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Effect of Mg additions, Hot-Extrusion and Cold-Rolling on Microstructure and Mechanical Properties of 2024 Alloy during Aging

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Al alloys of 2xxx series (2024) with high specific strength, good fracture toughness, and excellent fatigue properties have been found important applications in the aerospace industry. In commercial 2024 alloys, Cu and Mg are the main alloying elements with small amount of Si and other minor elements such as Mn, Zn, Ti and Fe. Nonetheless, has recently been reported an increment on strength and hardness by Mg addition (< 2 wt. %); however, this is accompanied by a decrease in ductility and impact resistance [1]. In this work is evaluated the effect of hot-extrusion and cold-rolling on microstructure and hardening of the 2024 alloy modified with magnesium during aging heat treatment.

The 2024 alloy fabrication with Mg additions (0.25 wt. %) was made by conventional direct casting, the melt was degassed with argon gas (20 psi) for 5 min period and AlTiB was added as grain refiner (0.13 % wt.). Modification with Mg was performed with addition of pure Mg (99.99 %). The hot-extrusion (HE) consisted of a thickness reduction in the samples (10 mm in diameter) by using indirect extrusion and an extrusion ratio of 16 at 480 °C. The solution heat treatment (SHT) was at 495°C for 7h. The cold-rolling (CR) involved 5 to 15% thickness reductions; and a final aging step (195°C) at several times was realized. The microstructural characterization was done using an optical microscope (OM) ZEISS model Scope A1, a SEM Hitachi model SU3500 and a TEM PHILIPS model CM-200; XRD analyses were performed in a Panalytical X'Pert PRO diffractometer. The mechanical properties were evaluated using hardness test in a LECO LM300AT microhardness tester in accordance with the ASTM standards.

The Fig. 1 shows the HE and SHT effects on microstructure of 2024 (Mg) alloy. The microstructure changed of dendritic grains in as-cast condition to equiaxed grains after HE. The spatial distribution of Cu-rich phases becomes more homogeneous and smaller particles are observed. In addition, after SHT dissolution of Cu-rich phases was carried out. The Fig. 2 shows a) age-hardening curves of 2024 (Mg and 2024 (Mg) HE alloys after of CR 5 and 15 %; b-c) shows XRD graphs of 2024 and 2024 HE alloys in conditions as cast, as cast+ HE, SHT and at the maximum peak during aging.

For Fig. 2a, it is evident highest hardness value in samples after CR 15% just after plastic deformation associated to dynamic precipitation and a second peak at 600 min aging associated to Al_2Cu and Al_2CuMg precipitates. For Figs. 2b-c, it is evident the formation of Al_2Cu and Al_2CuMg precipitates, which are responsible of second peak hardening. It is concluded that the HE and CR generate changes microstructural that improve the hardness of 2024 alloy and a double peak hardening due dynamic precipitation.

References:

[1] C.G. Garay-Reyes, I. K Gómez-Barraza, M. A. Ruiz-Esparza-Rodríguez, I. Estrada-Guel, J. P Flores-De los Ríos, M. C. Maldonado-Orozco and R. Martínez-Sánchez, Microsc. Microanal. 23 (Suppl 1) (2017) p. 400-401.

