Solution Treatment AC8A Aluminum with Aging Temperature Variations on Density, Hardness and Microstructure

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Keywords: Aluminum AC8A, Temperature *aging*, Density, Microstructure and Hardness.

Abstract: Solution Treatment is the process of heating the material and cooling it with a fast cooling rate. The solution treatment process with rapid cooling can cause dislocations, so it is necessary to carry out the aging process. This study aims to smooth the coarse primary silicon structure and eliminate dislocations on the surface of the piston material and also to determine the hardness of the material and the density of the material through solution treatment with variations in aging temperature. The method used in this study is a direct experiment with AC8A aluminum solution treatment at a temperature of 490 ^{0}C for 1 hour then quenched with water cooling media. The material resulting from the solution treatment was observed for microstructure, density and hardness. Then the material is subjected to an aging process with variations in aging temperatures of 125 ^{0}C, 150 ^{0}C and 175 ^{0}C holding time for the same 30 minutes. After completion, observations of microstructure, density, and hardness tests were carried out for each treatment. The results of the study of homogeneous microstructure with the smallest crystal grain size occurred in the aging process with a temperature of 150 ^{0}C. Density value or the highest density occurs in the aging process with a temperature of 150 ^{0}C. The highest hardness value occurs in the aging process with a temperature of 175 ^{0}C.

1 INTRODUCTION

Aluminum alloy is a material that is widely used in industry and automotive, AC8A aluminum material is one of the aluminum alloys used for automotive components, one of which is the piston. The piston is the main component in an engine that moves up and down in the cylinder doing the intake, compression, effort, exhaust. The main function of the piston is to receive combustion pressure and transmit combustion pressure through the piston rod to the crankshaft. Pistons receive high temperatures and pressures, so a material that has good durability is needed. AC8A aluminum is aluminum silicon alloy which has Si content between 11-13% wt. The high silicon content in AC8A aluminum or piston material acts as an insulator to prevent aluminum from absorbing excessive heat and silicon can increase the hardness and wear-resistant properties of the piston. The weakness of pistons with high silicon content is brittle or brittle as the silicon content increases so that the morphology of the primary silicon is coarse and large. (Indriyati, 2008). For this reason, it is necessary to have Solution Treatment to get a solid solution that is close to homogeneous. Refining the silicon crystal structure to remove or eliminate the coarse and large primary silicon crystal structure this structure can cause brittle properties. Solution Treatment is a process of heating the material and cooling it with a fast cooling rate (Wibowo & Nurato, 2018). The solution treatment process with rapid cooling can cause dislocation, so an aging process is necessary (Dimu, 2020).

In this research, the piston material that has been treated with solution treatment with water cooling media will be subjected to an aging process with variations in aging temperature. By varying the aging temperature, it is expected that maximum hardness and a homogeneous structure without dislocation can be obtained. And also in this study, we want to know the density of the material after solution treatment and after the aging process.

2 LITERATURE REVIEW

This study aims to smooth the coarse primary silicon structure and eliminate dislocations on the surface of the piston material and also to determine the hardness

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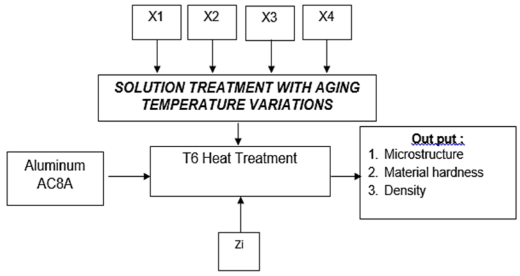
of the material and the density of the material through solution treatment with variations in aging temperature.

