Assessment of the Corrosion Behavior of a Sintered Al-Cu-Mg Alloy in Aeronautical Environments as a Function of the Heat Treatment

S. Sánchez-Majado[1, a], J. M. Torralba[1,b] and A. Jiménez-Morales[1,c]

[1]Materials Science and Metallurgical Engineering Department. Universidad Carlos III de Madrid. Avda. de la Universidad, 30. E-28911. Leganés. Madrid. Spain
[a]mssanche@ing.uc3m.es, [b]torralba@ing.uc3m.es, [c]toni@ing.uc3m.es

Abstract

The corrosion performance of a powder metallurgical aluminum alloy in aeronautical environments was studied for both as sintered and heat treated states. Sintered samples were obtained by uniaxial pressing of an Al-Cu-Mg prealloyed powder followed by liquid phase sintering. The heat treatments applied were T4 and T6. Corrosion behaviour was assessed by means of potentiodynamic polarization. Results for the equivalent commercial wrought counterpart, AA2024-T3, are also presented for comparison. Similar corrosion performance was observed for both as sintered and AA2024-T3 samples, while corrosion resistance of the PM materials was improved by the heat treatment, especially in the T4 state.

Keywords: electrochemical corrosion; sintered; Aluminum alloy; aeronautics

1. Introduction

The lightweight of aluminium alloys combining along with the advantages of the P/M method are gaining increasing interest for aeronautical applications [1]. Engineering Al alloys in aqueous environments are prone to localized corrosion attack, because they generally contain constituent particles with different electrochemical activity compared to the matrix, which form readily local galvanic cells on the metal surface. In this work, the corrosion behaviour of an Al-Cu-Mg base alloy produced by powder metallurgy (PM) in the as sintered, T4 and T6 state was evaluated by means of potentialodynamic polarisation tests and microstructural studies of the alloys. Corrosion tests were run on Dilute Harrison Solution (DHS) because it is considered to be closer to the atmospheric conditions often encountered by airplanes [2].

2. Experimental and Results

Powder metallurgical samples were obtained from an Al-Cu-Mg prealloyed powder which was uniaxially pressed at 600 MPa, followed by sintering at 590ºC in nitrogen for 60 minutes. As sintered samples were subsequently heat treated according to the literature [3,4] to the T4 and T6 states. Commercial AA2024 wrought alloy, in the T3 state, that is the heat treatment typically used for this alloy in aeronautical applications, was also used for comparative purposes.

Potentialodynamic polarisation tests were performed using a three-electrode system comprised of a silver/silver chloride reference electrode, 0.5 cm^2 of the alloy under study as working electrode and a platinum counterelectrode to ensure homogeneous distribution of the current. The system was connected to an EG&G Instruments Model 263A potentiostat interfaced to a computer. Potentialodynamic polarisation scans were performed at a scan rate of 0.16 mV/s, commencing from a potential 200 mV below E_{corr}. All tests were done by triplicate and performed in an aerated DHS at room temperature.

Fig. 1.a shows the three different kinds of intermetallics presented in the AA2024-T3 alloy, as well as table 1 represents their corresponding composition. On the other hand, it can be observed in figs. 1b-1c and in table2 how PM alloys are constituted by round grains of Aluminium with some alloying elements, only one kind of particles of the type *Al-Cu-Mg-Mn-Fe* and some irregular pores among the grains.

Fig. 2 depicts the polarization curves obtained for all of the studied samples. Every curve is composed by a bottom branch which represents the oxygen reduction of water, for the case of a naturally aerated neutral chloride-containing solution as the DHS, and a top anodic branch related to the oxidation of aluminum. It is important to remark that all of the PM specimens revealed a passive range, while the wrought material undergoes localized corrosion from the commencement of anodic polarization, what will lead to a faster deterioration of the latter.

Corrosion current densities (i_{CORR}), which are directly proportional to the corrosion rate, can be calculated from the polarization curves and are presented in table 3 for all of the studied alloys. The as sintered and the wrought specimens developed a very similar i_{CORR} value, which in turn, resulted to be higher than those for the heat treated PM samples. This could be attributed to the fact that the high population density of constituent particles presented in these alloys, see table 3, facilitates the propagation of the corrosion process. Sintered sample in the T6 state developed an i_{CORR} value higher than that for the T4 state.

