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Phase Selection and Mechanical Properties of Permanent-Mold Cast Mg-Al-Ca-Mn Alloys and the Role of Ca/Al Ratio

Hamid Ali ELAMAMI[1], Alper INCESU[1], Konstantinos KORGIOPOULOS[2], Mihriban PEKGULERYUZ[2], Ali GUNGOR[1,*]

[1]*Metallurgical and Materials Engineering, Karabuk University, 78050, Karabuk, Turkey.*
[2]*Materials Engineering, McGill University, H2A 0C5, Montreal, Quebec, Canada.*
✉ C*orresponding Author Email: agungor@karabuk.edu.tr*

ABSTRACT

In this work, phase selection, microstructure and mechanical properties of Mg-Al-Ca-Mn alloys with three different Ca/Al ratios (0.58, 0.79 and 0.91) were studied. The Mn content of the alloys was kept constant at □0.30 wt.%. Thermodynamic non-equilibrium (Scheil) simulations, X-Ray Diffraction (XRD) analyses and Scanning Electron Microscopy/Electron Dispersive Spectroscopy (SEM/EDS) determined that all three alloys contain α-Mg solid solution phase, Al_8Mn_5 intermetallics and, depending on the Ca/Al ratio, combinations of C36-$(Mg,Al)_2Ca$ (hP24 a=0.577-0.586 nm, c=1.819-1.835 nm), binary C14-Mg_2Ca (hP12, a=0.620 nm c=1.023 nm), ternary C14-Mg_2Ca (hP12, a=0.561-0.599 nm, c=1.025-1.051 nm), and/or C15-Al_2Ca (cF24, a = 0.793 nm) Laves phases. It is observed that Ca/Al ratio shows a direct relationship with the total amounts of Laves intermetallics and the amount of the C36 phase, and an indirect relationship with the amount of C14 phase. Microhardness measurements, room and elevated temperature (150 °C and 200 °C) tensile tests, as well as tensile creep tests (175 °C/50 MPa), were carried out to determine the mechanical properties of the alloys. Results show that the hardness and room temperature yield and ultimate tensile strengths (UTS) increase while the ductility at all temperatures decreases with increasing Ca/Al ratio. At elevated temperatures, in the range of Ca/Al ratios investigated, the UTS has a relationship with the dissolved amount of Ca and Mn in the α-Mg phase. Creep strain was found to decrease from 0.35 % to 0.05 % as Ca/Al increases from 0.6 to 0.9 and as the amount of the C36 phase which can strengthen grain boundaries increases. One order of magnitude improvement seen in creep resistance as the Ca/Al ratio increases from 0.6 to 0.8 is attributable to the presence of C36 and C14 phases rather than C36 and thermally unstable C15 phase in the alloys and to the increased amounts of dissolved Mn and Ca in the α-Mg matrix.