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The Effect of Variation of Aluminum Thickness Series 7075 in Heat Treatment Solution on Tensile Strength and Microstructure

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Abstract. This research was conducted to examine the comparison of tensile strength and microstructure between two different aluminum heat treatments. This study aims to compare the microstructure and tensile strength of aluminum 7075 specimens after undergoing solution heat treatment at a temperature of 495˚C with soaking time for 30 minutes and experiencing quenching cooling and those without solution heat treatment. The data collection process was carried out by conducting tensile testing and microstructural testing with two specimens each. The test results will be analyzed using tensile strength data and visual microstructure analysis. From the results of the analysis of tensile and microstructural test data, it can be concluded that only the 7075 aluminum specimen with a thickness of 1.4 mm shows the greatest decrease in tensile strength and spread of Mg-Zn and Fe-Al particles, when compared to specimen 7075 with a thickness of 0.6 mm which on the other hand, undergo the separation of Mg-Zn and Fe-Al particles. Meanwhile, the Al 7075 specimen with a thickness of 2.5 mm, the changes that occur only in the diffusion of Mg-Zn particles, which have a slight spread, appear a little faint.

Introduction

The aircraft industry has demands for lightweight and strong materials to be utilized as a part of the aircraft fuselage [1]. In making aircraft, PT Dirgantara Indonesia has various stages and processes in processing aluminum metal as the main ingredient in the structure of an airplane, one of which is the heat treatment process. In the heat treatment of aluminum alloys, there are several types of heat treatment, for example, such as annealing heat treatment, solution heat treatment, artificial aging, and stress relief [2]. The purpose of heat treatment is to change the physical and mechanical properties of aluminum metal to suit the needs of the production process [3].

The various types of non-ferrous metals and types of heat treatment, the author chose the aluminum 7075 T6 series because it is most widely used in aircraft components and wanted to examine more deeply whether the impact of thickness on changes in microstructure and mechanical properties would be very different if the same heat treatment was carried out. As well as the heat treatment solution heat treatment was chosen by the author because research on solution heat treatment on non-ferrous metal 7075 aluminum series is very important because the aluminum 7075 series has a very important role in aircraft components [4].

The aluminum 7075 series is widely used as an aircraft component due to its high strength and low density [5]. Solution heat treatment carried out on 7075 aluminum can cause a gradual increase in the hardness value during heat treatment at a maximum temperature of 460°C and will decrease the hardness value if the heat treatment is carried out at a higher temperature [6].

Temperature variations in solution heat treatment can affect the value of hardness and grain roughness of the 7075 series aluminum microstructure. The author chooses a thickness variation on the 7075 aluminum specimen, namely 0.6 mm, 1.4 mm, and 2.5 mm with the aim of examining what the differences are in each thickness.

Methods

The material in this study is aluminum sheet 7075. 7075 aluminum alloy is an aluminum alloy, with zinc as the primary alloying element. The thickness of our aluminum sheet is made with variations of 0.6 mm, 1.4mm, and 2.5 mm. For each specimen, we clean the surface first before heat treatment. Heat treatment of Al 7075 specimens has been carried out in the field of heat treatment, Department of Detail Manufacturing Part PT. Indonesian Aerospace. Furthermore, heat treatment is carried out using a dry furnace (Kraft) machine. The solution heat treatment process was carried out at a temperature of 495°C with a long holding time duration of 30 minutes. To obtain a precipitation hardening reaction, a saturated solid solution is required beforehand [7]. For the aluminum alloy material to pass through these conditions, a solution heat treatment process is needed [8]. The purpose of the solution heat treatment process is to make the aluminum material go through a supersaturated solid solution phase, the solution heat treatment process consists of heat treatment at a temperature between the solvus line and the melting point of the phase diagram eutectic until it homogenizes the constituent atomic particle solution. At the solution heat treatment stage, the existing phases are dissolved into a solid solution. The purpose of solution heat treatment itself is to obtain a solid solution that is nearly homogeneous [9].

