# The Effect of Ageing Treatment of Aluminum Alloys for Fuselage Structure-Light Aircraft

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***Abstract*—**As the material used for fuselage structure must possess low density, high strength to weight ratio, the selection of appropriate materials for fuselage structure is one of the most important tasks. Aluminum metal itself is soft and low in strength. It can be made stronger by giving proper combination of suitable alloy addition, mechanical treatment and thermal treatment. The usual thermal treatment given to aluminum alloys is called age-hardening or precipitation hardening. In this paper, the studies are carried out on 7075 aluminum alloy which is how to improve strength level for fuselage structure. The marked effect of the strength on the ternary alloy is clearly demonstrated at several ageing times and temperatures. It is concluded that aluminum-zinc-magnesium alloy can get the highest strength level in natural ageing.

***Keywords*—**Aluminum alloy, ageing, heat treatment, strength.

## I. Introduction

THE very early airplanes were built from very light weight materials such as bamboo, wood and fabric. As the metal manufacturing techniques was improved in the early wooden components in airplanes. Nowadays, better and more consistent alloys and composite materials are all contributing to new structural designs [1]. Materials currently used in aircraft construction are classified as either metallic materials or non metallic materials. The most common metals used in aircraft constructions are aluminum, magnesium, titanium, steel and their alloys. Among the light metals, although aluminum itself is soft and low in strength, it can be made stronger by giving proper combination of suitable alloy[2]. The properly treated aluminum alloy may posses a strength level about thirty times that of pure aluminum. In terms of specific strength (the ratio of strength to density) a properly treated aluminum alloy is about three times that of normal structural steels [3]. For aircraft structure, the construction material must be as light as possible so as to increase pay load and fuel consumption. Among the aluminum alloys, 7075 aluminum alloy (Al-Zn-Mg) has the highest strength and good strength to weight ratio. It is ideally used for highly stressed parts. It may be formed in the annealed condition and subsequently heat treated.7075 aluminum alloy offers good machinability when machined using single-point or multi-spindle carbide tools on screw machines [4]. The anodizing response rating for 7075 alloy is good using commercially available methods. The alloy can be both hard and clear-coat anodized. The target alloy composition is 2.5% Mg and 5.6% Zn [5].

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## II. Methodology

### *A. Preparation of 7075 Aluminum Alloy (Al-Zn-Mg)*

The target composition of zinc must be 5.6% and the composition of magnesium must be 2.5% in 7075 aluminum alloy. Firstly, aluminum was melted until all are in the liquid condition. In this step, flux was covered over the melt. By this way, metal loss is less. After complete melting of aluminum, the required amount of zinc was added to the melt. A little stirring was carried out in the green sand mould. And then pouring was carried out. The addition of magnesium to binary aluminum zinc alloy causes a marked increase in their response to age-hardening. The effect is much greater than that obtained by adding small quantities of zinc to binary aluminum-magnesium alloys. So, magnesium was added to aluminum zinc alloy. Aluminum zinc alloy was melted again in a graphite crucible under a flux consisting of equal parts of zinc chloride and aluminum chloride. Magnesium addition was made just before pouring. Care being taken to avoid burning at the surface of the melt. There are many magnesium addition methods. In this melting, magnesium was packaged with pure aluminum scrap. This package was directly added into the melt. To avoid magnesium burning on the surface of the melt, a little stirring was carried out. To get homogeneous aluminum zinc magnesium alloy, this alloy was melted again.

Chemical analysis was carried out on samples machined from near the top and bottom of each ingot. The billets, after machining were homogenized at 375°C for 24 hr in muffle furnace. When possible, the billets were hot forged and annealed at 375°C for 24 hr. When the magnesium content exceeded 1%hot forging was necessary with intermediate anneals at 375°C. The specimens were cut from the strips and the machined surfaces were polished on emery papers.

### *B. Chemical Analysis*

This sample was drilled to obtain the chips for testing chemical analysis. Then this sample was sent to the Department of Chemical Analysis at Ministry of Mine in Myanmar.

