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## Hardness improvement of aluminum alloy 2024 t3 after artificial aging treatment

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# Hardness improvement of aluminum alloy 2024 t3 after artificial aging treatment

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**Abstract.** The needs of having strong and light material for many construction is increasing. Aluminum is one of materials that fulfill this requirement with other advantages such as corrosion resistant and easily formed. Generally, hardness of aluminum and its alloys is lower than ferrous metal such as iron and steel. Aluminum hardness improvement can be conducted by heat treatment namely artificial aging. Artificial aging in aluminum alloy type 2024 T3 in this study was conducted in 2 phases that is solution treatment in 500 °C for 1 hour and continued with artificial aging process in 180 °C by holding time 2, 4 and 6 hours. From the conducted research, it was found that there was hardness improvement on aluminum type 2024 T3 in line with the increasing of aging time. The gained microstructure was getting smooth which means the precipitation hardening process was getting perfect.

## 1. Introduction

Aluminum is one of non-ferrous materials which is corrosion resistant, light and strong. It is mostly applied on construction of airplane, vehicles or building. Compared to ferrous metal, aluminum and its alloys are less strong. Aluminum strength improvement can be done by heat treatment process in its fabrication process. One of heat treatment processes on aluminum and its alloys is artificial aging, especially in aluminum alloy with composition of Cu 2.5 – 5.0%.

Artificial aging with variation of time and temperature aging as well as variation of temperature solution treatment could improve the hardness of any kind of aluminum types as reported by previous researchers. Ekhlas Ahmed [1] conducted a test on Aluminum Alloy 2024 T6 with heating temperature of 500 °C for 1 hour and artificial aging on temperature of 190 °C with holding time variation 1, 2 and 5 hours and resulted the best precipitation phase in 5 hours of aging time. Naveed Afzal, et al [2] studied aluminum alloy 2024 with aging time of 2 hours and temperature variation of 105, 135, 165 and 195 °C. The study showed that the maximum tensile strength and hardness was gained with aging temperature of 135 and 195 °C. Gowrishankar M. C. et al [3] used AA 6061 material with aging temperature variation of 100, 150 and 200 °C and aging time of 3-10 hours. This study showed that better mechanical quality on lower temperature. Aytekin Polat et al [4] with AA 6061 material varied temperature and time aging. Temperature solution treatment of 550 °C for 2 hours. Artificial aging temperature variation of 160, 180 and 200 °C with holding time variation of 2, 5, 5, 10, 20, 40, 60 and 80 hours. The result showed that the mechanical quality was decreasing as the increasing of aging temperature but it was improving by the increasing of aging time. DAP Reis et al [5] varied solution treatment temperature on 495, 505 and 515 °C, and artificial aging on 190 and 208 °C. It was reported that the highest hardness was gained in combination 505 °C and 208 °C with aging time of 2 hours. MS Khan et al [6] used AA 2014 material with solution treatment temperature of 502 °C for 2 hours. The result showed improvement of hardness from 85 HV to 136 HV on artificial temperature of 180 °C and increased into 145 HV on aging temperature of 233 °C. MFIA Imam et al [7] got the highest hardness of aluminum alloy material on solution treatment temperature of 500 °C and artificial aging temperature of 165 °C.

Hardness of aluminum also could be improved by coating technique of the surface of the material and continued with artificial aging process. Jianzhong Zhou, et al [8] studied Aluminum Alloy 2024