There are several previous studies that serve as the first reference, namely the analysis of the effect of temperature instability on the results of the material hardness of the piston heat treatment process resulting in the hardness of the material obtained depending on the aging temperature setting, the lower the temperature, the higher the hardness, while the higher the temperature the hardness will decrease (Wibowo & Nurato, 2018). The solution treatment process with rapid cooling can cause dislocation, so an aging process needs to be done (Dimu, 2020). The solution treatment temperature is 490 ºC and the temperature of the fluid itself must be in the range of 60 ºC, this is because to prevent the material from cracking / breaking during immersion due to significant temperature differences (Wibowo & Nurato, 2018). the effect of artificial aging time on the crystal structure of dislocation density and hardness in the Al-7075 alloy resulted in Aluminum 7075 reaching its maximum hardness at an artificial aging temperature of 200 ºC with a holding time of 1 hour of 23,035 HBN and the smallest crystal size occurred in artificial aging heat treatment at a temperature of 200 ºC holding time 24 hours at 3.4405 nm (Dian Permata Putri*, Budiarto Jono Siswanto, 2020). Testing the crystal size of the micro-lattice strain dislocation density with XRD on the effect of artificial aging temperature on Al 5052 alloy shows that the crystal size value is inversely proportional to the artificial aging temperature where the higher the artificial aging temperature the smaller the crystal size, while for the dislocation density and density the lattice is proportional to the temperature so that along with the high temperature, the value of dislocation density and lattice density also increases (Regi Megantara, Budiarto Djono Siswanto*, 2020). The effect of solution treatment and artificial aging on the mechanical properties and microstructure of A383 aluminum alloy. From the optimization results, the best hardness is with aging temperature of 200ºC and holding time of 88 minutes or aging temperature of 100ºC with holding time of 30 minutes. (Sultan & Hamzah, 2019).

Furthermore, in the study of the microstructure and mechanical properties of al-si alloys under heat treatment conditions, the results of microstructural observations show that the eutectic silicon particles are spherical and homogeneously distributed in grain boundaries after T6 heat treatment. (Moh. Indra P, Mahros Darsin, 2011).



With : Xi = controllable factors.
Zi = uncontrollable factors (factors *noise*).

Figure 1: Research roadmap.

3 METHOD

The steps in this research:

1. Making specimens taken from pistons on the market
2. Prepare all tools and materials.
3. Put the specimen into the furnace and carry out the solution treatment process with a heating temperature of 490 ^{0}c.
4. After heating the specimen to 490 ^{0}c, do the holding time for 1 hour.
5. Remove the specimen from the furnace quickly, do quenching with water media (cooling media temperature 60 ^{0}c ± 2).
6. Testing density, hardness and hardness materials from solution treatment.
7. Put the specimen into the furnace and carry out the aging process at a heating temperature of 125 ^{0}c with a holding time of 30 minutes.
8. Repeat step 7 for aging temperatures of 150 ^{0}c and 175 ^{0}c with the same holding time of 30 minutes.
9. Observing the microstructure using an optical microscope, hardness and density.

Density is a physical quantity that is the ratio of mass (m) to the volume of the object (v). The measurement of the density of the material in the form of solids or bulk used the Archimedes method. To calculate the actual and theoretical density values used Equation:

Actual density:

$$\rho_m = \frac{m_s}{(m_s - m_g)} x \rho_{H_2O}$$ ……..(Fahmi Fasya, 2015)

With:
ρm : Actual density (gr/cm^3)
ms : Dry sample mass (gr
mg : mass of sample suspended in water (gr)
ρ H2O : density of water = 1 gr/cm^3

4 RESULT AND DISCUSION

4.1 Test Result

4.1.1 Hardness Test Result Data

Table 1: Material Solution Treatment 490 ^{0}C holding time 1 hour.

No	Treatment	Hardness Value (HRB)
1	Solution Treatment 490 ^{0}C holding time 1 hour	67,29
2		69,74
3		69,95
Average Hardness Value (HRB)		**68,99**

Table 2: Treatment material Solution Treatment 490 ^{0}C followed by the Aging process at a temperature of 125 ^{0}C.

No	Treatment	Hardness Value (HRB)
1	Aging 125 ^{0}C	75,26
2		76,51
3		77,12
Average Hardness Value (HRB)		**76,29**

Table 3: Material treatment Solution Treatment 490 ^{0}C followed by Aging process at a temperature of 150 ^{0}C.