*C. Heat Treatment of 7075 Aluminum Alloy*

Solution treatment of the specimens was carried out at 460°C for at least 20 hr in muffle furnace. And then, the specimens were quenched in a standard manner into water. After that, ageing treatment was carried out at 100°C, 150°C, 200°C and room temperature. The time required for a specimen to reach each temperature was determined, and allowance for this has been made in plotting the ageing curves.

*D. Hardness Testing*

In order to obtain a reliable average hardness, Rockwell Test was used in determination of hardness. In a sample preparation for hardness testing, the surface layer of test specimen was removed by grinding. To obtain the actual value of hardness, samples were measured and their average values were calculated from at 3 tests. In Rockwell test, Rockwell B and Rockwell F scale are used. The Rockwell F scale mostly used for aluminum alloys employing a 1/16 in diameter ball and 100 kg load gives direct reading for hardness value.

## III. Results and Discussions

*A. Chemical Analysis Results*

Composition of Al-Zn-Mg Alloy Sample

| Element | % |
|---|---|
| Zinc | 5.8 |
| Magnesium | 2.2 |

Standard Composition of 7075 ( Al-Zn-Mg) Alloy

| Element | % |
|---|---|
| Zinc | 5.6 |
| Magnesium | 2.5 |

By comparing these two compositions, it is obvious that the chemical composition of test sample Al-Zn-Mg alloy is very similar to the standard composition. And so, it can be said that the chemical composition of prepared Al-Zn-Mg alloy is suitable to use as structural materials.

*B. Microstructural Examination*

The microstructure of as cast Al-Zn-Mg alloy shown in Fig. 1, dendrites structures were observed in fast cooling rate samples.

This structure was obtained from the ingot which has been cooled quickly to obtain equi-axed network structure. This network structure is made up of particles of several intermetallic compounds formed by combinations of the alloying elements in this alloy. Some of these compounds are soluble while others have slight or practically insolubility.

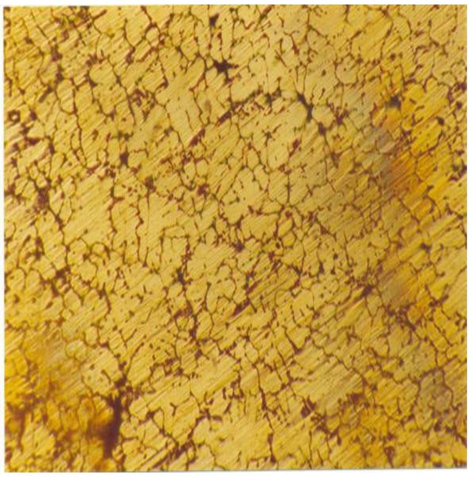

Fig. 1 Microstructure of As Cast Al-Zn-Mg Alloy, 40 X

In as cast condition, this alloy contains grain boundary precipitate phases along the grain boundary and near the grain boundary as shown in Fig. 2.

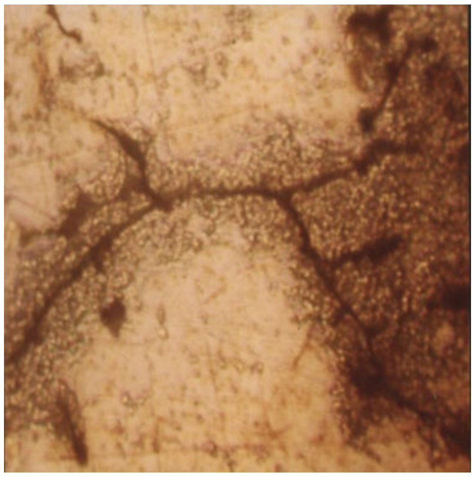

Fig. 2 Microstructure of as cast Al-Zn-Mg which contains Many Precipitate Phases along the Grain Boundary before Solution Treatment, 200X

And then, the alloy should be solution treated above solidus temperature as the liquation occurs of the compound at the grain boundary regions, render the alloy brittle and thus adversely affects the ductility and other mechanical properties. After solution treatment, some precipitate along and near the grain boundary are soluble. Some insoluble precipitates remains along the grain boundary as shown in Fig. 3.

