Effect of Heat Treatment and Anodizing of Aluminum 2024 on Hardness Test and Impact Test

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Abstract

Aluminum alloy 2024 is an alloy that is widely used in the aircraft industry, especially in the structure. This research was carried out with the Vikers hardness test method and the Charpy Impact test to determine the mechanical properties of the 2024 Aluminum alloy after going through the Solution heat treatment process with a temperature of 505oC with variations in natural aging time for 5, 7, 9, 11 days and through the Anodizing process with a time of 30 minutes and carried out Vikers hardness testing and Charpy Impact testing. The final results obtained in the Vickers hardness test obtained the highest average value in specimens that went through solution heat treatment with variations in natural aging time for 11 days and through the anodizing process of 80.2 HVN. Heat treatment and anodizing can improve mechanical properties in terms of toughness and hardness of the material, namely by using a stable temperature during heat treatment. In the Impact test, the highest average toughness value is obtained in specimens that go through solution heat treatment with a variation of natural aging time for 11 days and through the anodizing process of 0.76 J/mm². This shows that the Heat Treatment and Anodizing process affects the hardness and impact value of 2024 aluminum.

Keywords: Aluminum Alloy 2024, Heat Treatment, Aging, Anodizing, Mechanical properties.

INTRODUCTION

The development of the global aviation industry is rapid. The demand for technology and the demand for strong and lightweight aircraft structures challenge several aviation industries as they compete to meet consumer demand. This development has also greatly affected the development of the metal material industry. When metal materials are used in aircraft structures, various evaluations must be made until the metal is deemed suitable for the aircraft structure. Because in the use of materials for aircraft, lightweight and strong materials are required.

Aluminum is the most abundant element in the atmosphere and third in use and production. If present in nature, it is about 8% in nature. This is why aluminum is often combined with certain material elements to meet industrial needs. In the aircraft industry, aluminum is widely used in most parts of the aircraft, especially the fuselage, which requires large-sized materials, light weight, low manufacturing costs, and long service life, high corrosion resistance and good.

In addition to making aluminum alloys with other materials, people also perform surface coating, also known as surface treatment on aluminum. Anodizing is an electroplating process to improve its mechanical and protective physical properties. During the anodizing process, aluminum is connected at the anode so that its surface undergoes an oxidation reaction and forms an oxide layer on the surface which makes it a surface coating. Anodizing turns the aluminum surface into aluminum oxide which forms a layer on the surface of the object.

Andika Wisnujati (2023) about Characterization of Anodizing Process on Aluminum Series 6 with Variable Voltage. The voltage in anodizing has a big effect on the variable voltage of 20, 24, and 28 V in 10 minutes the surface hardness value on Aluminum series 6 before anodizing is 54.58 VHN on raw materials. Hardness value of the material decreases with the increase of variable voltage. The same is shown in the graph of the effect of voltage change on pore diameter. The graph shows a continuous decrease as the voltage increases. The highest hardness value with a voltage variation of 20

V and obtained at 59.117 HVN, obtained by a voltage variation of 24 V at 58.723 HVN, and the lowest hardness value with a voltage of 28 V obtained 57.718 HVN.

Suhair Ghazi Hussein (2020) on Effect of Heat Treatment on Mechanical and Vibration Properties for 6061 and 2024 Aluminum Alloys. The mechanical properties of 2024 aluminum alloy material are better than the mechanical properties of 6061 aluminum alloy material., also modifying the mechanical properties of 2024 alloy by heat treatment is better than the modification of mechanical properties for 6061 alloy.

Yanto Budi Prasetya (2022) on Optimization of Wear Parameters of 2024 Aluminum Alloy in Natural Aging Heat Treatment. Based on the results of the above research, it can be concluded that the parameter that has the greatest effect on increasing the wear resistance of 2024 aluminum alloy is the cooling medium, namely water followed by aging time, natural aging for 5 days.