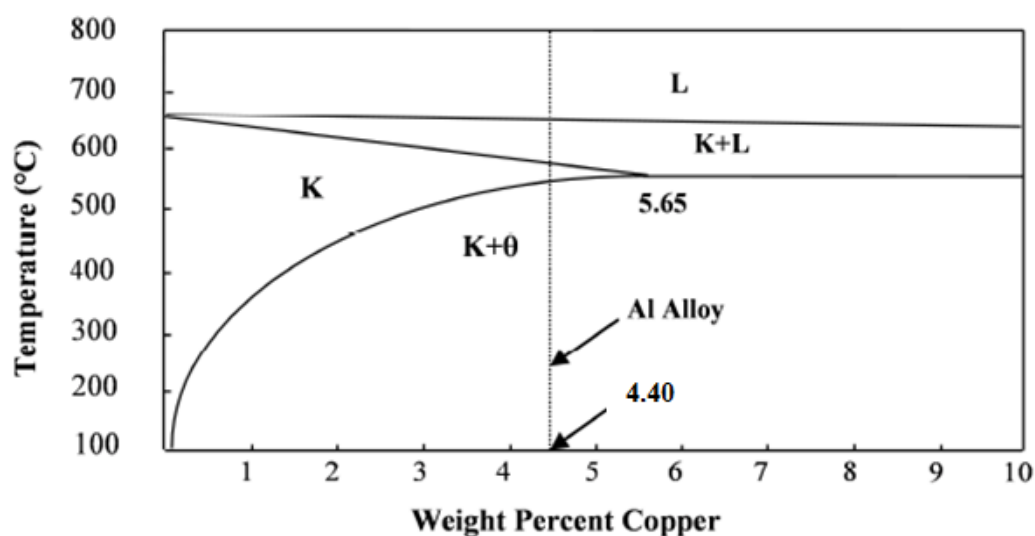
T3 with Cryogenic Treatment (CT) with time variation of 2, 4, 6, 8 and 12 hours on 77 °K by using liquid nitrogen. The finding showed that CT heat treatment could improve the hardness of the material. M.H. Goodarzy et al [9] conducted ECAP process on AA 2024 T8 with natural aging on 70 and 100 °C. Heat treatment was conducted on 500 °C for 40 minutes. The result showed that on time aging 70 °C, the hardness increased.

Artificial aging process on composition variation of aluminum alloy could also improve aluminum hardness. Aondona P. Ihom et al [10] studied composite with composition of Al/0.05% particle glass. Treatment solution on 500 °C for 45 minutes. Variation of aging temperature 150 – 210 °C. The result showed that the tensile strength and hardness increased in line with the improvement of aging temperature. J.K. Odusote et al [11] proposed that his research used variation of Al-Cu-Zn with heat treatment temperature of 460 °C for 2 hours. Artificial aging on 160 °C for 5 hours. The best result was gained on composition 81.2 Al-1.56 Cu-8.33 Zn.

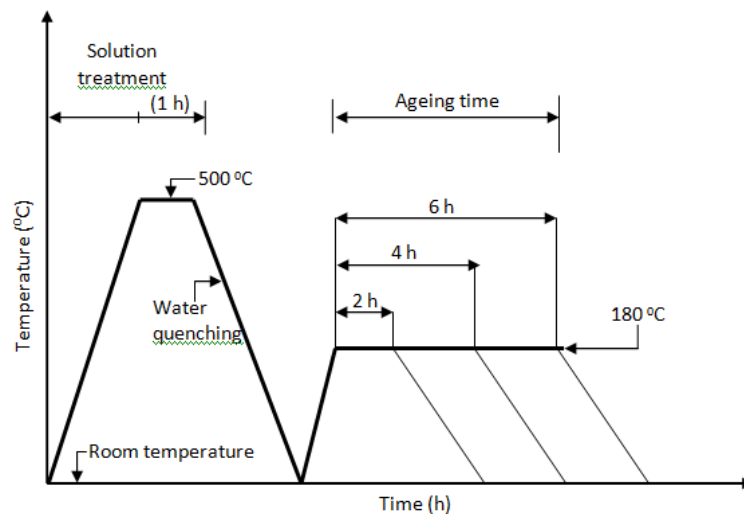
## 2. Method

Method of this research was heat treatment in form of solution treatment and artificial aging. Solution treatment process by heating material until 500 °C for 1 hour. The next process was artificial aging on 180 °C with holding time variation 2, 4 and 6 hours. Schematic heat treatment process is shown in Figure 2 [12, 13]. Composition of aluminum alloy type 2024 T3 used in this research are:

Cu	Mg	Mn	Fe	Zn	Ti	Cr	Si	Al
4.40%	1.50%	0.60%	0.50%	0.25%	0.15%	0.10%	0.05%	96.90%



**Figure 1.** Phase diagram of the aluminum alloy



**Figure 2.** Schematic of aging time and solution treatment on aluminum alloy type 2024 T3 [12, 13]

### 2.1 Hardness Test

Hardness test was conducted to get the value of material hardness. It was done Vickers' hardness test with hardness test machine of Wolpert with pyramid-shaped diamond indenter with square pedestal and peak angle between two opposite sides of  $136^\circ$ . The given load depended on the tested metal hardness and in this research, the load was 5 kg. The value of Vickers's hardness is expressed with HVN or HV.

$$HV = \frac{2P \sin(\frac{\theta}{2})}{d^2} = \frac{1.854P}{d^2}$$

in which: P = the applied load (kg)