After the aluminum alloy material is in the supersaturated solid solution for a specified period (soaking time), then the follow-up process is carried out in the form of fast cooling (quenching). Quenching is done so that the solid solution is saturated with aluminum when the solution heat treatment process is in an uncertain condition (condition W). Condition W is an unstable temper that can only be applied to alloys whose strength naturally (spontaneously) changes at room temperature for several months or even years after being subjected to solution heat treatment and then undergo precipitation hardening (aging).

In the next process, each specimen was tested for tensile strength and microstructure. Tensile strength and microstructure tests were conducted at the Metallurgy Laboratory of PT. Indonesian Aerospace. Testing was carried out using the Instron 5982 machine with the ASTM E8, ASTM B557 & IK-UTL-M007 test methods and at room temperature of 25°C. In the tensile test, two repetitions were carried out for each specimen.

Result and Discussion

Tensile Test Results

Tensile tests were carried out with the number of specimens 2 in each condition, with the following results in Table 1.

Table 1. Tensile test results Al 7075

Thickness	Specimen	No.	Max Load (N)	Tensile stress at Max Load (MPa)	Tensile stress at Yield (MPa)	% Strain at After Break
0.6	Before	1	4148.38	525.19	443.76	12.24
0.6	HT	2	4145.02	525.57	445.43	11.44
0.6	After HT	1	3806.26	469.06	291.98	18.76
0.6		2	3704.94	461.7	287.94	20.16
1.4	Before	1	9741.84	545.18	474.04	13.04
1.4	HT	2	9703.86	543.14	473.1	12.96
1.4	After HT	1	8692.73	485.86	288.15	21.2
1.4		2	8674.17	488.01	307.68	22.24
2.5	Before	1	17188.57	545.88	469.69	12
2.5	HT	2	17138.03	545.58	467.71	11.6
2.5	After HT	1	16201.7	512.09	332.5	22.68
2.5		2	16098.3	510.44	328.13	22.44

From the tensile test that has been carried out, the results show that the test specimens that have undergone solution heat treatment have decreased the maximum load strength, decreased the maximum load strength at tensile stresses, and increased elongation. This occurs because the temperature of the solution heat treatment given is high enough which is close to the melting point of the specimen material in the phase diagram. The specific conditions of the T6 material are very important (such as the level of property and other effects of processing variables) for example, temperature, heating time, and material thickness. If overheating occurs, in which the heating of the saturated solid solution (between the solvus line and the melting point) and exceeds the eutectic melting temperature (liquid / melting solution), it can decrease the mechanical properties of the material such as tensile strength, ductility and crack toughness.

The tensile strength and yield strength of alloys gradually increase with an extension of the holding time when the solution temperature is 460°C. Among them, the mechanical properties of the alloy were best at a holding time of 2 hours. When the temperature of the solution treatment was 470°C, the yield strength and tensile strength showed an increase and then a decrease with increasing holding time. At this time, the renewal value has changed little. The comprehensive properties of the alloy are best when the holding time is 1 hour. The yield strength, tensile strength, and elongation of the alloy began to decline at a solution temperature of 480°C. Compared to solution temperature, the comprehensive properties were best at 470°C, followed by 460°C, and worst at 480°C. In aluminum 7075-T6 the heating process of solution treatment and the aging process with a predetermined temperature and time changes the larger granules present in the aluminum alloy [10]. The decreased tensile strength changes due to the quenching cooling process and too long heating time [11].

On the other hand, the flame heating and discharge treatment processes Cooling water against aluminum 7075 cause the specimen to become brittle with a hardness value of 93.43 VHN because it uses a coolant flow rate variation of 1000 cc/minute. As well as the impact strength value given in flame heating heat treatment without aging with a coolant flow rate variation of 1000 cc/minute shows the highest value than the coolant variation of 1400 cc/minute. This shows that the greater the flow rate of the coolant, the lower the value of the impact strength of the material.

Then the temperature of the solution heat treatment is getting closer to the melting point will cause an increase in the diameter of the constituent atoms, which causes a decrease in tensile strength. Thus, the fast heating and cooling process that is carried out causes a decrease in the tensile load strength, causing the Al 7075 material to become softer.