Diki Aditia (2019) the effect of current variation and anodizing time type hard procces on aluminum surface hardness. In the calculation results, the higher the current density used, the thicker the layer obtained. The anodizing process can significantly increase the hardness of the surface layer of 6061 aluminum alloy material from 107.03 HVN to 301.03 HVN within 30 minutes and a current density of 2.8 Ampere/dm2. At 40 minutes and current densities of 2.8 Amps/dm2, 3 Amps/dm2, 3.6 Amps/dm2 provide stable stiffness against other Time variations. There is a decrease in hardness after 50 minutes and a current density of 2.8 Amps/dm2, 3 Amps/dm2, 3.6 Amps/dm2 because the anodizing solution is not replaced so that the anodizing solution becomes saturated and the oxidation reaction slows down. The hardness value produced on the surface of 6061 aluminum alloy appears on the material with a test piece with a time variation of 30 minutes and a current density of 2.8 Ampere/dm2 of 301.03 HVN.

METHOD

The test material specified for this test is Aluminum alloy 2024. This test material has passed the Solution Heat Treatment process with a variation of aging and anodizing time for 30 minutes. Furthermore, the specimen is formed into a slab and then 10 specimens are made which are used in Vickers hardness testing and Charpy impact testing.

Specimen Making

a) Vickers Testing Specimens

The seed material used for this research is an aluimine alloy with magneisiuim enhancer that has undergone several stages of processing and heating. The mateirial teirseibuit beirbeintuik leimbaran keimuidian diceitak meinjakan 10 pattern deingan meital cuitteir sheieit at Hangar Sheieit Meital Shop AMTO 147D/10 Politeiknik Peineirbangan Suirabaya. The equipment was manufactured to ASTM Ei92 which was used in the Vickeirs test. Skeitsa and dimeinsi mateirial will be the material for vickeirs, namely:

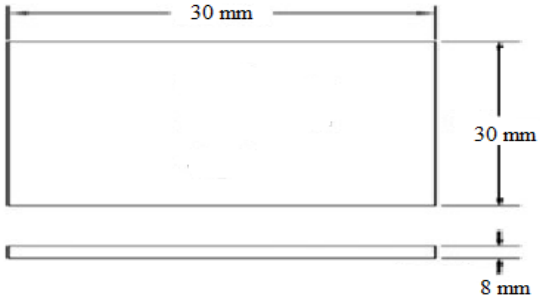

Figure 2. 1 Specimen vickers

2.1.2 Charpy Impact Testing Specimen

The test material used in the tensile test is 2024 aluminum alloy, with dimensions of 55mm x 10mm x 10mm according to ASTM E23, as shown in the figure below.

Figure 2. 2 Specimen impact

b) Heat Treatment

The first step was carried out after forming the samples for each test, namely solution heat treatment was carried out on all samples with a temperature of 505°C and a sample holding time of 1 hour. After the solution heat treatment is carried out on all samples, the next step is cooling in aqueous media for 3 minutes. The last stage is natural weathering for all test specimens with variations in holding time of 5 days, 7 days, 9 days and 11 days. The following are the test steps:

1. The part is put into an oven at 505°C and held for 1 hour. 2. When the holding time reaches 1 hour, the part is removed from the oven with tongs, and then quenched with water-based coolant for 3 minutes at 26-27oC.

3. Allow the remainder to cool to room temperature in water.

4. After the part passed the solution treatment and cooling stages, natural aging was performed by placing the part at room temperature from 15oC to 25oC and

changing the holding time from 5 days to 7 days, 9 days, 11 days.

5. After the natural aging treatment, the part is ready for the next step.

c) Anodizing Procces

1. Sanding The process in which the test specimen is sanded with metal sandpaper to remove dirt from the aluminum surface. After the sanding process is complete, the sample is washed with RO (reverse osmosis) water.

2. Cleaning process where the sample is washed or cleaned with sodium carbonate solution (Na2CO3) as the main raw material for making detergents with the aim of increasing the cleaning ability of the washing process, the concentration used in the process is (10 gr/liter) RO (reverse osmosis) water. Cleaning is done in 5 minutes. The function of this procedure is to clean the sample from dirt from sanding and polishing, but also to clean oil from the pores of bare hands and dust from the surface of the sample. The sample is then rinsed with permeation water.