No	Treatment	Hardness Value (HRB)
1	Aging 150 ^{0}C	79,55
2		79,66
3		78,05
Average Hardness Value (HRB)		**79,08**

Table 4: Material treatment Solution Treatment 490 ^{0}C followed by Aging process at a temperature of 175 ^{0}C.

No	Treatment	Hardness Value (HRB)
1	Aging 175 ^{0}C	84,74
2		85,49
3		84,69
Average Hardness Value (HRB)		**84,97**

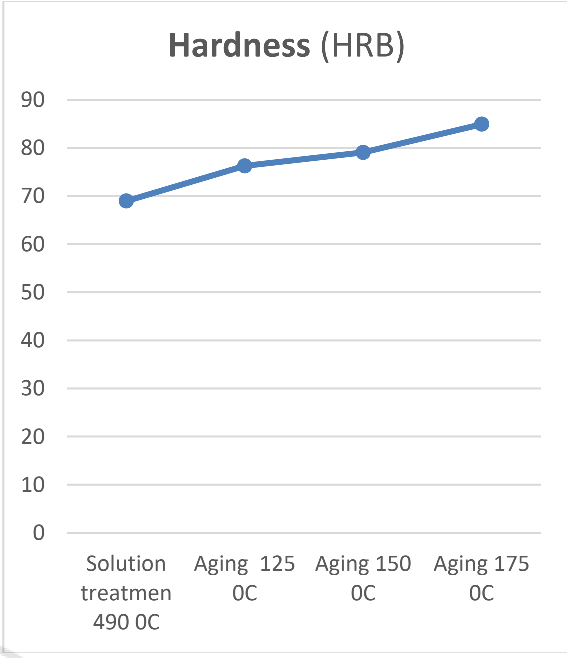


Figure 2: Graph of the relationship between material treatment and the average hardness value.

4.1.2 Density Test Data

Density testing is carried out based on Archimedes' law. Density testing is carried out to find the value of porosity in the specimen. The equipment used is the One Mad brand scale with an accuracy of 0.01 grams and water fluid. The results of the density test can be seen from Table 5.

Table 5: Density Test Data.

NO	Treatment	Dry mass of the test specimen (gr)	Mass of the test specimen was hung in water (gr)	Actual density (gr/cm^{3})
1	Solution Treatment 490 ^{0}C	1,81	0,66	**1,57**
2	Aging 125 ^{0}C	1,82	0,67	**1,57**
3	Aging 150 ^{0}C	2,51	0,98	**1,64**
4	Aging 175 ^{0}C	2,88	1,11	**1,62**

4.1.3 Microstructure Observation Data

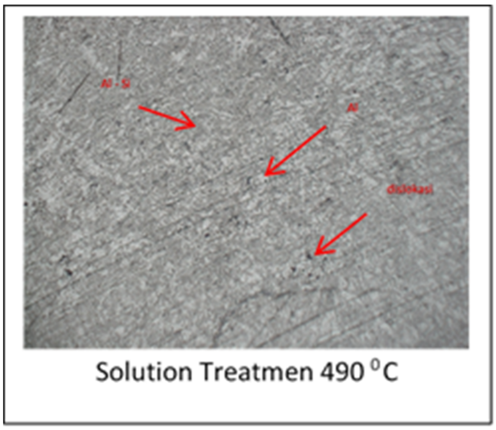


Figure 3: The microstructure of the material resulting from the solution treatment process at a temperature of 490 ^{0}C.

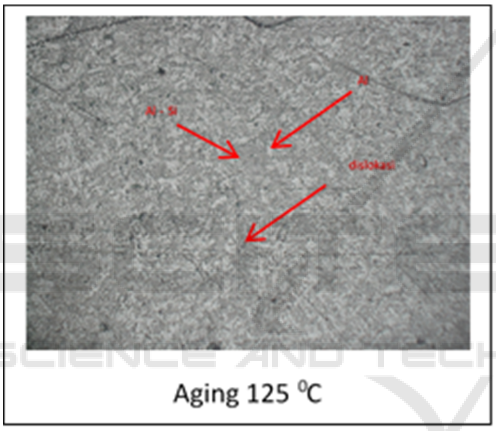


Figure 4: The microstructure of the material resulting from the solution treatment process at a temperature of 490 ^{0}C and continued with the Aging process at 125 ^{0}C.

