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RESEARCH ON THE INFLUENCE OF PLASTIC DEFORMATION AND THERMAL TREATMENT ON THE MICROSTRUCTURE AND ITS MECHANICAL PROPERTIES OF THE ALUMINIUM ALLOY 2024

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Abstract: *Due to the excellent combination of good mechanical properties and low specific weight, the alloy AlCu4Mg1, series 2000, is used in industry leading, particularly in the aerospace and building cars, but also for casting molds for plastics. As part of alloys hardened by natural aging category, separate precipitates in solid solution strongly influence the mechanical properties and corrosion resistance. This work presents some research on the influence of plastic deformation and thermal treatment on the microstructure and its mechanical properties.*

Keywords: alloy 2024, microstructure, intermetallic particles, mechanical properties

Introduction

The alloys of the 2000 series, structural hardening, form a wide range of alloys characterized by good heat resistance, resistance to corrosion in relatively low corrosive atmosphere, average strength in the quenched condition matured, but relatively high condition revenue dipped. Aluminum is the second most used metal in the world mainly because of its lightness and its excellent corrosion resistance in many quarters. It is indeed one of the lightest materials with a density of 2700 $kg.dm^{-3}$ [1] This property makes aluminum and its alloys materials highly acclaimed in the aviation industry and especially in the design of aircraft (up to 73% on the A340) [2]. The "Duralumin", is the first aluminum alloy having mechanical properties comparable to those of ordinary steel. Aluminum alloy 2024 is an alloy that is in the 2000 series, a type alloy Al-Cu-Mg. The copper alloy element content is added to the order of 2 to 6% by mass. Copper enhances the mechanical properties and in particular the hardness, improved flow ability compared to pure aluminum for copper concentrations between 7 and 8%, but the addition of copper induces a poor corrosion resistance. It allows, during the thermomechanical process, the precipitation hardening phase called phases, the origin of the mechanical properties of alloys of this series. The addition of magnesium alloy Al-Cu also caused a significant increase in the mechanical properties of the alloy during the maturation stage or income. The 2024 alloy contains spherical particles rich in Cu and Mg that correspond to S phase or Al_2CuMg. They have an average size of about 5 microns and regular shape. Also present are irregularly shaped particles rich in Cu, Fe and Mn. These particles have an average size of 30 microns and occupy a surface fraction of 2.8% while the surface fraction covered by particles Al_2CuMg is only about 1% [3]. In a study of pitting corrosion on the 2024 T3 alloy using analysis "nuclear microprobe", Boag et al. [4] have confirmed the presence of intermetallic particles of the Al-Cu-Mn-Fe with an average size of 20 microns, and particle type Al_2CuMg smaller than previous ones. In addition, research conducted by Buchheit et al. [5] showed the presence of 61.3% of Al_2CuMg (S phase), 12.3% of Al_6 (Cu, Fe, Mn), 5.2% of Al_7Cu_2Fe and 4.3% of $(Al,Cu)_6Mn$ in 2024 (in under surface fraction covered by the intermetallic particles). The natural aging of the grain boundary solid solution precipitated secondary phases.

Materials and experimental procedure

The material used for this study is an aluminum alloy 2000 series, alloy 2024. The samples are taken from the rolling direction through long (TL), with the following dimensions: length 110mm, width 10mm and thickness 1.5mm. The chemical composition of alloy 2024 is shown in Table 1.

Table 1. Chemical composition (wt%) of the material of the study

Chemical elements	Al	Cu	Mg	Mn	Fe	Si	Ti
wt (%)	base	4,2	1,5	0,60	<0,5	<0,5	0,03

For this study we used 2024 aluminum alloy in four conditions: T351, temper and artificial aging at two temperatures.

1.Initial condition - after solution treatment at 495°C for 30min, cold plastic deformation with strain hardening (1-3%) and aging at ambient temperature (T351).