3. Corrosion process is the process of removing the oxide layer on the aluminum surface that cannot be removed by the previous process, either cleaning or rinsing. In addition, this process results in a flatter and smoother part surface. In the corrosion process using caustic soda (NaOH) with a concentration of (100 g/liter) RO (Reverse Osmosis) water, use a plastic bath at room temperature for corrosive solutions ± 28-30 ° C, then specimens that have passed the cleaning and washing process are immersed in the peeling solution for ± 5 minutes. After etching is complete, the sample is washed with reverse osmosis water.

4. After cleaning and etching, the next step is reduction. The Desmut process is a process that removes carbon from aluminum. The term carbon itself is a thin gray to black layer of aluminum alloy that forms a metal that cannot dissolve in corrosive solutions. It also gives a polished effect (Deep Shine) to the surface of the aluminum metal. In this process, the sample is immersed in a desmut solution containing 75% phosphoric acid (H3PO4), 15% sulfuric acid (H2SO4) and 10% acetic acid (CH3CO2H), using a plastic bath at room temperature. desmut solution, which is ±28-35°C, for 5 minutes. After removal, the samples were washed with RO (reverse osmosis) water. 5. In this procedure, the samples were immersed in a plastic tub containing sulfuric acid solution (H2SO4) mixed with osmotic water (reverse osmosis), with a concentration of sulfuric acid solution (H2SO4) of 400ml d and water of 600ml. osmosis (reverse osmosis) and the temperature was recorded as 29°C to 47°C. In the anodic oxidation process, the workpiece is the anode (+) and the conductive aluminum is the cathode (-). Before immersing the sample in the solution, first adjust the amount of strain used. The voltage used in this procedure is 24 V. In addition, the current on the power supply is adjusted after the sample is immersed in a 2 Amp current solution. The immersion time was 30 minutes. After anodic oxidation is complete, it is washed with RO (reverse osmosis) water before continuing with the immersion process.

5. After the oxide layer is formed by anodic oxidation, the next step is the dyeing process. In this process, the material is immersed in a dye solution (15 gr/liter) of RO (reverse osmosis) water for 5 minutes. This coloring process serves to give the desired color to add decorative value to metallic aluminum, but also serves as a protective layer of oxide layer.

6. Sealing process to close the pores of the oxide layer formed during the anodic oxidation process, while also having a color locking effect. This process uses acetic acid solution (50 gr/liter) RO (Reverse Osmosis) water, with a soaking time of ± 5 minutes.

7. After the sample has been anodized, it will undergo testing.

d) Data Retrieval Technique

In collecting the data needed in my Final Project is to do vickers testing

- Vickers Hardness Testing

Vickers hardness testing uses one type of indenter, a pyramid-shaped diamond indenter that can be used to test almost all types of metals ranging from soft to hard. The Vickers hardness testing procedure is as follows:

Before testing the specimen is sanded so that the surface is flat and smooth.

1. Prepare the Vickers hardness test device on the Universal Hardness Tester:
2. Install a 60 kgf (588 N) load pendulum.
3. Indenter used Diamond pyramid indenter (diamond pyramid).
4. Place the specimen on the anvil.
5. The handle is set in the up position.
6. The indenter is pressed into the specimen by turning the disk clockwise until the large needle on the scale rotates 21/2 times and the small needle points to 3. If it feels heavy, do not force it but must be turned back and repeated. (micro range 10g - 1000g and micro range 1kg - 100kg).

7. Slowly release the handle forward. Do not push the handle down, but let the handle move itself downward. The large needle on the scale will move as the handle goes down. Wait for the large needle on the scale to stop on its own.
8. Wait for 10 - 20 seconds (usually 15 seconds).
9. Measure the 2 diagonals of the square (rhombus) indentation that occurs using the measuring microscope. (measure carefully and find the average).