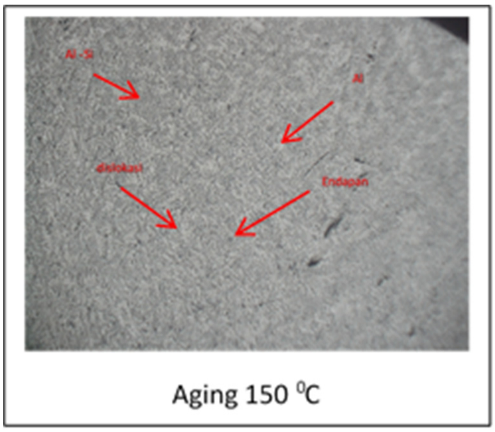


Figure 5: The microstructure of the material resulting from the solution treatment process at a temperature of 490 ^{0}C and continued with the Aging process at 150 ^{0}C.

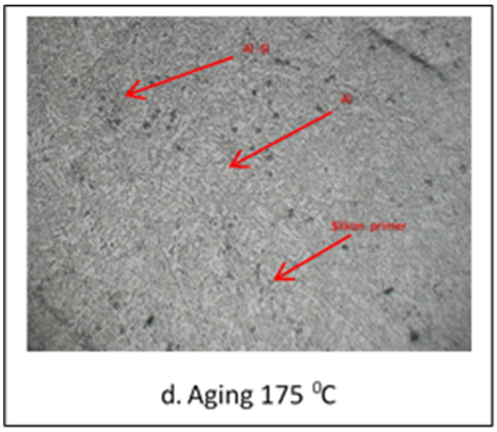


Figure 6: The microstructure of the material resulting from the solution treatment process at a temperature of 490 ^{0}C and continued with the Aging process at 175 ^{0}C.

4.2 Discussion

4.2.1 Analysis of Hardness Test

From the results of hardness testing, it can be seen that the average hardness value of the solution treatment material with a temperature of 490 ^{0}C holding time 1 hour is 68.99 HRB. In the Aging process with a temperature of 125 ^{0}C the material experienced an increase in the hardness value to 76.29 HRB. and also for the aging process with a temperature of 150 ^{0}C an increase in the hardness value of 79.08 HRB. The hardness value continues to increase to 84.97 HRB for the aging process with a temperature of 175 ^{0}C. It can be seen that the material resulting from solution treatment which continues with the aging process, the hardness value continues to increase in direct proportion to the increase in aging temperature.

4.2.2 Density Test Analysis

From the results of the density test, it can be seen that the density value in the solution treatment treatment of 490 ^{0}C is 1.57 gr / cm^3 and in the aging process at 125 ^{0}C the density value does not change, namely 1.57 gr / cm^3. In the aging process at 150 ^{0}C the density value increases to 1.64 gr /cm^3. The density value decreased to 1.62 gr/cm^3 in the aging process with a temperature of 175 ^{0}C. The highest density value or density occurs in the aging process of 150 ^{0}C, if it is seen from the observation data of the microstructure of the smallest or smoothest crystal size, it is also in the aging process of 150 ^{0}C.

4.2.3 Analysis of Microstructure Observations

From the observation of the microstructure, it can be seen that the material resulting from the 490 ^{0}C solution treatment occurred dislocation due to the rapid cooling process. In the aging process at 125 ^{0}C, it is still visible at the location and in the aging process at 150 ^{0}C, a fine and fairly homogeneous microstructure is formed. Starts to form primary silicon structure deposits in the aging process with a temperature of 175 ^{0}C.

5 CONCLUSION

Based on the results of this study, several conclusions can be drawn as follows:

1. Homogeneous microstructure with the smallest crystal grain size occurs in the aging process with a temperature of 150 ^{0}C.
2. Density value or the highest density occurs in the aging process with a temperature of 150 ^{0}C.
3. The highest hardness value occurs in the aging process with a temperature of 175 ^{0}C.

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