2 After solution treatment at 495°C with cooling in water (20°C) for 15-20seconds (Tf).

3. After solution treatment at 495°C and tempered at 170°C for 365h (TR=170°C).

4. After solution treatment at 495°C and tempered at 190°C for 80h (TR=190°C).

The T351 – after solution treatment at 495°C for 30min, cooling, hardening, aging at room temperature.
The tempering is fresh in rapid cooling, for 15-20 seconds, in water (20°C) after solution. Artificial aging is a follow heating temper. We performed the artificial aging at two temperatures and different time periods, respectively 170°C for 365h and 190°C for 80h, under conditions encountered in the literature. [6,7]
The method of surface preparation and surface conditions are important parameters for the study of intermetallic particles using AFM (Atomic Force Microscopy).The roughness of the sample must be low to highlight changes in topography of the sample. The surface preparation consisted of mechanical polishing since SiC paper (grade 1000 and 4000) to a diamond polishing paste (particle size of 3 microns and 1μm) using ethanol.
The main results are summarized in Table 2.

Table 2. Roughness of samples alloy 2024

Condition	Ra (μm)	Rt (μm)
Al2024 (T351)	0,036	1,36
Al2024 (Tf)	0,04	1,29
Al2024 (TR=170°C)	0,030	0,92
Al2024 (TR=190°C)	0,035	1,62

Tensile tests were performed on samples with dimensioned 110mm/10mm/1, 5mm. We conducted tensile tests for 2024 T3 alloy, tempering, revenue 1 and revenue 2. The tensile curves are shown in Figure 1.

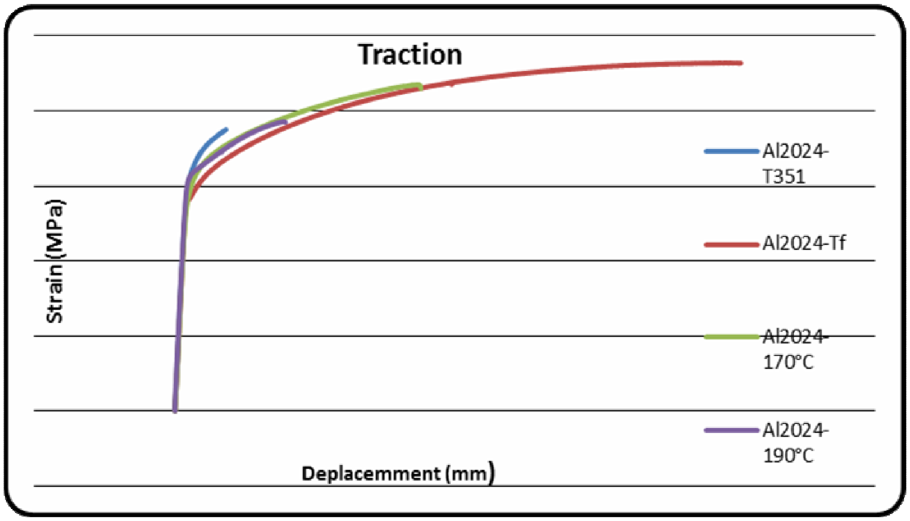

Fig. 1. Tensile curves for alloys 2024 complete in different conditions

Results and discussions

In Table 3 are presented the values of mechanical properties determined after tensile testing. The scanning electron microscopy has allowed us to achieve micrograph of samples alloy 2024 for conditions T351 and temper. To obtain the micrographs we used the backscattered electrons, because this mode uses the chemical contracts.

Table 3 . Values of mechanical properties for different conditions

Conditions	R_m (MPa)	R_e (MPa)	A (%)	E (GPa)
Al2024 (T351)	447	312	7,2	75,9
Al2024 (Tf)	464	270	19	74,2
Al2024 (TR=170°C)	435	290	8,5	73,2
Al2024 (TR=190°C)	385	302	3,9	73,07

(a) (b)

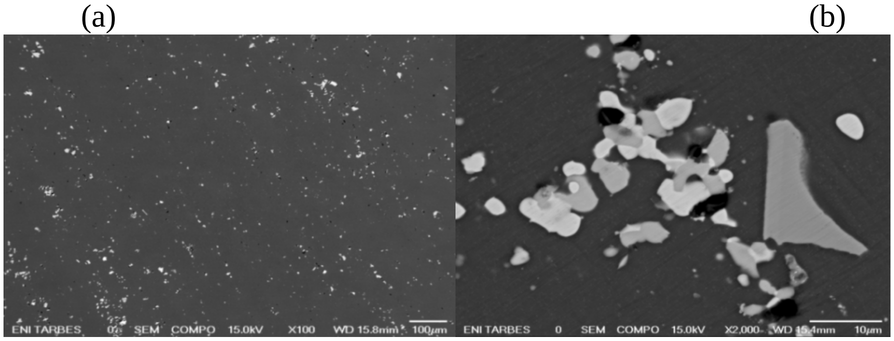

Fig. 2. SEM image of a surface (a) and intermetallic particles (b) alloy 2024 T351

