MICROSTRUCTURAL ANALYSIS OF Al-Mg-Si-Zn ALLOY

ANÁLISIS MICROESTRUCTURAL DE LA ALEACIÓN Al-Mg-Si-Zn

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ABSTRACT: As a part of an overall effort to develop a new Al-alloy appropriated for structural applications, a characterization research was directed towards the development of microstructure and their relationship with heat treatment. The Al-Mg-Si-Zn was chose for that purpose due to the presence of precipitates in α-Al matrix and at grain boundaries, capable to get an excellent relationship between hardness and mechanical resistance. With regards to microstructure, this was characterized in the as-cast and as-aged condition. This treatment was carried out in two stages, the first one at 450ºC during 3 hr which correspond to homogenization treatment and the second one, the ageing treatment at 160 ºC 1hr. Results of microstructure characterization in the as-cast ingots showed the α-Al dendrites, and in addition the presence of a binary eutectic and particles of Mg_7Zn_3 type in interdendritic regions. The eutectic and particles were modified by the aged treatment. Transmission electron microscopic observations carried out in specimens with and without heat treatments showed a uniform distribution of precipitates with different morphologies like cubic, spherical and platelet; in the matrix, which were no detected during the scanning electron microscope observations.

KEY WORDS: Microstructure*,* eutectic*,* precipitates*,* heat treatment.

RESUMEN: En un esfuerzo por desarrollar una nueva aleación con aplicación estructural, se ha desarrollado una aleación base Aluminio aleada con magnesio, silicio y zinc. La investigación pretende correlacionar la microestructura y con el tratamiento térmico. La aleación Al-Mg-Si-Zn, fue elegida para ese propósito debido a la presencia de precipitados tanto en la matriz del α-Al, como en los límites de grano, los cuales permiten una excelente relación entre la dureza y la resistencia mecánica. En lo que respecta a la microestructura, esta fue caracterizada bajo condición de colada y después de ser tratada térmicamente por envejecimiento. Este tratamiento fue realizado en dos etapas, la primera a 450ºC durante 3 horas que corresponde al tratamiento de homogeneización; y la segunda al proceso de envejecimiento artificial llevado a cabo a 160ºC durante 1hr. Los resultados indican la presencia de dendritas de α-Al, además un eutéctico binario y partículas de Mg_7Zn_3 adentro de las regiones interdendríticas. El eutéctico y las partículas fueron modificados por el tratamiento de envejecido. Las observaciones realizadas con el microscopio electrónico de transmisión en especímenes con y sin tratamientos térmicos, demostraron una distribución uniforme de precipitados con diversas morfologías, tales como cúbico, esférico y plaqueta; para la matriz de α-Al, los cuales no fueron detectados durante las observaciones en el microscopio electrónico de barrido.

PALABRAS CLAVE: Microestructura, eutéctico, precipitados, tratamiento térmico.

1. INTRODUCTION

Aluminium element has considerable merit as the basis for structural material due to its low density, availability and reasonable cost [1-2]. Also, AlMgZn based alloys are widely used in aerospace applications due to the unique combination of lightweight and high mechanical properties [1–5]. In addition, aluminium-silicon (Al-Si) foundry alloys are popular because of their good castability, surface finish and resistance to corrosion, coupled with their high strength-to-weight ratio [3].

For instance, in the as-cast condition, the AlMgZn alloy has been reported a microstructure consisting of the α-solid solution and the $Al_{32}(MgZn)_{49}$ phase precipitated in α-Al matrix. The eutectic consisting of a fine dispersion of the $\alpha + Al_{32}(MgZn)_{49}$, was found to be segregated at grain boundaries [4]. Further dispersion of the $Al_{32}(MgZn)_{49}$ phase in the matrix was increase by means of thermal treatments, carried out in as-cast ingots, by taking advantage of the fast kinetic reactions taking place in solid state at 160ºC, giving as a result Al-alloy with improved mechanical properties.

This research has as a main scope to identify the possibility of used the AlMgSiZn alloy as structural material. The first part of this research has been focused in the distribution of precipitates in the Al-base alloy, in order to achieve two targets: one of them is to identify the Zn effect on the microstructure and their relationship after a heat treatment.

As a first step we characterized the resulting microstructure in the as-cast ingot and latter the resulting microstructure in aged ingots, looking for eutectic and $Al_{32}(MgZn)_{49}$ phases and searching at the same time the effect of Zn additions by means of some kind of precipitation phase at grain boundaries and/or matrix, by taking advantage that the Zn decreases their solid solubility in the α–Al phase [6].