- Charpy Impact Testing

The purpose of this test is to determine the value of hardening and impact strength on the test specimen after being given heat treatment. Impact testing is done using the Charpy method. The researchers chose the Charpy method because it provides more accurate test results. The steps that can be used are:

1. The specimen is cleaned from the remaining scale that occurs in heat treatment.
2. Each specimen with a different holding time is marked so that the data to be taken is not confused.
3. Because it uses the charpy method, place the workpiece horizontally on the support with the notch right in the middle, the notched part is placed on the inside so that the pendulum will hit the test object on the side opposite to the notched side of the specimen.
4. Next, the striking hammer is set at a certain height.
5. Set the measuring instrument according to the predetermined amount.
6. The hammer is released at a height and then hits the specimen on the outside of the specimen.

The energy received by the specimen is calculated based on the difference in hammer potential energy before and after the beating (can be seen directly on the scale of the testing machine).

- Data Analysis Technique

I will display the test results data in the test table below as a comparison between the test object variables

Table 2. 1 Testing Table

Material	Solution Heat Treatment Temperature	Natural Aging Time	Anodizing Time	Hardness Test	Impact Test
Aluminium 2024	-	-	-		
Aluminium 2024	-	-	30 Minutes		
Aluminium 2024	505°C	5 Day	-		
		7 Day			
		9 Day			
		11 Day			
Aluminium 2024	505°C	5 Day	30 Minutes		
		7 Day			
		9 Day			
		11 Day			

RESULTS

Research Results

In this study, two tests were carried out, namely Vickers hardness testing and charpy impact testing to determine the strength of the mechanical properties of aluminum alloy 2024 with treatment. In addition, the test results obtained data on the distribution of impact strength and Vickers hardness values on each specimen that has gone through the Solution Heat Treatment process with variations in Natural Aging and Anodizing time.

Vickers Hardness Test Results

From the data of the vickers hardness test results of aluminum alloy 2024 specimens with solution heat treatment and anodizing to find out each different specimen hardness value with variations in holding time for 5 days, 7 days, 9 days and 11 days.

The hardness value of Aluminum Alloy 2024 after being treated with Solution Heat Treatment with variations in Natural Aging time and Anodizing process has increased in hardness value. In this test using Natural Aging time variations of 5, 7, 9 and 11 days and the Anodizing process. The hardness test data can be seen in the following table.

Table 3. 1 Data Recapitulation of Vickers Hardness Test Results

Material	Natural Aging Time	Anodizing Time	Point 1	Point 2	Point 3	Average test results (HVN)
Aluminium 2024	-	-	53,4	54,7	53,2	53,76 HVN
Aluminium 2024	-	30 Minutes	63,3	64	63,7	63,6 HVN
Aluminium 2024	5 Day	-	67,8	66,2	66,7	66,9 HVN
Aluminium 2024	7 Day	-	69,8	69,4	69,7	69,6 HVN
Aluminium 2024	9 Day	-	73,2	74,8	74,6	74,2 HVN
Aluminium 2024	11 Day	-	77,6	78,6	77	77,7 HVN
Aluminium 2024	5 Day	30 Minutes	73,2	73	72	72,7 HVN
Aluminium 2024	7 Day	30 Minutes	77,3	76,2	76	76,5 HVN
Aluminium 2024	9 Day	30 Minutes	79,2	78,2	78	78,4 HVN
Aluminium 2024	11 Day	30 Minutes	80,6	81,2	81,8	81,2 HVN

In the vickers hardness test results, it can be seen that the aluminum alloy 2024 specimens with Solution Heat Treatment treatment with variations in Natural Aging time and Anodizing process increased in line with the increase in aging time used. The highest hardness value is located in specimens with natural aging time of 11 days and through anodizing process of 81.2 HVN, while the lowest hardness value is located in 2024 aluminum specimens with anodizing process of 63.6 HVN. This value is greater when compared to the hardness value of the RAW material specimen which is 53.76 HVN which is not heat treated and acts as a comparison in this study. The increase in the hardness value of this specimen is due to the grains in the material starting to close together, indicating that there has been a hardening process in the material precipitates which results in an increase in material hardness as well as the anodizing process which provides an additional layer on the surface of the material according to the following graph.

