Microstructural and scanning Kelvin probe force microscopy characterization of WE43 magnesium alloy

G. S. Pereira [1], T.R.F. Cavalcante[1], J. A. Avila[2], M. A. Ferreira[3], M. H. Miyazaki[3], F. Fernandez[3], W. W. Bose Filho [1]

[1]São Carlos School of Engineering, University of São Paulo , SP, Brazil
[2] São Paulo State University, Campus of São João da Boa Vista, SP, Brazil
[3]Brazilian Aerospace Conglomerate, SP, Brazil
e-mail: gualter@usp.br

Abstract

The growth of the aerospace market has increased the competition among aircraft manufacturers, leading them to reduce operational costs through more creative solutions. From this perspective, new ultralight metallic alloys have been developed to replace the traditional ones, aiming weight reduction without significant resistance compromise. This work aims to characterize microstructure and corrosion micromechanisms taking place on the non-flammable Mg alloy, WE43 (Mg-Y-Nd-Zr). Optical and scanning electron microscopies and Kelvin probe scanning microscopy were used. As result, the microstructure depicted precipitates dispersed within and at boundaries of the grains. From the digitalization of the scanning Kelvin probe microscopy results, it was possible to verify that the intermetallic particles are nobler than the αMg matrix. Indicating a local preference for microgalvanic corrosion and subsequently by WE43 pitting in such corrosive environment. These results and their consequences will be discussed in detail.

Keywords: *Magnesium alloy WE43; Microstructure; Microgalvanic; Non-flammable.*

Introduction

Magnesium (Mg) is an element full of opportunities, among them is the fact that it is one of the most abundant materials on the planet; being 100% recyclable and having a low density of approximately 1.80g/cm3. Its alloys enable the parts production with a weight reduction of up to 1/3 concerning similar aluminum alloys products, commonly used in the aeronautical industry. Mg alloys can be considered an innovative technology if applied for structural weight reduction of aeronautical components [1].
Between the 1950s and 1970s, Mg was widely used in the aviation industry. However, its use has decreased significantly due to structural collapses caused by fatigue, corrosion and flammability. Recent studies have shown the effectiveness of adding rare earth elements and alkali metals in improving the creep, mechanical and corrosion resistance of Mg alloys. Among the alloys already developed, we can highlight the non-flammable WE43 (Mg-Y-Nd-Zr) in which the mechanical properties and corrosion resistance have been claimed to be superior to the AZ and AM alloys. The WE43 alloy is comparable in terms of mechanical properties with some Al alloys used in the aeronautical industry [2,3].
The results presented here are part of a research project that aims to associate the effect of intrinsic features, such as grain

boundary orientation, crystallographic characteristics and precipitates, and extrinsic characteristics, like environment and galvanic contact on the mechanical properties of the WE43 Mg alloy.

Experimental Procedure

The material used in this study was the magnesium alloy WE43 (Mg-Y-Nd-Zr), with aerospace specification AMS 4371. Metallographic samples were prepared using Nital 2% as an etchant and examined in a Carl Zeiss ™ model AxioLab A1 optical microscope and an FEI® model FE-50 scanning electronic microscope (SEM). Kelvin Probe Force Microscopy (KPFM) was used to map the surface topography using their electric potential difference.

Results and Discussion

Figure 1 shows the microstructure of the WE43 alloy obtained by OM and SEM analysis, L-T plane (Fig. 1 a) MO and b) SEM) and S-L plane (Fig. 1 c) MO and d) SEM). It can be noticed that a homogeneous microstructure with a grain size of approximately 20 µm.

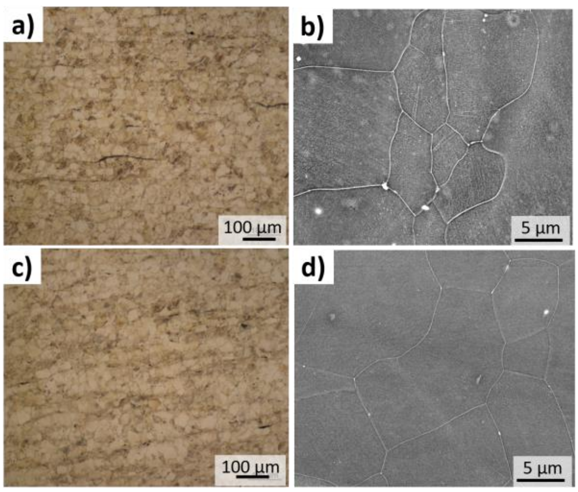

Figure 1: Microstructure of MgWE43 alloy obtained by OM and SEM analysis, a) and c) MO image in L-T and S-L planes respectively, b) and (d) SEM image, L-T and S-L planes respectively. Source: Elaborated by the author.

SEM images show the dispersed precipitates inside the grains and at the grain boundaries. According to RIONTINO (2006), these precipitates are probably intermetallic phases rich in Y and Nd. The resulting microstructure is due to the manufacturing process, and precipitation hardening occurred during heat treatment [4]. During this stage, precipitates dissolve, and rare earth elements are positioned in a solid substitutional solution in the Mg crystal lattice. Secondly, quenching, rare earth elements keep their substitutional positions. Finally, during the artificial aging, a dispersion of the rare earth precipitates in the Mg matrix arise [5].

Figure 2 shows the surface topography and contact potential difference map. The lighter regions correspond to the regions with the most potential. KPFM was used to measure potential differences between intermetallic particles and Mg matrix.

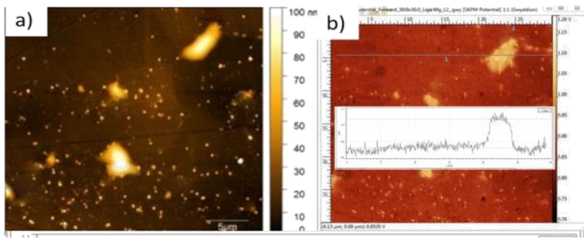

Figure12: KPFM analysis a) surface topography and b) contact potential difference map. Source: Elaborated by the author.

The intermetallic particles have the highest potential, indicating that these particles are nobler than the Mg matrix. This potential difference is cited by several authors as a major cause of microgalvanic corrosion, indicating that particles may be preferred sites for WE43C-T5 Mg alloy pitting corrosion in a corrosive environment [6,7].

Conclusions

The morphology of the equiaxed grains in the T-L and L-T planes are similar, and the

precipitates are located dispersed in the contours and dispersed within the grains.
The intermetallic particles are nobler than the matrix αMg.

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