The morphology and distribution of Al_8Mn_5 in high pressure die cast AZ91

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Automotive magnesium components are typically produced by high pressure die casting (HPDC). When conducted with an optimised vacuum system, die and process parameters, HPDC can generate microstructures with fine αMg grains (5-20 μm), a sub-micrometre intermetallic lengthscale, and acceptable porosity.

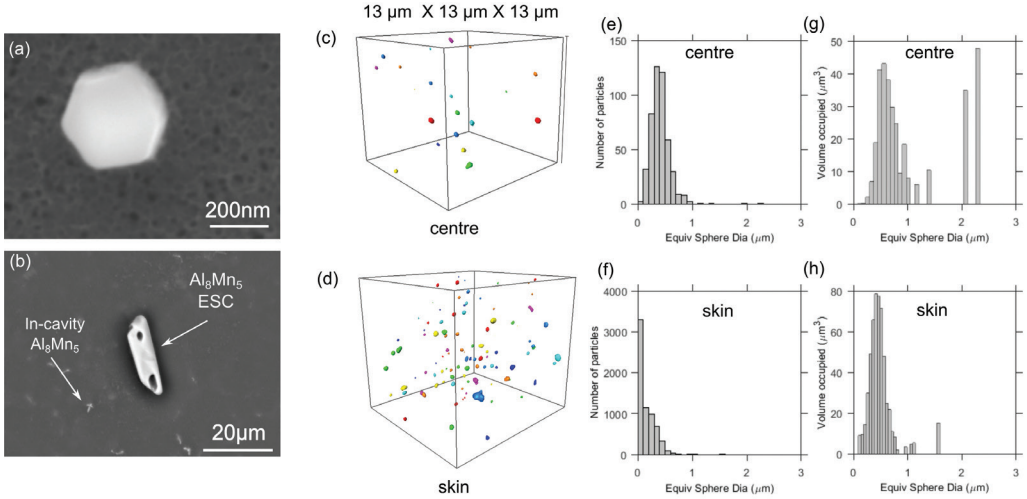

FIGURE 1. (a) to (b) typical Al_8Mn_5 particles in HPDC AZ91D. Most particles are similar to (a). A small number of much larger externally solidified Al_8Mn_5 (ESCs) such as (b) are also present. (c) to (d) rendered images of Al_8Mn_5 in 13x13x13 μm volumes based on focused ion beam tomography. (c) The centre of the cross-section; (d) 10μm from the surface. (e) to (h) Al_8Mn_5 particle size distributions in the centre and skin regions.

However, in many cases, these potential benefits are over-ridden by casting defects including porosity. A feature of Mg HPDC is partial solidification in the shot chamber that leads to large αMg externally solidified crystals (ESCs) being injected into the cavity that reduce Hall-Petch strengthening and can inhibit filling and feeding. Most Mg-Al-based alloys contain sufficient Al and Mn that Al_8Mn_5 forms before αMg during solidification. A consequence of this in HPDC is that Al_8Mn_5 can form and settle in the holding pot (enhanced by Fe pick-up from the pot), leading to die casting sludge. Furthermore, since Al_8Mn_5 forms at higher temperature than αMg, it might be expected that Al_8Mn_5 begins to form in the shot chamber prior to injection as Al_8Mn_5 externally solidified crystals (ESCs) analogous to the Mg ESCs that are widespread in HPDC Mg components.

Work is being conducted to understand the nucleation and growth of Al_8Mn_5 in the shot chamber and die cavity, and how this determines the size and distribution of Al_8Mn_5 particles in HPDC components.

Electron backscatter diffraction (EBSD), selective etching, and focussed ion beam (FIB) tomography are being combined to quantify the three dimensional distribution and morphology of Al_8Mn_5 at different locations in high pressure die cast AZ91D.

It has been found that primary Al_8Mn_5 particles take a wide range of sizes and morphologies within the same HPDC component spanning from faceted polyhedra to weakly-faceted equiaxed dendrites. In low magnification images, some Al_8Mn_5 particles can be seen that have much larger size than most Al_8Mn_5. Figure 1b is a particularly large Al_8Mn_5 particle that is ~20 μm long and has a faceted morphology. Adjacent, is a smaller particle (~1 μm across) with a similar composition. The large Al_8Mn_5 particles (e.g. Figure 1b) are similar to those in samples solidified at low cooling rate (1-3 K/s), suggesting that the larger polyhedral particles are externally solidified crystals (ESCs) that nucleated and grew in the shot chamber analogous to αMg ESCs. Al_8Mn_5 ESCs are a small population of 5-20 μm equiaxed-faceted crystals that are significantly larger than the in-cavity solidified Al_8Mn_5.

The great majority of primary Al_8Mn_5 particles are sub-micrometre, similar to Figure 1a. These are being studied using focused ion beam (FIB) tomography as overviewed in Figure 1c-d and quantified in Figure 1e-h. It can be seen that there is a significant difference in the Al_8Mn_5 particle size and number density in the centre compared with the HPDC skin. The skin region has a mean Al_8Mn_5 particle size (equivalent sphere diameter) of ~160 nm, whereas the centre has a mean Al_8Mn_5 size of 430 nm, excluding ESCs and a wider interparticle spacing.

HPDC of AZ91D can generate numerous Al_8Mn_5 particles with diameter 100-400 nm and a small interparticle spacing. However, partial solidification in the shot sleeve ties up Mn in larger Al_8Mn_5 ESCs, similar to the widely reported αMg ESCs.

REFERENCES:
[1] G. Zeng, X. Zhu, S. Ji, and C.M. Gourlay. The Morphology and Distribution of Al_8Mn_5 in High Pressure Die Cast AM50 and AZ91. *Magnesium Technology 2018*, (2018) 137-144. DOI: 10.1007/978-3-319-72332-7_21.

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