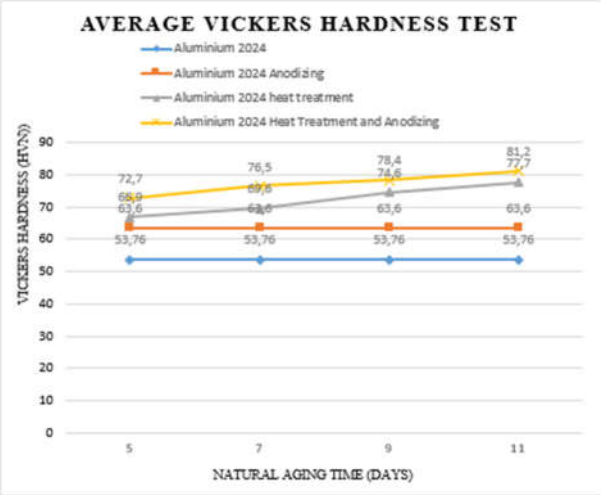

Figure 3. 1 Graph of Vickers Hardness Test Results

Based on the test results of aluminum alloy 2024 specimens that have gone through the solution heat treatment process with variations in natural aging time of 5 days, 7 days, 9 days, and 11 days. The following table shows the best results from testing each specimen with certain treatments.

Charpy Impact Test Results

This test serves to determine the mechanical properties in the form of impact strength on specimens with existing standards. The specimens used in this test go through the Solution Heat Treatment process with Natural Aging variations of 5, 7, 9, and 11 days and through the Anodizing process with 30 minutes. The following is the data from the impact testing data:

Table 3. 2 Charpy Impact Test Result Data

Material	Natural Aging Time	Anodizing Time	W (kg)	L (m)	α (°)	β (°)	Capacity Absorbed	HI (J/mm²)	Average Charpy Impact Test (J/mm²)
Aluminium 2024	-	-	13,17	0,6	140	96	3,713	0,37	0,36
						96	3,920	0,38	
						100	3,511	0,34	
Aluminium 2024	-	30 Minutes	13,17	0,6	140	76	5,974	0,59	0,56
						78	5,772	0,57	
						82	5,365	0,52	
Aluminium 2024	5 Day	-	13,17	0,6	140	84	5,159	0,51	0,53
						79	5,671	0,56	
						81	5,467	0,54	
Aluminium 2024	7 Day	-	13,17	0,6	140	82	5,365	0,52	0,56
						78	5,772	0,57	
						76	5,974	0,59	
Aluminium 2024	9 Day	-	13,17	0,6	140	77	5,873	0,58	0,58
						79	5,671	0,56	
						75	6,074	0,60	
Aluminium 2024	11 Day	-	13,17	0,6	140	73	6,273	0,61	0,57
						70	6,567	0,54	
						78	5,772	0,57	
Aluminium 2024	5 Day	30 Minutes	13,17	0,6	140	74	6,174	0,60	0,62
						75	6,074	0,60	
						69	6,664	0,66	
Aluminium 2024	7 Day	30 Minutes	13,17	0,6	140	65	7,045	0,70	0,69
						61	7,413	0,73	
						70	6,567	0,65	
Aluminium 2024	9 Day	30 Minutes	13,17	0,6	140	54	8,023	0,80	0,74
						63	7,231	0,71	
						61	7,413	0,73	
Aluminium 2024	11 Day	30 Minutes	13,17	0,6	140	53	8,107	0,80	0,76
						57	7,766	0,77	
						62	7,322	0,72	

The test results show that specimens that have gone through the Solution Heat Treatment process with variations in Natural Aging time and through Anodizing have increased impact strength, this can be seen from the graph below.

