Improved defect control and mechanical property variation in HPDC A380 alloy by HSMC

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High pressure die casting (HPDC) is a cost-effective and net-shape manufacturing process for mass production of thin walls and complex shapes. There are three typical advantages of the HPDC process which include high filling, cooling and solidification rates with high intensification pressure.

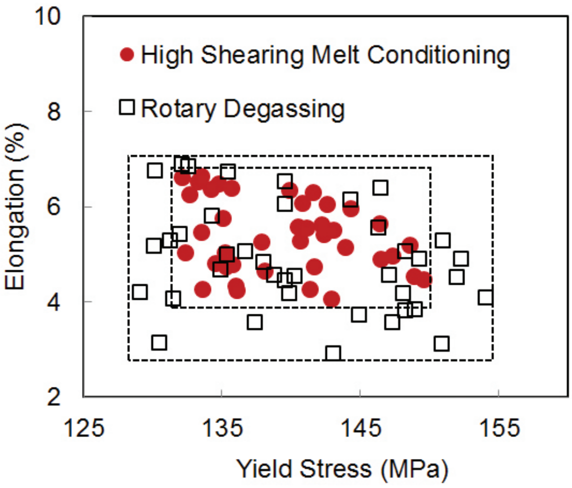

FIGURE 1. A comparison to show the MC-HPDC improvement on yield strength and elongation of the HPDC A380 alloy.

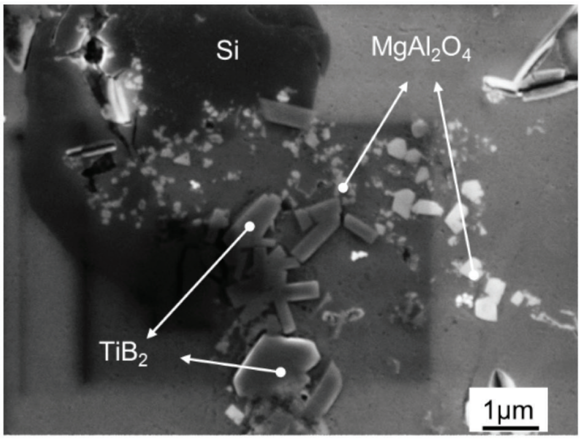

FIGURE 2. Microstructure of the prefil sample showing that $MgAl_2O_4$ and TiB_2 were the key particles in the A380 alloy with high shear melt conditioning.

The characteristic of very high cooling rate can lead to very fine microstructures, resulting in components with excellent surface finish, high dimensional tolerance and excellent fatigue performance. These advantages mean that the automotive industry is further selecting HPDC Al castings, from the demand to meet their ever-increasing lightweighting requirements and to reduce CO_2. However, HPDC does have a disadvantage, as the high filling rate and intensification pressure can create high porosity defects within the castings. Therefore, the traditional HPDC process has unavoidable mechanical property variations.

In the past few decades, many efforts have focused on the filling process, solidification and grain refinement, which included increasing the temperature of the shot sleeve and pouring temperature, aiming to minimise the mechanical property variation. Unfortunately, only limited improvement was achieved. Recently, a physical refinement method by high shear melt conditioning (HSMC), patented by BCAST, has been proven to refine Mg and Al alloys via dispersing the existing oxide films into fine particles, to form potential nuclei for Mg, and accelerate the formation of $MgAl_2O_4$ as effective nuclei for Al alloys.

In this project, HSMC prior to HPDC (melt conditioned-HPDC) was employed to produce A380 alloy components. HSMC includes two steps: the first is degassing with an Ar flow rate of 0.2L/min and shearing 5 minutes at rotor speed of 1500 rpm, and the second is shearing at 1500 rpm for 10 minutes to complete the melt conditioning treatment without introducing Ar. With the application of HSMC, both the yield strength and elongation of the HPDC A380 alloy were improved, as shown in Figure 1. The distribution range of the yield strength and elongation of the A380 alloy with rotary degassing was from 129.1 MPa to 152.9 MPa, and from 2.91 % to 6.88 % respectively. With HSMC, the distribution range of the yield strength and elongation was from 130.7 MPa to 149.9 MPa, and from 3.73 % to 6.62 % respectively. The particles in the A380 alloy were analysed using SEM after collecting via the Prefil®-Footprinter, with the result shown in Figure 2. Figure 2 demonstrates that besides the TiB_2 particles, $MgAl_2O_4$ with bi-modal size distribution were also found in the A380 alloy when applying HSMC. The size of the large $MgAl_2O_4$ particles were approximately 300 nm, and the size of the small particles were approximately 80 nm. The formation of bi-model $MgAl_2O_4$ particles resulted in refinement of the α-Al, with each formed in the shot sleeve and die cavity due to the small misfit of about 1.4 % between the particle and Al. The refined primary α-Al reduces the formation of shrinkage porosities and improves their distribution. Both the refinement and defect control were ascribed to the contribution of mechanical property variation improvement.