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Directional Solidification and Characterization of Zn-Al, Zn-Ag and Zn-Al-Ag Alloys

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Abstract – Zinc-Aluminum, Zinc-Silver and Zinc-Aluminum-Silver alloys have been directionally solidified and analyzed. Several correlations were found between thermal parameters (cooling rate, temperature gradient and interphase velocity), grain size, dendritic spacing and microhardness in directional solidified samples which present different types of structures: columnar, equiaxed and columnar-to-equiaxed transition (CET). The correlation between cooling rate and dendritic spacing, density of grains and temperature gradient in columnar and equiaxed grains were analyzed. Also, correlations between grain size and dendritic arm spacing and the variations in microhardness were investigated as a function of both type of microstructure and load applied.

The Zinc-Aluminum (ZA), Zinc-Silver and Zinc-Aluminum-Silver (ZINAG) alloys can be cast using a variety of casting methods. The fabrication costs are competitive and at present it is used in some vehicle components in transmission and suspension systems [1].

Alloy samples 25 mm in diameter were solidified unidirectionally upwards in an experimental set up consisting of a heating unit, a temperature control system, a temperature data acquisition system, a sample moving system and a heat extraction system [2].

The temperature at different points in the sample was measured using K-type thermocouples, which were previously calibrated. The thermocouples were located inside the samples at known distances from the base.

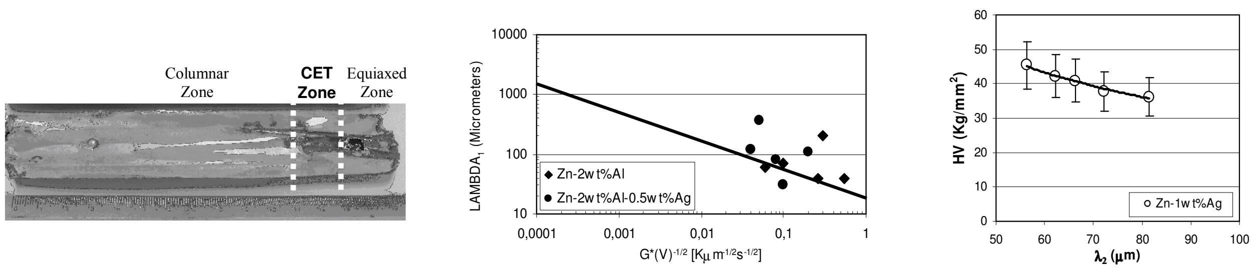
After solidification the samples were cut in the axial direction, were polished and the alloys were etched using concentrated hydrochloric acid for approximately 100 seconds at room temperature, followed by rinsing and wiping off the resulting black deposit and for microstructures with a mix containing chromic acid (50 g Cr_2O_3; 4 g Na_2SO_4 in 100 ml of water) for 15 seconds at room temperature, which resulted adequate for revealing the structure. The position of the columnar to equiaxed transition in the samples was determined by observation under an optical microscope.

The equiaxed grain size was measured using the ASTM E112 standard norm, at equally spaced intervals. The columnar region was divided in similar way and the width and length of the grains were measured directly.

The measurements of dendritic spacings were done using the line intersect technique, preferentially in regions near thermocouple positions for a closer correlation with the solidification parameters.

Microhardness measurements were performed at room temperature with a Buehler® microhardness tester. Loads between 10 g_f and 1000 g_f were used. The measurements were performed under ASTM E 384-89 standard using a pressing time of 15 seconds.

The main results show that a) the width of the columnar grains decrease with cooling rate, b) the columnar length can be estimated within the transition region from the position of the fronts, c) the density of equiaxed grains is linearly related to the temperature gradient in most cases; however the exact relations cannot clearly be established, d) microhardness values increases when atomic radii difference increases and diminishes with the increasing in the grain size and secondary dendritic spacing.



(a) (b) (c)

Figure 1: a) Macrostructure of Zn-1wt%Al alloy showing different structures: columnar, CET and equiaxed. **b)** Primary dendritic spacing, λ_1, as a function of $G * V^{1/2}$ for Zn-Al alloys (wt %). **(c)** Microhardness (HV) as a function of secondary dendritic arm spacing, λ_2 for Zn-1wt%Ag.

References

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