(a) (b)

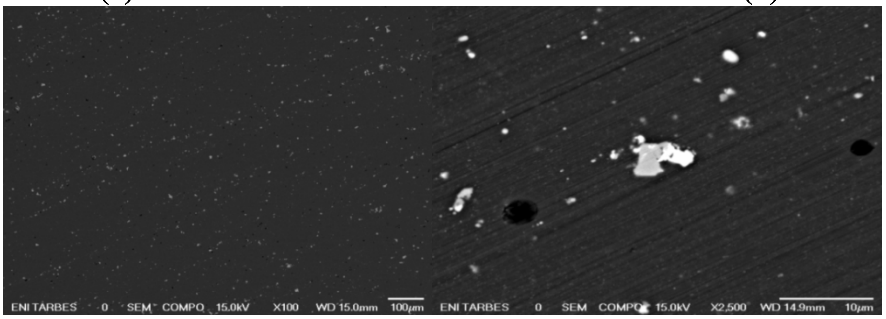

Fig. 3. SEM image of a surface (a) and intermetallic particles (b) 2024 alloy tempering

The EDS analysis carried out confirms the existence of intermetallic particles.
To receive state (T3) is confirmed the presence of a particle type Al_2Cu (θ) and Al-Cu-Mn-Fe.
In the case of 2024 alloy quenching fresh EDS analysis confirmed the presence of the intermetallic particles such as Al-Cu-Mn-Fe.

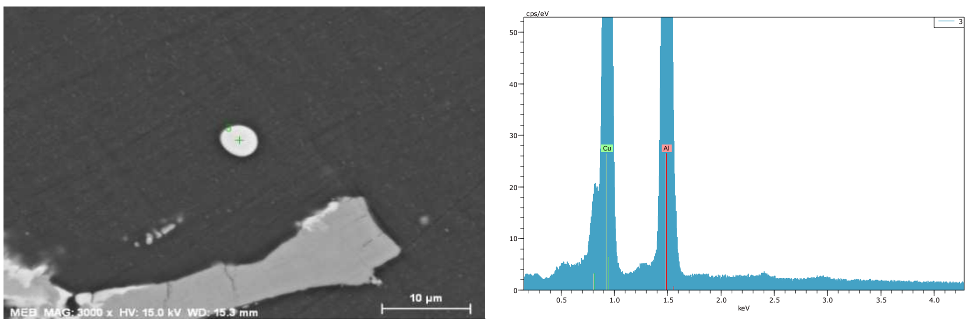

Fig. 4. The EDS analysis of particle type Al_2Cu

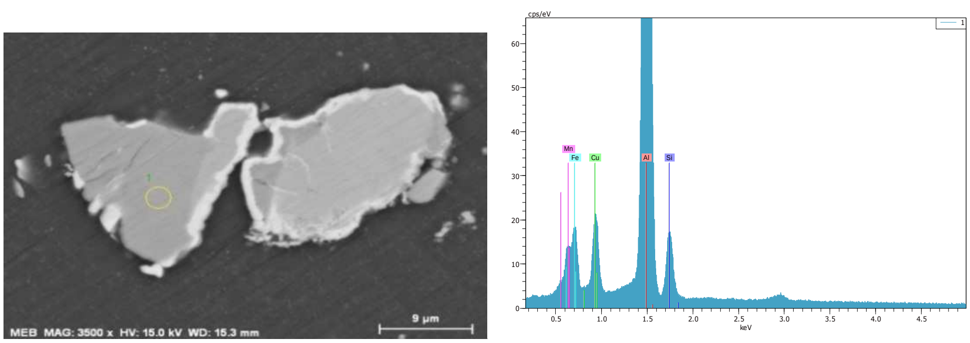

Fig. 5. The EDS analysis of particle type Al-Cu-Mn-Fe

Using atomic force microscope, it was realized a surface topography and also a mapping of potential. The identification of intermetallic particles was carried out after a tracking microscope.

