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THE ANALYSIS OF THE ALLOY $AlCu_4Mg_{1,5}Mn$ USED IN THE CONSTRUCTION OF UTILITY AIRCRAFTS

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Abstract: *In this paper we conducted a physic-chemical analysis for a $AlCu_4Mg_{1,5}Mn$ alloy propeller, from a small utility aircraft. Regarding the mechanical properties of the alloy, they are very good, especially machinability. Thus, if to an aluminium alloy a heat treatment for tempering is applied, it becomes more pliable and can be easily machined. After the processing operations, the alloy may be subjected to ageing, such treatment leads to an hardening, thereby improving the hardness thereof.*

Keywords: *aluminium, SEM, dilatometry, plane, propeller.*

1. INTRODUCTION

Aluminium is the most common metal in the earth's crust and in the chemical elements ranks third after oxygen and silicon. It has a high chemical activity and therefore, is found in nature only as compounds.

The first attempt of aluminium separation dates from 1810 and belongs to Davy, an english physicist who achieved electrolysis for aluminium hydroxide. Following this experience was not achieved aluminium but a Al-Fe alloy [1].

In 1854 Saint-Clair-Deville, used the Wohler method to obtain the aluminium in industry, replacing potassium with sodium and aluminium chloride, unstable and hygroscopic with double aluminium chloride solution [1].

2. ALUMINIUM IN THE AIRCRAFT INDUSTRY

To the evolution of metallic and non-metallic materials and building airplanes was observed a close connection. The development of this field, industry aircraft manufacturing was the collaboration result between metallurgists specialist's and aircraft manufacturers. From this collaboration has resulted efficient equipment and materials used to improve characteristics.

Aluminium alloys are numerous, with different and various properties. For example, Al-Zn-Mg-Cu alloy has a low weight and that is why it had been used with success in the aircraft manufacturing industry. This is highlighted in figure 1.

Figure 1. Highlighting construction aluminium alloy features from a commercial aircraft [2].

Alloys of Al-Zn-Mg-Cu may be used on some resistance elements which are loaded with compression stress due to high values of yield strength of the alloy.

The components made from 7075 are: aluminium fuselage, upper wing panels and sustaining pillars.

Also from the Al-Cu-Mg alloy, which is a hard aluminium, can be constructed elements which requires higher hardness such as the exterior case and the front of the wings [3].

3. SPECTROMETRIC ANALYSIS OF THE $AlCu_4Mg_{1,5}Mn$ ALLOY

Spectrometric analysis on our aluminium sample was performed using Foundry Master 01J0013 optical spectrometer.

Following the three aluminium sample tests, came out the following results as shown in Table 1.

Table 1. Spectrometry analysis results of the aluminium alloy.

No test	Al	Si	Fe	Cu	Mn	Mg	Zn
1.	91,7	0,294	0,522	4,85	0,683	1,38	0,0768
2.	92,2	0,269	0,562	4,68	0,65	1,44	0,0356
3.	92,2	0,269	0,565	4,59	0,664	1,46	0,417
Average	92,0	0,277	0,55	4,71	0,666	1,43	0,517

After spectrometry analysis we found an aluminium alloy which is $AlCu_4Mg_{1,5}Mn$. Aluminium alloys are divided into two categories: foundry alloys and plastic alloy deformation.

$AlCu_4Mg_{1,5}Mn$ is an aluminium alloy plastic deformation. This alloy is part of those who can be processed by hot or cold rolled, by drawing, by extrusion, by stamping or forging. Deformable alloys are divided into two categories, depending on the possibility of heat treatment hardening by quenching and aging: treatable and untreatable [4].

Propeller is a high strength 2024 aluminium alloy which is a commonly used material in aviation, due to its advantages of resistance to crack growth, good reparability, and perfect damage tolerance properties [5].

Magnesium added to the Al-Cu alloy, improves its properties. Magnesium plays an important role in reducing the weight and increasing the hardness by heat treatment.

Figure 3. Image of the studied propeller.

4. HEAT TREATMENTS AND MICRO-STRUCTURE ANALYSIS

The heat treatment is the technological process comprising in heating and maintaining the metal or the alloy at a given temperature, usually followed by cooling with a certain speed, in an environment. The heat treatment may be applied to such semi-finished and finished parts in order to obtain superior operating characteristics and properties of the material, by modifying the structure.

After performing spectral analysis and determining the chemical composition of the material, thermal quenching and ageing treatments was applied. These treatments were applied to highlight hardened aluminium structure and ageing.

4.1. SEM analysis. After applying quenching and ageing thermal treatments, microstructural analysis was performed on a scanning electron microscope SEM VEGA II LSH, model shown in figure 4.

Using this electron microscope we may determine material surface properties, based on the study of its structure, i.e. based on the constituent's present and possible structural defects, cracks and inhomogeneities.