2. EXPERIMENTAL DETAILS

2.1 Alloy design

An Al-2.7 at.% Mg-5.5 at.% Si-1.0 at.% Zn alloy was prepared by using commercial Al, Mg, Si and Zn element ingots with purities of 99.98%. Firstly, the commercial Al, Mg, Si and Zn were placed in an alumina/graphite coated crucible and melted into a resistance furnace under an argon atmosphere, the bath was stirred with a flux of argon for five minutes and then, the liquid alloy was poured into a copper mold of dimensions 50mm x 120mm x 20mm.

Thermocouples were introduced through the side of the mold and were located centrally at 50 mm. The thermocouple outputs indicating cooling rate for the Al-Mg-Si-Zn alloy of ≈50 K/s.

2.2 Heat treatments

Aged treatments were performed in the as-cast ingot in two steps:
i) Homogenization at 450ºC for 3 hours and then quenched in hot water at 80ºC .
ii) Artificial aged at 160ºC for 1 hour.

2.3 Microstructure characterization

In order to carry out the characterization of the resulting microstructure, the ingots were sectioned longitudinally and centrally in the plane normal to the diverging mould faces, grinded, polished and etched in Keller`s reagent, prepared with 15 volumens of HNO_3, 10 volumens of HCl, 5 volumens of HF and 70 volumens of H_2O at room temperature for a while of 30 secs; in order to reveal the different phases, and precipitates present in the ingot. The resulting microstructure was characterizated by using a Stereoscan 440 scanning electron microscope (SEM) and a 2100 Jeol transmission electron microscope (TEM). Both electron microscopes were equipped with WDS-microanalyses facilities. X-ray diffractometer which employed a CuKα radiation, a Ni filter and a scan velocity of 2º/min.

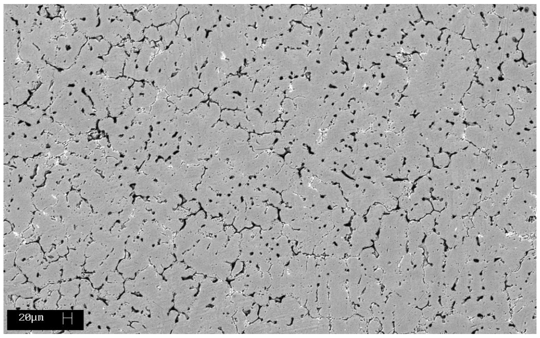

Figure 1. Microstructure of the Al-Mg-Si-Zn alloy in the as-cast condition. Showing the dendritic structure

3. RESULTS AND DISCUSSION

3.1 Microstructure

The microstructure observed in the as-cast ingots, as that shown in Figure 1, consisted of α-Al dendrites with sizes between 110 to 140 μm. In interdendritic regions (figure 2), it was observed the presence of eutectic and spherical particles. The eutectic showed a white color with a maximum width of 10 μm, always following the contour of the dendritic arms. This eutectic, instead of presenting a platelet morphology as that has been reported previously [5], showed the presence of rows of spherical particles.

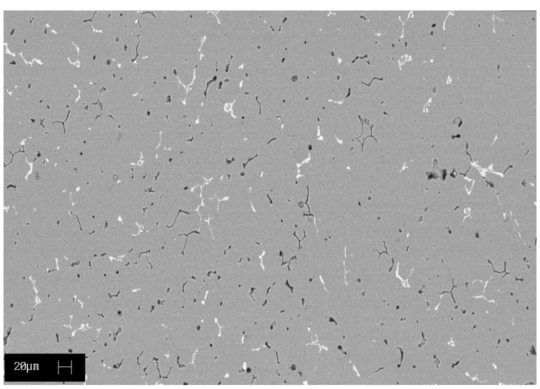

Figure 2. Eutectic type microstructure of the Al-Mg-Si-Zn alloy in the as-cast condition

In samples aged. It was observed a modification of the as-cast structure, the white eutectic (with a maximum width of 7 μm) takes the morphology of white spherical particles which were present as rows started to grow. The black spherical particles located at secondary dendritic arm spacing did not show any change at this stage. In addition, in this kind of samples was observed an increase in the amount of spherical particles which followed the contours of the secondary dendritic arm spacing, sometimes, as the dendrites were modified by the heat treatment, these spherical particles were trapped in the α–Al matrix. The width of the black spherical particle regions increased from 2μm (as cast) to 6μm. Also a change in the white eutectic was observed, for instance, the spherical particles which started to grow during the first aging stage, now developed a dendrite-like pattern.