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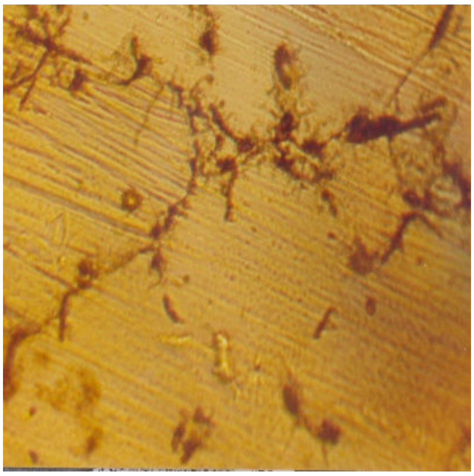

Fig. 3 Microstructure of Al-Zn-Mg which contains Remain Precipitate Phases along the Grain Boundary after Solution Treatment, 200X

And then, to increase the strength and hardness of the alloy, ageing treatment was carried out. During the solution treatment, the alloy constituents were dissolved. If the alloy was rapidly cooled, by quenching in water, much of the dissolved material was remained in solution. This artificially rich solid solution was not stable and the excess element or compound was precipitated out of the solution. These precipitate was the fundamental factor determining the strength of the hardened material. These are shown in Fig. 4.

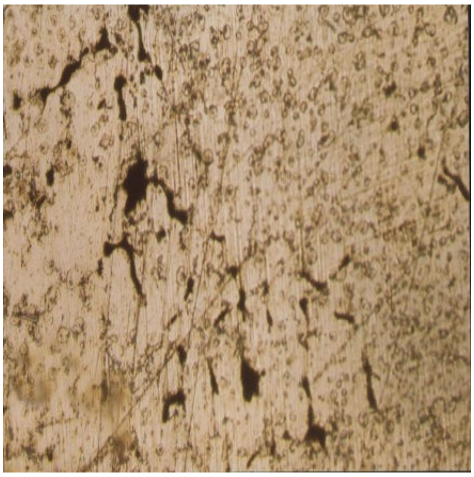

Fig. 4 Microstructure of Al-Zn-Mg Alloy Sample (Ageing 95 days at Room Temperature), 100X

### C. *Heat Treatment Results*

The marked effect of small quantities of magnesium on the extent of hardening in the ternary alloys was early demonstrated at several ageing temperatures. Firstly, Al-Zn-Mg alloy is aged at 100° C.

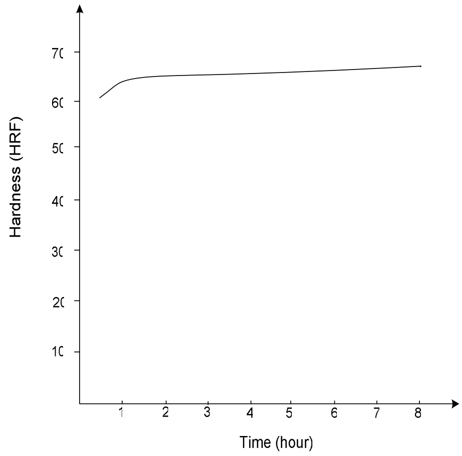


Fig. 5 Variation of Hardness of Al-Zn-Mg Alloy Sample with Ageing Time at 100 °C

In Al-Zn-Mg alloy, hardness is continued to increase even after eight hour ageing time. In this case an initial period of gradual hardening was recorded. At this temperature, Al-Zn-Mg alloy needs long period for days to get well-defined peak hardness. So as to observe the hardening behavior of Al-5.6%Zn-2.5%Mg alloy within practical ageing time limit, the tests were carried out at 150 °C. These results are shown in Fig. 6.