Microstructure Test Result Data Microstructure

Microstructure tests were carried out on the specimens before and after heat treatment, with the results shown in Figure 1:

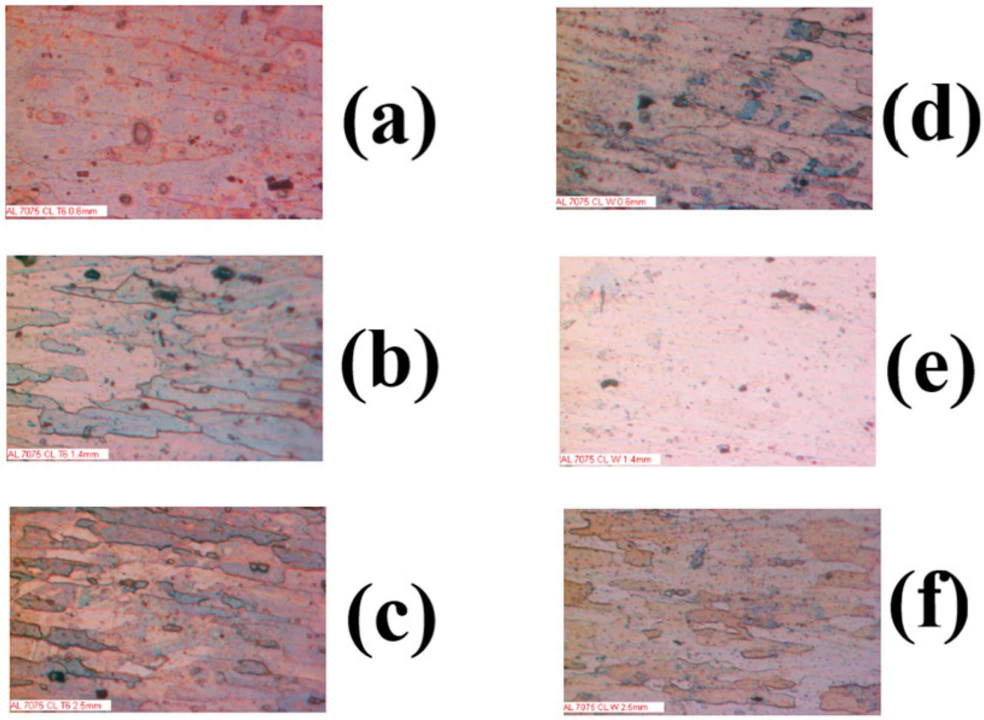

Figure 1. Microstructure of Al 7075 before and after HT

(a) Al 7075 0.6mm before HT (d) Al 7075 0.6mm after HT

(b) Al 7075 1.4mm before HT (e) Al 7075 1.4mm after HT

(c) Al 7075 2.5mm before HT (f) Al 7075 2.5mm after HT

Mg-Zn (dark gray) fine particles are deposited at a lower temperature, during heating or cooling from the annealing temperature [12]. Meanwhile, the insoluble FeAl particles (dark gray) were not affected by the annealing treatment [13]. As shown in Figure 3, the part that looks dark gray is the structure of Mg-Zn particles, while Fe-Al particles are light gray [14].

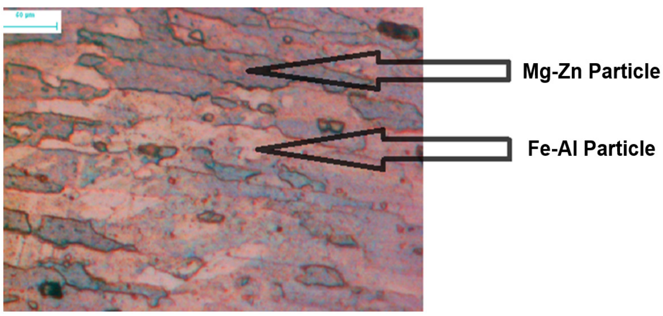

Figure 2. Microstructure of Al 7075 after HT

In the solution heat treatment of aluminum 7075, the property level and processing variables are very important and affect the capability. Examples include thickness, heating temperature (the higher the alloy series, the temperature is controlled within tighter limits), and heating time. Different material thicknesses also have different heating times (soaking time for solution heat treatment) such as 0.6 mm (25-35 minutes), 1.4 mm (30-40 minutes), and 2.5 mm (40- 45 minutes). Although the maximum temperature of the saturated solid solution must be limited to avoid melting, which will affect the solution velocity, diffusion, and dissolution of the resulting precipitate.