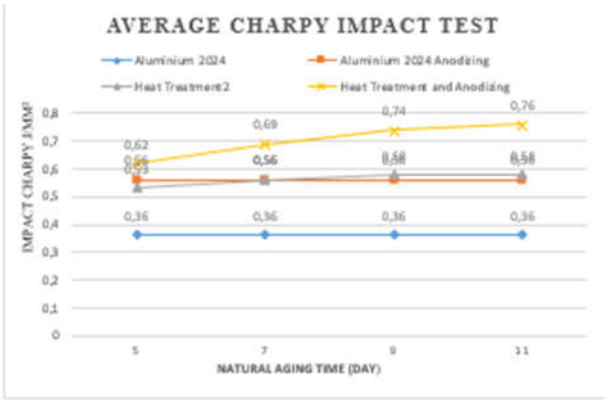

Figure 3. 2 Graph of impact test results

From the impact test data that has been converted into a graph, on the graph it can be seen that the impact strength value has increased to the highest value in the natural aging time variation for 11 days and through the anodizing process of 0.76 J/mm² while the lowest impact strength value is located on the 2024 aluminum specimen without natural aging time variation and anodizing process of 0.36 J/mm².

Discussion of Research Results

Table 3. 3 Data Recapitulation of Research Results

Material	Temperatur Solution *Heat Treatment*	Natural Aging Time	Anodizing Time	Best Results of Hardness Test	Best Results Impact Test
Aluminium 2024	-	-	-	53,76 HVN	0,36 J/mm²
Aluminium 2024	-	-	30 Minutes	60,1 HVN	0,56 J/mm²
Aluminium 2024	505°C	5 Day	-	66 HVN	0,53 J/mm²
		7 Day	-	69,1 HVN	0,56 J/mm²
		9 Day	-	72,8 HVN	0,58 J/mm²
		11 Day	-	73,2 HVN	0,58 J/mm²
Aluminium 2024	505°C	5 Day	30 Minutes	74,1 HVN	0,62 J/mm²
		7 Day	30 Minutes	76,5 HVN	0,69 J/mm²
		9 Day	30 Minutes	77,3 HVN	0,74 J/mm²
		11 Day	30 Minutes	80,2 HVN	0,76 J/mm²

Based on the research results above, solution heat treatment with variations in natural aging and anodizing time can improve the mechanical properties of 2024 aluminum using the vickers hardness test and charpy impact. In table 4.5, the best result of the vickers hardness test is aluminum 2024 that has gone through the solution heat treatment process with a natural aging time of 11 days and through the anodizing process with a result of 77.3 HVN. While the best charpy impact test results are 2024 aluminum that has gone through the solution heat treatment process with a natural aging time of 11 days and through the anodizing process with a result of 0.76 J/mm2.

CONCLUSION

Dalam pengujian yang dilakukan, dapat kita ambil beberapa kesimpulan sebagai berikut:

1. Proses anodizing dapat mempengaruhi sifat mekanis dari aluminium 2024. Pada hasil uji aluminium 2024 dengan proses anodizing memiliki peningkatan kekerasan dari 53,76 HVN menjadi 60,1 HVN dan peningkatan terhadap uji impact dari 0,36 J/mm2 menjadi 0,56 J/mm2 . Proses anodizing terhadap spesimen aluminium 2024 yang melalui proses solution heat treatment dengan variasi waktu natural aging 5, 7, 9, 11 hari terlebih dulu dapat mempengaruhi sifat mekanisnya. Pada uji kekerasan spesimen yang telah melalui solution heat treatment dengan variasi natural aging mendapat hasil terbaik 73,3 HVN setelah proses anodizing menjadi 80,2 HVN. Sedangkan pada uji impact spesimen yang telah melalui solution heat treatment dengan variasi natural aging mendapat hasil terbaik 0,74 J/mm2 setelah proses anodizing menjadi 0,76 J/mm2.

2. Solution Heat Treatment process with Natural Aging time variations of 5, 7, 9, 11 days can affect the mechanical properties of 2024 aluminum specimens through hardness and impact tests. The results of the 2024 aluminum hardness test are 53.76 HVN after going through the solution heat treatment process with natural aging variations have the best 73.2 HVN. While the impact test results of aluminum 2024 are 0.36 J/mm2 but after going through the solution heat treatment process with natural aging variations have the best 0.57 J/mm2.

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