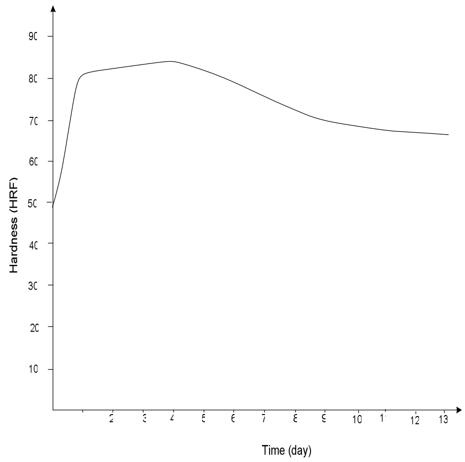


Fig. 6 Variation of Hardness of Al-Zn-Mg Alloy Sample with Ageing Time at 150°C

Fig. 6 shows that maximum hardness of 85.7 HRF was obtained at four hour ageing time. Overageing was occurred after four hour.

To find out whether useful peak hardness is obtained within short period of ageing time, the test were conducted even higher ageing temperature (200°C). These results are presented in Fig. 7.

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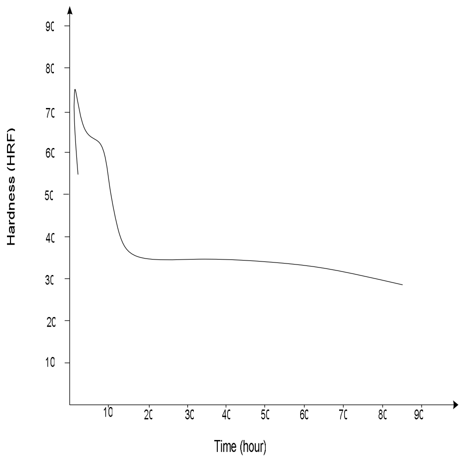


Fig. 7 Variation of Hardness of Al-Zn-Mg Alloy Sample with Ageing Time at 200 °C

Maximum hardness 71.5 HRF was obtained at two hour ageing time. Overageing was occurred after two hour ageing time. Comparatively, maximum hardness value of ageing at 150°C is greater than maximum hardness value of ageing at 200°C. Therefore, higher grain coarsening was occurred at higher temperature. Besides, overageing behavior was occurred at higher temperature. So, hardness value was decreased at higher temperature. At this alloy precipitate coarsening is so high at higher temperature. And then ageing of the alloy at room temperature is also studied.

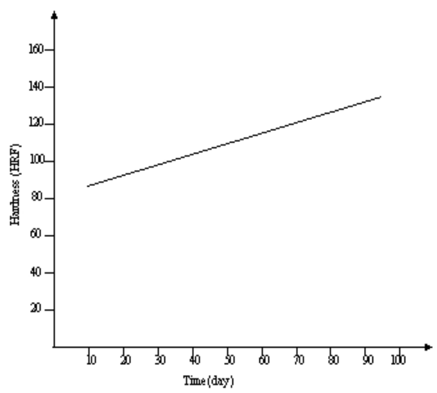


Fig. 8 Variation of Hardness of Al-Zn-Mg Alloy Sample with Ageing Time at Room Temperature

In room temperature ageing, it was observed that hardness value was increased until 95 days, which data agreeds with the result given by I.J.POLMEAR [5].

## IV. CONCLUSION

In this research, the desired material composition for fuselage structure can be made by standard melting and alloy making practice. The composition was also confirmed with XRF and chemical analysis. And then Al-Zn-Mg alloy was aged hardened at various temperatures. Firstly, Al-Zn-Mg alloy was ageing at 100°C. In this treatment, an initial period of linear hardening was recorded. Then this alloy was aged at 150°C. In this treatment maximum hardness 89.7 HRF was obtained four days ageing time. After that, ageing of this alloy at 200°C was further studied. Maximum hardness 71.5 HRF was obtained at two hour ageing time at 200°C. Then, this alloy was aged at room temperature. Maximum hardness 135 HRF was obtained at 95 days at this temperature.

Comparing the following testing, maximum hardness value was obtained at room temperature. At room temperature, hardening behavior cannot be decreased when time is increased. So, natural hardening behavior was observed in Al-Zn-Mg alloy.

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