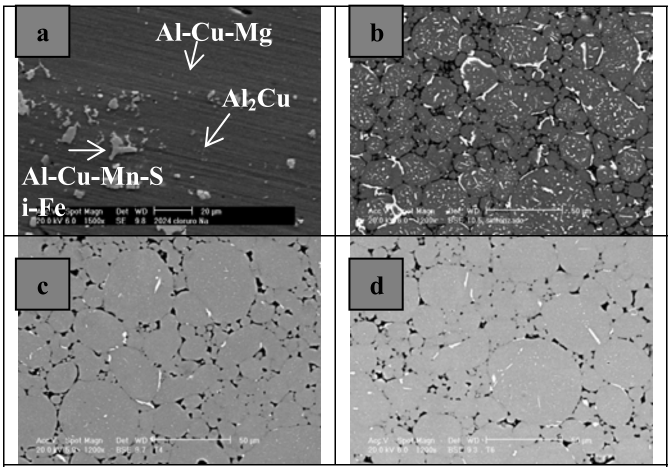

Fig. 1. SEM micrographs of (a) AA2024-T3, (b) as sintered, (c) T4 and (d) T6 sintered samples.

Table 1. Composition of intermetallics and matrix for commercial AA2024-T3

Particle	*Al*	*Cu*	*Mg*	*Mn*	*Si*	*Fe*
Matrix	*93.0*	*3.8*	*2.3*	*0.7*	*-*	*-*
Al_2Cu	*47.6*	*50.9*	*1.4*	*-*	*-*	*-*
Al-Cu-Mg	*83.7*	*13.7*	*2.7*	*-*	*-*	*-*
Al-Cu-Mn-Si -Fe	*64.0*	*9.0*	*-*	*8.8*	*4.7*	*12.7*

Table 2. Compositional differences between matrix and constituent particles for as sintered and heat treated PM samples

	Al	*Cu*	*Mg*	*Mn*	*Fe*
Matrix As sintered	*94.0*	*2.5*	*2.7*	*0.6*	*0.2*
Al-Cu-Mg-Mn-Fe	*88.4*	*6.7*	*2.4*	*1.7*	*0.7*
Matrix Sintered-T4	*93.3*	*3.5*	*2.0*	*0.8*	*0.4*
Al-Cu-Mg-Mn-Fe	*73.8*	*4.2*	*1.9*	*12.7*	*7.4*
Matrix Sintered-T6	*92.5*	*4.2*	*2.1*	*0.9*	*0.3*
Al-Cu-Mg-Mn-Fe	*75.9*	*6.8*	*1.8*	*11.4*	*4.1*

Since they both have presented similar population density, this fact could be associated with the major copper content difference between the particles and the matrix for the T6 samples, see table 2, which leads to an enhancement of pits formation through galvanic cells, because copper is the noblest metal presented in the alloys under study.

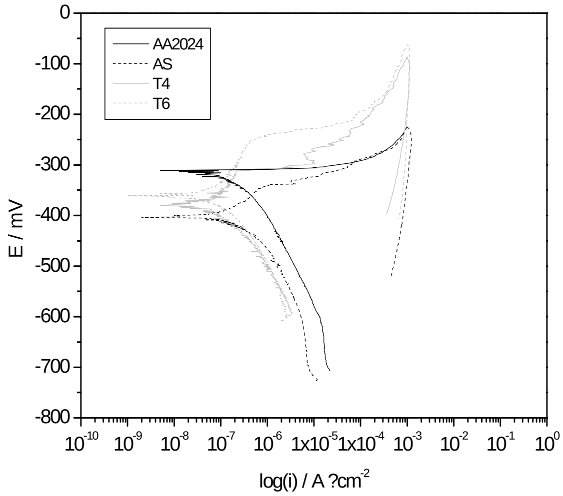

Fig. 2. Polarization curves of studied samples in DHS.

Table 3. corrosion current and population densities for as sintered and heat treated samples

Sample	*i_{CORR} / [A· cm^{-2}]*	*Population density / %*
AA2024-T3	*$1.8 \cdot 10^{-7}$*	*7.18*
As sintered	*$1.2 \cdot 10^{-7}$*	*9.66*
Sintered-T6	*$7.5 \cdot 10^{-8}$*	*1.60*
Sintered-T4	*$4.7 \cdot 10^{-8}$*	*2.07*

3. Summary

It has been observed that the corrosion performance of a sintered Al-Cu-Mg base alloy, in aeronautical environments, can be similar or even better than that developed for its wrought commercial counterpart, making aluminum PM parts more competitive. It has been also demonstrated that heat treatments can improve the corrosion resistance of a sintered aluminum alloy through decreasing the population density of intermetallics in the material and lowering copper content difference from the particles to the matrix of the specimens.

4. References

[1] M. Hull, Powder Metall., 40, p.103 (1997).

[2] D. Battocchi, A. M. Simoes, D. E. Tallman and G. P. Bierwagen, submitted to Corrosion Science (2005).

[3] J. N. Generous and W. C. Montgomery in, 'Aluminum P/M; Properties and Aplications', chapter 8 OHIO, p. 213 (1983).

[4] K. B. Baker, H. J. Roe and H. M. Short in, 'Aluminum Fabrication and Finishing', vol. III chapter 9 LONDON, p. 330 (1967).