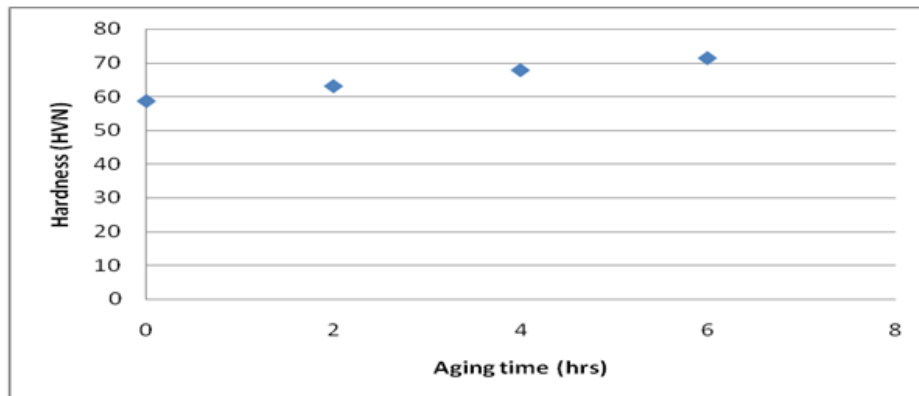
d = average diagonal length (mm)

$\Theta$  = angle between the opposite diamond surface

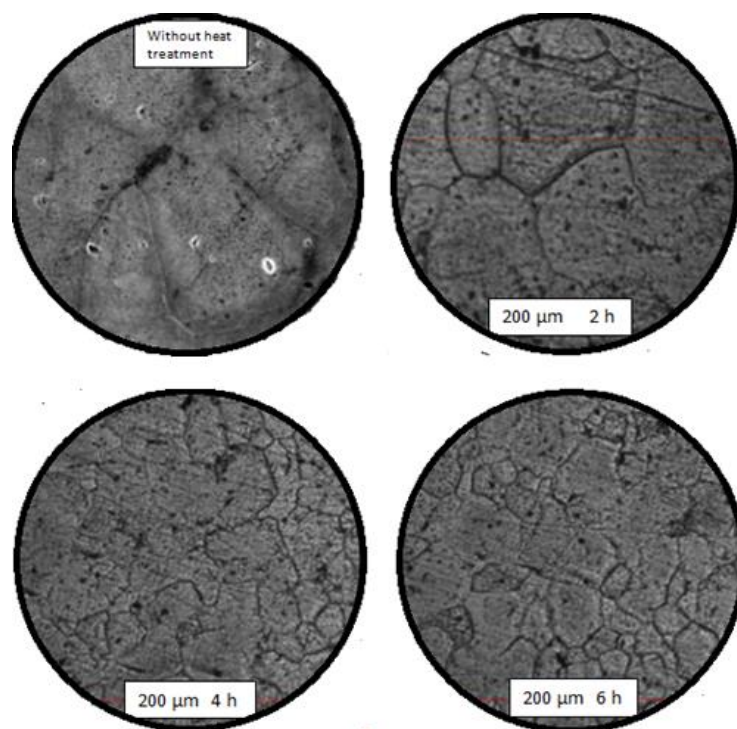
## 3. Result and Discussion

**Table 1.** The result of hardness test of aluminum alloy 2024 T3

No	Hardness (HVN)			
	Without heat treatment	Aging time		
		2 hrs	4 hrs	6 hrs
1	56.8	61.2	66.5	75.7
2	57.9	62.8	67.2	69.6
3	54.7	59.4	64.8	71.5
4	54.6	58.8	64.3	77.9
5	53.5	58.6	63.9	73.6
6	56.6	60.9	66.2	71.5
7	57.4	62.6	67.2	67.7
8	62.6	66.7	72.2	67.1
9	67.7	70.5	73.3	69.6
10	64.2	68.9	72.3	69.6
Average	58.6	63.04	67.79	71.38



**Figure 3.** Graphic of the relation between hardness and aging time



**Figure 4.** Microstructure of AA 2024 T3 with a variation of aging time.

The result of hardness test of aluminum alloy 2024 T3 after heat treatment of artificial aging shown on Table 1 and Figure 3. On graphic it can be seen the increasing of hardness in line with the addition of aging time. This increase happened because the improvement of precipitation to be more perfect shown by the smaller and more delicate precipitation size which is shown in Figure 4. The smaller and more delicate particle that was formed caused the hardness of material was getting higher.

#### 4. Conclusion

The research showed that aging time could improve the hardness of aluminum alloy 2024 T3. The result of the micro photo showed the formed-particle was getting delicate with more aging time which caused the hardness of the material was increasing.

## Acknowledgment

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