Figure 4. Scanning electron microscope VEGA II LSH SEM

4.2. SEM analysis of the hardened alloy. Tempering is the most critical step in heat treatment operations. The purpose of hardening is to maintain the solid solution formed at solubilization temperature after the heat treatment by rapid cooling close to 20°C.

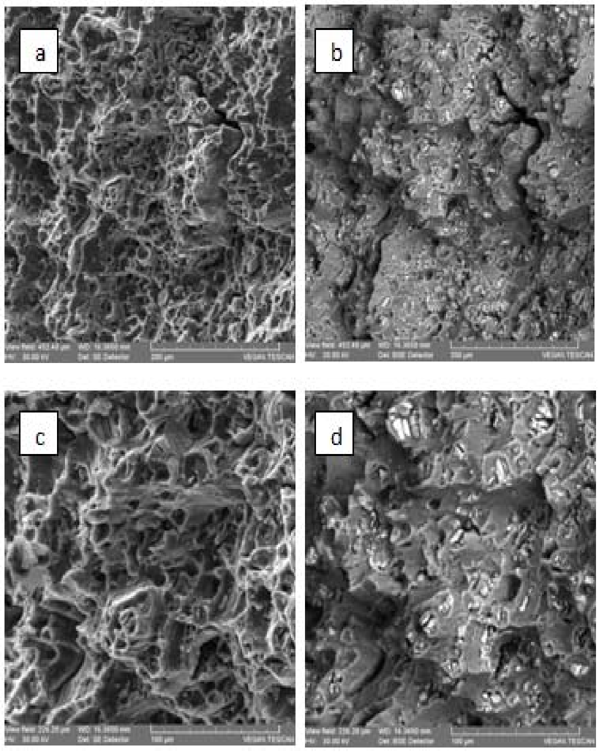

Figure 5. Fracture SEM image of a hardened structure: a)500x SE; b)500x BSE; c)1000x SE; d)1000x BSE.

When the alloy is subjected to solution treatment for hardening, a partial or complete dissolution of precipitates occurs, and the alloy will have a good cold workability.

The SEM uses two types of detectors: SE - secondary electrons and respectively BSE - back scattered electrons.

Elongated grains are observed in the fracture, also it is observed that fracture occurs inter and intra crystalline. Grain elongation occurs due to hardening thermo chemical treatment, figure 5.

4.3. SEM analysis of the aged alloy. Martensitic quenching heat treatment or solution treatment is followed by tempering, respectively ageing for increasing machinability properties.

Aluminium alloy ageing leads to hardening by precipitation of the second phase. These are highlighted in the SEM fracture, in figure 6.

Also in figure 6 we noted the particularly fragile structure, characteristic for biphasic alloys. For the aged aluminium alloys inter-granular fracture is observed.

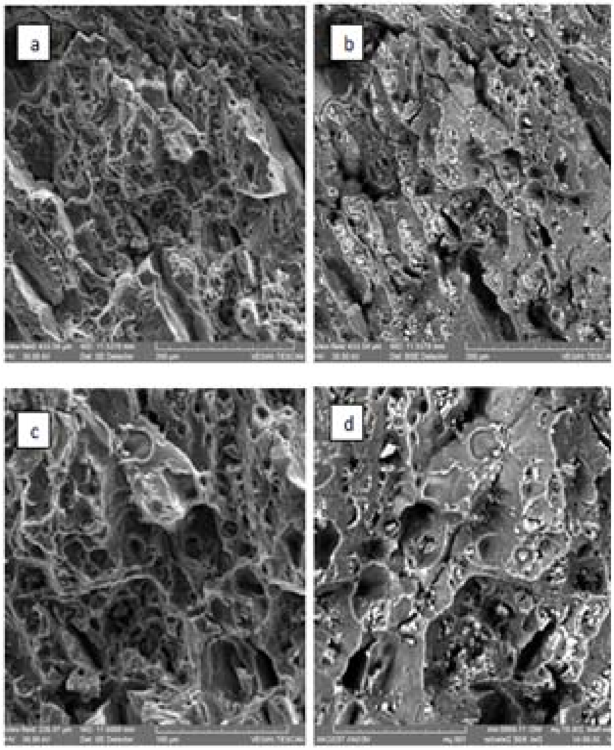

Figure 6. Fracture SEM image of the aging structure: a) 500x SE ;b) 500x BSE; c)1000x SE; d)1000x BSE.

5. DILATOMETER ANALYSIS

In this work we performed the analysis using a differential dilatometer type LINSEIS L75H/1400.

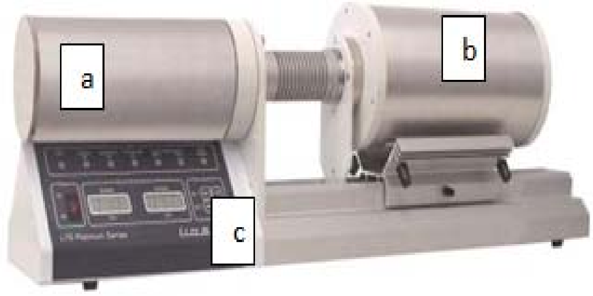

Figure 7. General Presentation: a) dilatometer measurement system; b) furnace; c) command and control system;

On this differential dilatometer can be studied in the solid state phase transformations.