Heat treatment of aluminum at high temperatures is up to austenitization (homogeneous austenite structural conditions) which is used to dissolve cementite in austenite which is then suddenly cooled by being immersed in a liquid as a cooling medium, this process is influenced by the thickness and shape of the specimen to be quenched, as well as the desired microstructure of the quenching process.

Quenching has a role in maintaining the condition of the solid solution that has been formed [15]. Through the fast cooling process, separation of the second phase from the solid solution can be prevented at lower temperatures [16]. The alloy is in an unstable, saturated solid solution state. In addition, the dissolved atoms are trapped and do not have the opportunity to diffuse. Another thing that happens is that the trapping of the dissolved atoms forms empty regions which are pushed to promote the occurrence of the low-temperature diffusion required for zone formation. The large number of empty lattice areas generated as a result of the dyeing process is influenced by the large cooling rate that occurs during immersion. The higher the cooling rate, thus the emptier the grid area is formed. The amount of cooling speed itself is influenced by, among other things, the immersion medium and the size of the specimen shape.

The three types of specimen thickness in Figure 1 show the results of the microstructure which can be concluded that the aluminum alloy 7075 which undergoes diffusion evenly is a specimen with a thickness of 1.4 mm after the solution heat treatment process Fe-Al particles and Mg-Zn particles almost coalesce and camouflaged.

In the 0.6 mm specimen the opposite happened to the 1.4mm specimen where the results after solution heat treatment showed the separation of Mg-Zn particles and Fe-Al particles, which in the 0.6 mm specimen image showed that there was re-binding of Mg-particles. Zn and Fe-Al. Whereas in specimens with a thickness of 2.5 mm, the changes that occurred were Mg-Zn particles, which looked fainter than those of the Al 7075 specimen prior to solution heat treatment, where diffusion was more prevalent in Mg-Zn particles compared to Fe-Al particles.

Conclusion

From the results of research that has been done, testing and discussion regarding the effect of solution heat treatment on the mechanical properties and microstructure of aluminum series 7075 with thickness variations of 0.6 mm, 1.4 mm, and 2.5 mm have been carried out. The tensile strength value of aluminum 7075 after heat treatment of solution heat treatment has decreased, where the most reduction occurred in specimens with a thickness of 0.6 mm when compared to specimens with a thickness of 1.4 mm and 2.5 mm. With the maximum tensile strength value of 465.38 MPa on average, the maximum load of 3755.6 N on average, the yield strength of 289.96 MPa on average. This is due to the temperature of the solution heat treatment which is getting closer to the melting point and the soaking time which exceeds the thickness limit of the specimen, causing an increase in the diameter of the constituent atomic grains and causing a decrease in tensile strength. Thus, the fast heating and cooling process that is carried out causes a decrease in the tensile strength, causing the Al 7075 material to become softer.

In the results of microstructural testing of the three variations in specimen thickness, it can be concluded that the aluminum 7075 specimen that diffuses evenly after undergoing solution heat treatment is a specimen with a thickness of 1.4 mm where Fe-Al and Mg-Zn particles are almost fused and look faint. In contrast to the 1.4 mm specimen, the 0.6 mm specimen shows the separation of Mg-Zn and Fe-Al particles, which results in the re-binding of the Mg-Zn and Fe-Al particles respectively. Whereas in the 2.5 mm specimen, there was only a small spread of Mg-Zn particles compared to Fe-Al particles. Processing variables and property levels are very influential in determining microstructural yield. Examples such as thickness, heating temperature, and heating duration. This greatly affects the speed of the solution, the diffusion of the particles, and the dissolution of the particles.

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