile testing and bending testing can be explained as follows:



Figure 6. a). Tensile test specimen b). Testing pull c). result testing pull
Source: Personal Documentation (2025)

From the tensile test results, the fracture position that occurs can be known. Figure 6 above shows one example of a fracture that occurs in the tensile test results for Specimen AA5052 and specimen AA6061. Where the type of fracture that occurs is different in each *feeding*. In feeding specimen AA5052, two fractures occur in the area around the parent metal, in feeding specimen AA6062, the fracture occurs in the HAZ (*Heat Affected Zone*) area of metal that is in contact with other metals during the welding process near *the nugget zone*.

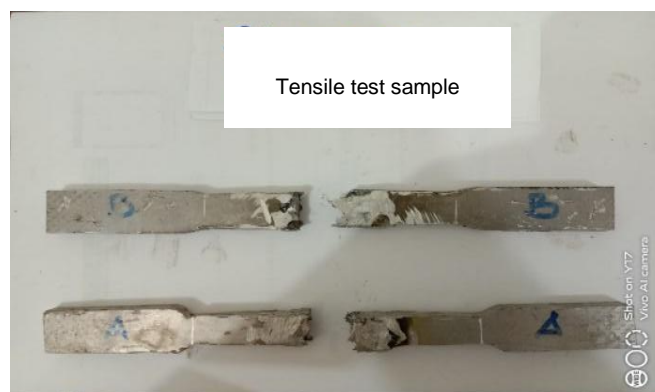


Figure 6. Test results pull
Source: Personal Documentation (2025)

From the image above, it can be seen that the fracture of the specimen is in the welding area. From the tensile test data on the AA5052 and AA6061 Specimen materials, the results of tensile strain, tensile stress, max force, brake force and elasticity can be obtained.

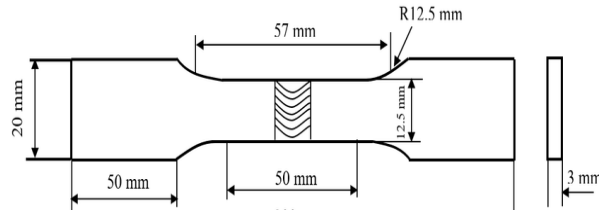


Figure 7. Tensile test specimen design (ASTM E8)
Source: Personal Documentation (2025)

Based on the test data above, the following mechanical properties of the material were obtained:

Welding tensile strength

1. Tensile strength is the ability of a material to not experience deformation or change in shape from a given load or tensile force. The tensile strength value can be obtained by testing using a tensile testing machine.
This limit shows the load that the test object can withstand before breaking. Tensile strength is the maximum load divided by the initial surface area of the specimen.

$$\sigma_u = \frac{F_u}{A_0} (\text{MPa}) \dots\dots\dots(1)$$

Where :

$$A_0 = W_0 \times T_0 (\text{mm}^2) = 12.5 \text{ mm} \times 10 \text{ mm} = 125 \text{ mm}^2$$

So the data from the tensile test calculation is obtained as follows:

$$\sigma_u = \frac{7900}{125} = 63.2 \text{ Mpa}$$

2. Welding Result Strain

Strain is the percentage increase in length obtained by dividing the increase in length after breaking by the initial measurement length of the test object.

$$\begin{aligned} \epsilon = x &= \frac{L_i - L_0}{L_0} \times 100 \% \dots\dots\dots(2) \\ &= \frac{(51,4 - 50)}{50} \times 100\% = 2.8\% \end{aligned}$$

3. Presentation subtraction wide surface on specimen

Tensile loading on the specimen is done continuously by adding loads will result in changes in the shape of the test object in the form of an increase in length and a reduction in the surface of the test object and will result in fracture. The percentage of shrinkage that occurs is expressed by the following formula :

$$r = \frac{A_0 - A_i}{A_0} \times 100 \% \dots\dots\dots(3)$$

Where:

$$A_0 = W_0 \times T_0 (\text{mm}^2) = 12.5 \text{ mm} \times 10 \text{ mm} = 125 \text{ mm}^2$$

$$A_i = W_i \times T_i (\text{mm}^2) = 12.35 \text{ mm} \times 9.85 \text{ mm} = 121.64 \text{ mm}^2$$

So that calculation his become:

$$r = \frac{A_0 - A_i}{A_0} = \frac{125 - 121,64}{125} \times 100 \% = 2,68 \%$$

4. Modulus of Elasticity (E)

At this limit shows the stiffness value of a material and the level of load that can be withstood by the test object with elastic deformation. The elastic modulus is the magnitude of the maximum tensile strength divided by the strain of the object. test.