3.2 X-Ray diffractometry

In order to have a qualitative information of the phases present in the Al-ingots with and without heat treatments, X-ray diffraction was carried out of them, and for the collected data, it were detected seven peaks from specimens in each condition. As was expected, the main peaks corresponded to the α–Al solid solution or α–Al dendrites.

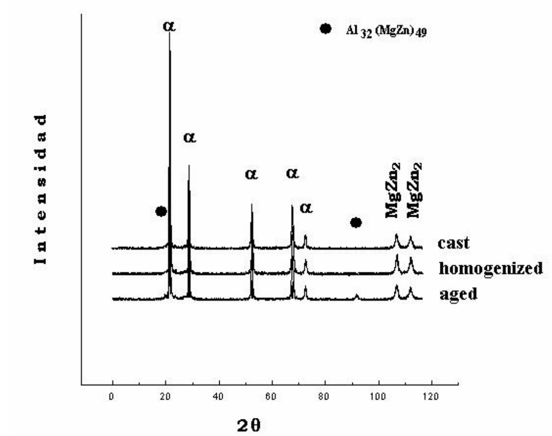

Figure 3. Phases identified by X-ray difracction in the AlMgSiZn ingots

Also, it was detected (from a qualitative point of view) the presence of binary precipitates of MgZn, Mg_4Zn_7, Mg_7Zn_3, $MgZn_2$, AlMg, Al_3Mg_2, $Mg_{17}Al_{12}$, ternary precipitates of $AlMg_4Zn_{11}$, $Al_{32}(MgZn)_{49}$ (figure 3). An interesting outcome of these X-ray diffractograms was an increase in the relative intensity (I/Io) of peaks II, III and VII for aged conditions, indicating from a qualitative point of view the precipitation or growing of particles after ageing treatment.

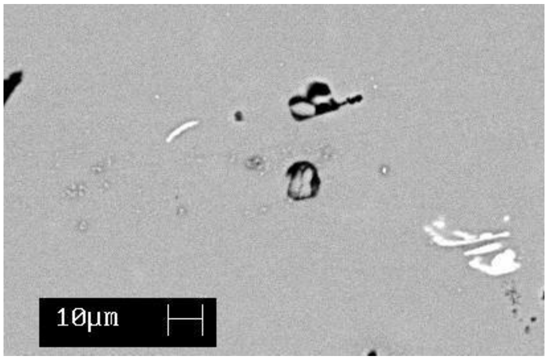

Figure 4. Precipitates observed in AlMgSiZn alloy aged

4. CONCLUSIONS

The resulting AlMgSiZn alloy showed the presence of α-Al matrix with dendritic structure with interdendritic phase identified as an $Al_{32}(MgZn)_{49}$. In the AlMgSiZn matrix, was detected the presence of Mg_7Zn_3 precipitates which were distributed heterogeneusly on the α-Al matrix. Precipitates with Si was not detected on the matrix.

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REFERENCES

[1] DÁVILA MUÑOZ F.D., A. GARCÍA H. A. GARCÍA, S. VALDEZ; XXIX Congreso Internacional de Metalurgia y Materiales. Saltillo, Coahuila. 2007.

[2] VALDEZ S. GARCÍA A. NACE-XIV International Materials Research Congress; 2008.

[3] KAZUHIRO NOGITA, STUART D. McDonald, Katsuhiro Tsujimoto, Kazuhiro Yasuda and Arne K. Dahle. J. Elec. Japan. Soc. Microscopy 53(4): 361–369 (2004).

[4] S.VALDEZ, M. TALAVERA, J. GENESCA AND J.A. JUÁREZ-ISLAS. Procc. MRS. 654 (2001) AA2.5.1-3.5.6.

[5] DUAN X, HAO Y, YOSHIDA M, ANDO T, GRANT N. Liquid Dynamic Compaction of Aluminum Alloy 7150. Int J Powder Metall 29, no. 2, pp. 149– 160.

[6] SHARMA M, AMATEAU M, EDEN T. Aging response of Al–Zn–Mg– Cu spray formed alloys and their metal matrix composites. Mater Sci Eng A StructMater PropMicrostruct Process 2006; 424:87–96.