When a phase transformation in the material occurs, because the new phase occupies a different volume, a discontinuity will occur on the variation curve of the thermal expansion coefficient with the temperature [6].

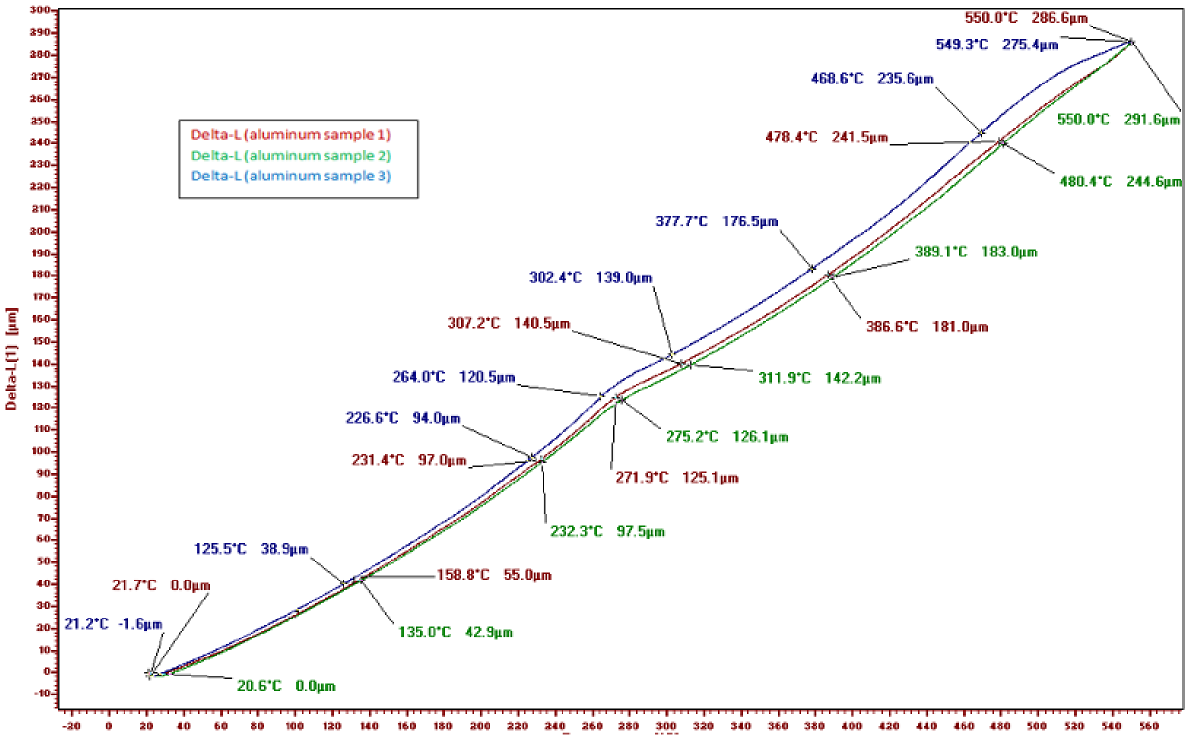

Figure 8. Dilatometer curve for alloy $AlCu_4\ Mg_{1,5}Mn$.

Table 2. Elongation of the three samples according to the temperature.

Aluminium Sample 1		Aluminium Sample 2		Aluminium Sample 3	
Temperature	Elongation	Temperature	Elongation	Temperature	Elongation
°C	µm	°C	µm	°C	µm
21,5	0	20,6	0	21,2	1,6
158,8	55	135	42,9	125,5	38,9
231,4	97	232,3	97,5	226,6	94
271,9	125,1	275,2	126,1	264	120,5
307,2	140,5	311,9	142,2	302,4	139
386,6	181	389,1	183	377,7	176,5
478,4	241,5	480,4	244	468,6	235,6
550	286,6	550	291,6	549,3	275,4

Dilatometer diagram of the alloy studied is shown in figure 8. From the chart we can see that at 275 °C the alloy presents a state variation passing from structure α+C" by dissolution of C" in a state of α saturation.

This is important in finding the heating temperature in order to achieve heating solution treatment at the variable solubility line for the alloy system.

Solution quenching treatment leads to a solution out the equilibrium, becoming more easily processed by cold plastic deformation.

CONCLUSIONS

From our research we conclude the followings:

1. The studied propeller is made from hard deformable aluminium alloy $AlCu_4Mg_{1,5}Mn$.
2. This propeller was made by plastic deformation, previously solution treated, and after deformation aged, in order to offer the necessary functioning hardness.
3. From the dilatometry analysis is observed that between 26 °C and 550 °C there are no phase transformations but only state transformation, due to the Mn percent.

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