From the tensile test, it was obtained that $\sigma_u = 118.6 \text{ MPa}$ and strain $\epsilon = 0.026$, so the elastic modulus value can be obtained using the equation above, namely:

$$\begin{aligned} E = E &= \frac{\sigma_u}{\epsilon} = \frac{63,2}{2,8} \dots\dots\dots(4) \\ &= 22.57 \text{ N/mm}^2 \end{aligned}$$

Using the same calculation method. The complete analysis results for tensile strength can be seen in the discussion below. After performing the calculation, the tensile test data can be compared with the certified tensile test data from the factory which can be seen in table 4.2 below.

Table 2. Comparison of tensile test results data

Material	Mechanical property parameters	Mechanical property values	
		Test results	Factory certificate
AA502	Tensile Strength (σ_u)	63.2 MPa	170 Mpa
	Strain (ϵ)	2.8%	>10%
AA601	Tensile Strength (σ_u)	78.4 MPa	290-315 Mpa
	Strain (ϵ)	2.4%	9-13%

Table 2 presents a comparison between the tensile test results and the factory certificate values for two materials, namely AA502 and AA601. The mechanical properties evaluated include tensile strength (σ_u) and strain (ϵ). Based on the test results, the tensile strength of AA502 is 63.2 MPa, which is significantly lower than the factory-specified value of 170 MPa. Similarly, AA601 shows a tensile strength of 78.4 MPa, whereas the factory certificate indicates a much higher range of 290–315 MPa. In terms of strain, AA502 recorded a value of 2.8%, far below the factory expectation of greater than 10%, while AA601 exhibited a strain of 2.4%, compared to the factory's 9–13% range. These discrepancies suggest that both materials did not meet the mechanical property standards as specified by the manufacturer. Possible reasons for this mismatch may include material degradation, improper heat treatment, differences in production batches, or errors during the testing process. Further analysis would be necessary to determine the exact cause of the deviation and ensure the materials' reliability for their intended application.

4. CONCLUSION

Based on the tensile test results on both specimens, it was found that the AA6061 Aluminum specimen had the highest tensile strength of 78.4 MPa. However, this value is relatively small, so the specimen is brittle and unable to withstand large loads. The quality of the welding joints is also poor as seen from the tensile test results, which is caused by irregularities in the welding process. This occurs because the oxy acetylene welding wire does not adhere well to the surface of the specimen, resulting in many cavities in the welding results. In the flexural test, the AA6061 specimen showed the highest flexural stress value of 70.44 MPa without any fracture in the weld metal, although there were cracks on the underside of the welding results. Meanwhile, the AA5052 specimen had the lowest flexural strength value of 50.1 MPa and experienced fracture in the weld metal. Overall, the welding results using the Oxy Acetylene Welding method in this study were defective, which was caused by the uneven melting of the welding wire during the welding process.

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Praise and gratitude writer raise it to the presence of God Almighty above all His mercy and grace, so writer can finish report study this is the one entitled "Comparative Analysis Mechanical Properties Strength Connection Welding Aluminum With Variations of AA 5052 and AA 6061 Plates". Research This No will completed without help from various the party that has give support Good in a way morale and also technical. Author convey accept the greatest love to lecturer the mentor who has guide and provide directions during the research process, as well as to all over staff and technicians in the Laboratory Material Testing and Workshop Mechanics Department of Mechanical Engineering Medan State Polytechnic above assistance and facilities that have been given. Speech accept thanks also to the author convey to family beloved on prayers, support and encouragement that are endless stop, and to colleagues who have give help and motivation during the research process ongoing. Author realize that report This Still own deficiency, therefore That the author really hopes constructive criticism and suggestions for future improvements.

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