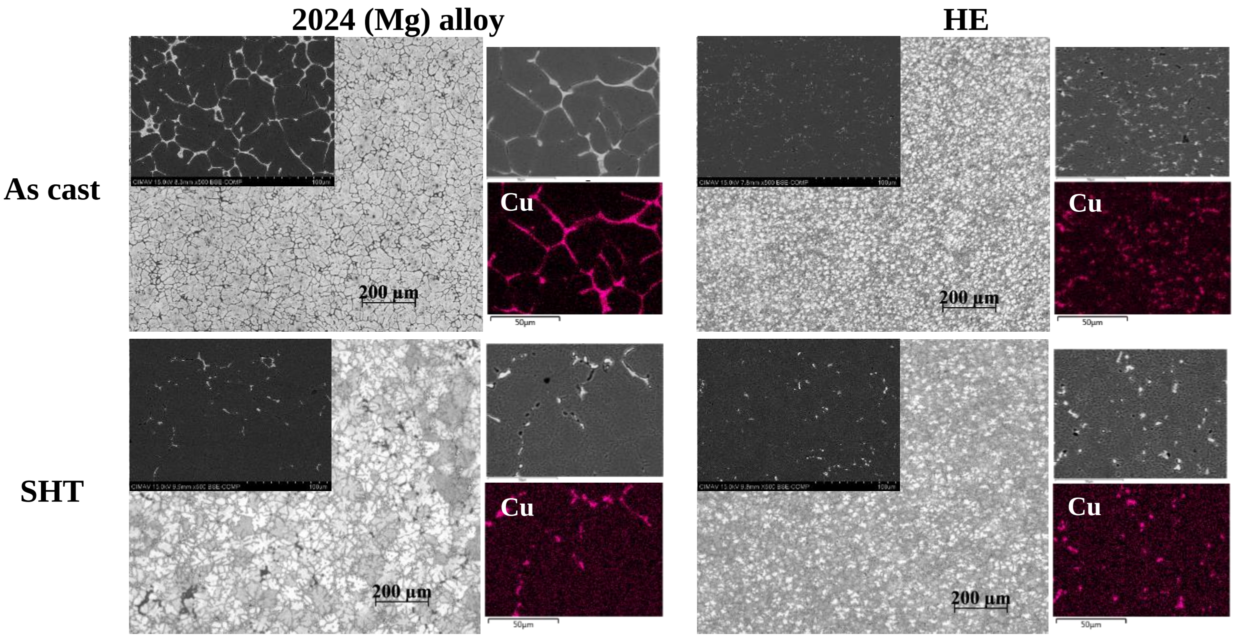

Figure 1. OM-SEM-Maps Micrographs of 2024 and 2024 HE alloys in as cast condition and SHT.

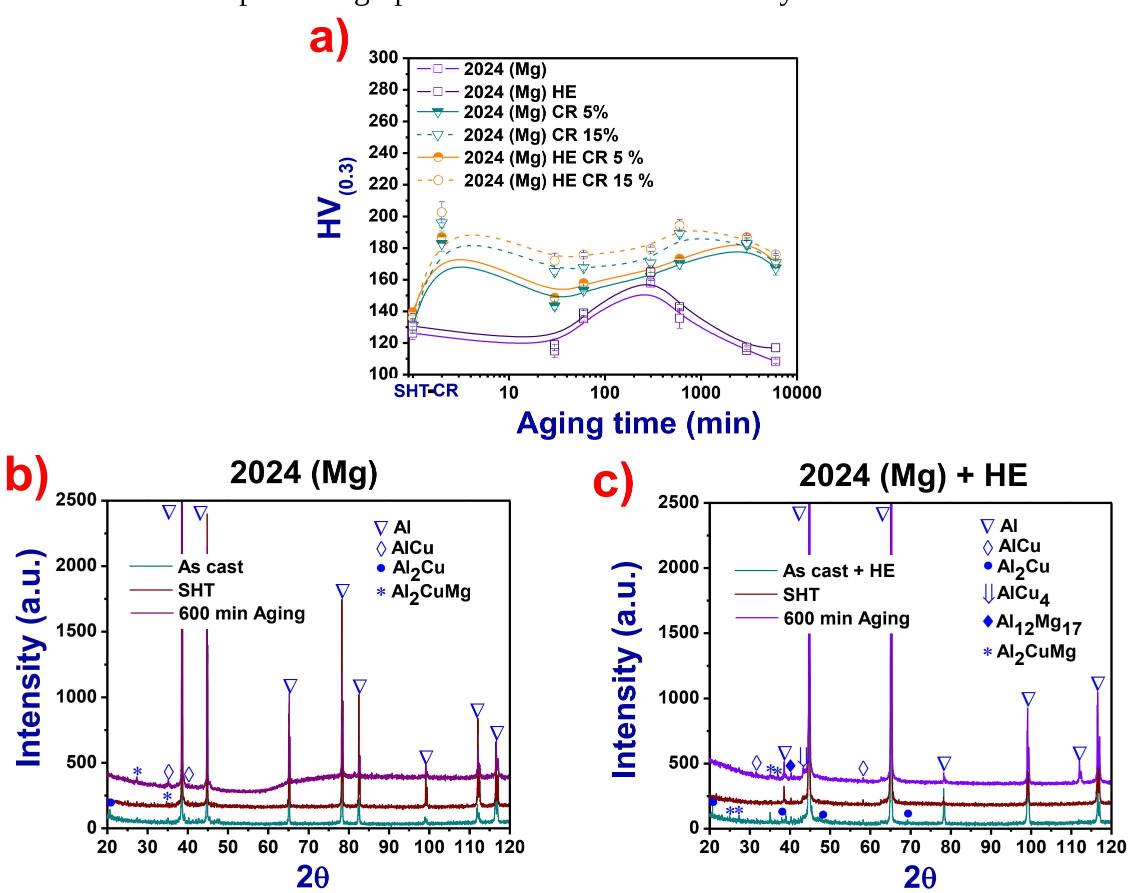

Figure 2. a) Graph of the Vickers hardness (HV) versus ageing time and b-c) XRD graph. For 2024 and 2024 HE alloys, in conditions as cast, as cast+ HE, SHT and peak aging.

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