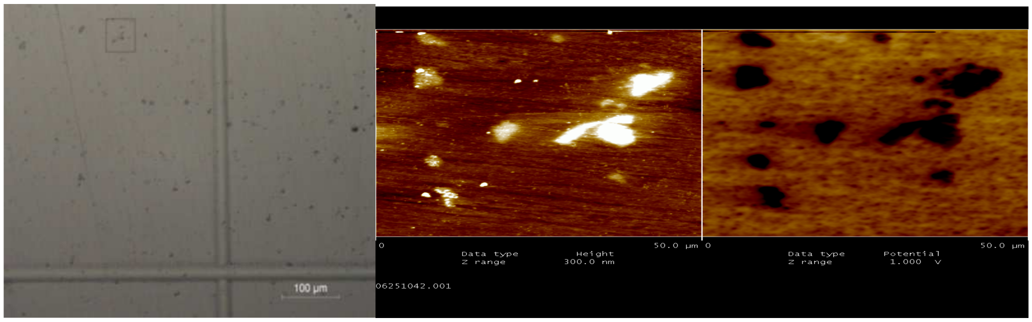

Fig. 6. AFM image Al2024-T351

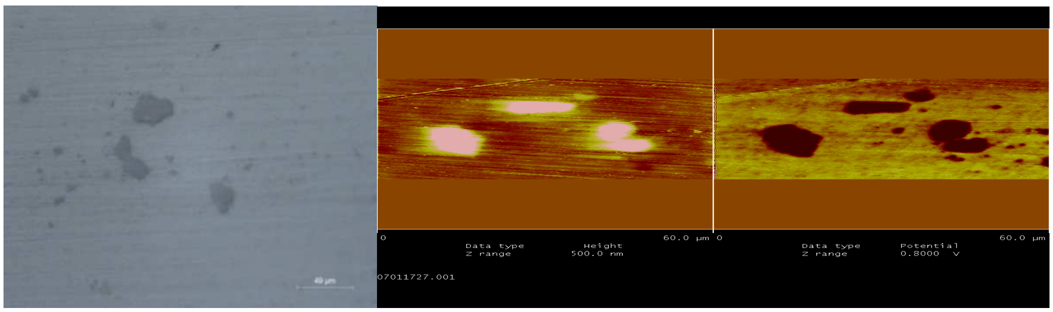

Fig. 7. AFM image Al2024-Tempering

Fig.8. AFM image Al2024(TR=170°C, 365h)

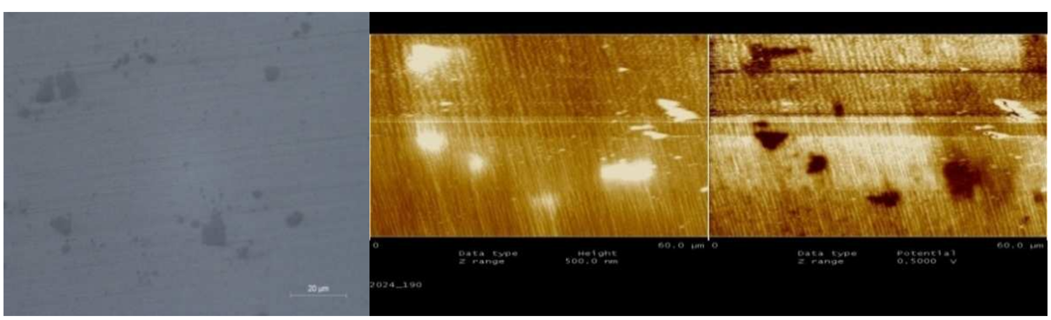

Fig. 11. AFM image (Al2024-TR=190°C, 80h)

Conclusions and perspectives

Scanning electron microscopy and atomic force microscopy confirmed the existence of intermetallic particulles type Al-Cu-Mg (S-phase Al_2CuMg) and type Al-Cu-Fe-Mn for the alloy aluminum 2024-T351 and tempering.

The results of tensile tests of the value obtained for mechanical stress (UTS) and yield strength (Re) are designed to give those in the literature, while the elongation values are somewhat lower.

The following work will follow the study of structure (nature of the precipitates, the precipitates size, distribution and surface density of the precipitates using a statistical approach for image analysis) and mechanical properties of alloy aluminum 2024 artificial aging to different temperature.

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