MCAST brings effective grain refinement to AM and AZ series Magnesium Alloys

By Geoff Scamans, Chief Scientific Officer, Innoval Technology Ltd.

In the April/May 2006 edition of Cast Metal and Diecasting Times, we introduced you to a novel melt processing technology from Brunel University that can be used to produce castings with superior property and performance characteristics. In the article below, Dr Geoff Scamans brings us up to date with the MCAST (Melt Conditioning by Advanced Solidification Technology) developments by explaining how this innovative process brings about the much sought-after grain refining of aluminium-containing magnesium alloys.

MCAST Process

The MCAST process has been developed at BCAST (Brunel Centre for Advanced Solidification Technology) to condition alloy melts prior to casting. The process has been applied to high pressure die casting to produce shape castings, and to continuous casting to produce feedstock materials for subsequent thermo-mechanical processing. The MCAST process results in significant grain refinement, considerable reduction of cast defects and substantial improvement of chemical uniformity.

The MCAST apparatus consists of a twin screw device, in which a pair of co-rotating and fully intermeshing screws are rotating inside a heated barrel with accurate temperature control. The liquid metal in the conditioning unit is subjected to intensive shearing at both a high shear rate and under a high intensity of turbulence. Consequently, the conditioned liquid metal has extremely uniform temperature, uniform composition and well dispersed inclusion particles. These individual particles after shearing have a fine size and a narrow size distribution, and more importantly, are completely wetted by the liquid metal under the intensive forced convection conditions.

Figure (1) shows a schematic diagram of the MCAST process.

Grain Refining

The control of the as-cast grain size of metals and alloys is usually achieved through the addition of grain refiner to the melt. For shape casting, grain refinement promotes equiaxed solidification, which results in better liquid feeding, a reduced tendency for hot tearing, a reduced and/or better dispersed porosity and an improved surface finish. All these benefits lead to improved mechanical properties of the final cast components. Since shape cast components are usually used in their as-cast state with little further processing, grain refinement and reduction of cast defects is more crucial than for continuous cast feedstock materials.

Zirconium is an extremely efficient grain refiner for aluminium-free Mg-alloys and such alloys can be easily grain-refined to as-cast grain sizes of a few tens of microns through minor additions of zirconium-containing master alloys. However, the search continues for effective grain refiners for the important aluminium containing alloys, such as the AM and AZ series, particularly in view of the rapid growth of the application of these alloys in the automotive industry.

MCAST and Magnesium Alloys

The team at Brunel have shown that melt conditioning using the MCAST process disperses magnesium oxide (MgO) and this then nucleates both the manganese containing intermetallic particles (Al_8Mn_5) and also triggers the solidification of magnesium. The Al_8Mn_5 particles do not participate in the nucleation of magnesium and it is clear that the magnesium oxide particles in the alloy melt are the potent nucleation sites for magnesium solidification.

For effective grain refinement of a given alloy composition, the potent nucleating particles need to have sufficient numbers, favourable particle size and size distribution. Without melt shearing, magnesium oxide exists in the alloy melt in the form of young oxide films, old oxide films and oxide skins. Although they all consist of fine magnesium oxide particles, each oxide film or skin segment acts as a single entity in terms of nucleation events. This reduces the number of active nucleating particles in the alloy melt, giving rise to a coarse grain structure in the as cast samples. Intensive melt shearing disperses the magnesium oxide particles in the oxide films and skins into individual particles with a narrow particle size distribution. This increases significantly the number of active nucleating particles, resulting in a much finer grain size after solidification. Therefore, the prime function of melt shearing is to disperse the oxide films and skins present in the alloy melt into individual nucleating particles. Melt shearing will remain effective as long as the dispersion of oxide is maintained. Since the magnesium oxide particles are loosely packed inside the oxide films and skin segments and held together by capillary force, dispersion of such oxide particles can be easily achieved if the shear rate and the shearing time are beyond a critical level. Once the oxide particles are dispersed, further increase in shear rate and shearing time will not result in any further grain refinement. Furthermore, after shearing, although the dispersed oxide particles have a tendency to agglomerate the rate of agglomeration is slow and this explains why the grain refining effects of intensive melt shearing persists for a long isothermal holding time after the melt shearing is stopped and cast metal can be remelted with the grain refining effect retained.

The MCAST process has demonstrated considerable potential for the direct recycling of magnesium casting scrap through the refinement of intermetallics and the reduction or elimination of the usually harmful effects of impurity elements and oxide inclusions.

Summary

Innoval Technology is leading three Technology Strategy Board Innovation Projects based on the BCAST high shear melt conditioning technology for aluminium and magnesium alloys. The process should be considered as a melt conditioning technology applicable to liquid metal in general, rather than a means of processing semi-solid metal. The use of oxides as a grain refiner rather than a defect is novel and suggests that the technique will be applicable to a wide variety of metal alloys in the future. The most significant development is the use of the technique to increase the tolerance to impurities that will help to increase the use of process scrap for magnesium alloys and post consumer scrap for aluminium alloys that can significantly increase the recycled content of aluminium alloys and/or enable the use of lower cost sources of scrap.

Footnote:

Dr Geoff Scamans is the Chief Scientific Officer of Innoval Technology. He is working with Professor Zhongyun Fan at Brunel University to industrialise the MCAST process. For further information, contact Professor Fan at Brunel University on +44 (0)1895 266406, or zhongyun.fan@brunel.ac.uk

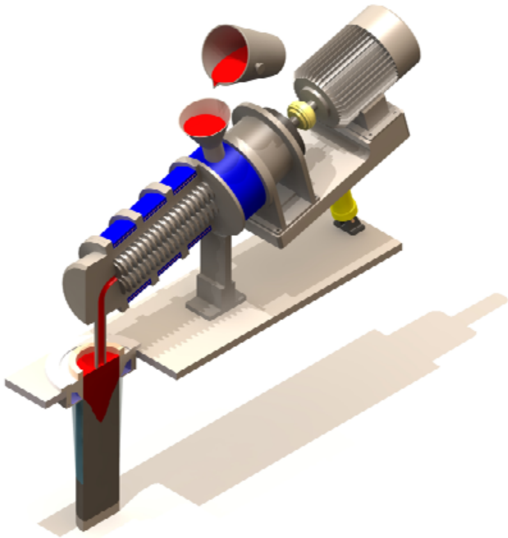

Figure 1: Schematic diagram of the twin-screw melt conditioner which forms the MCAST process

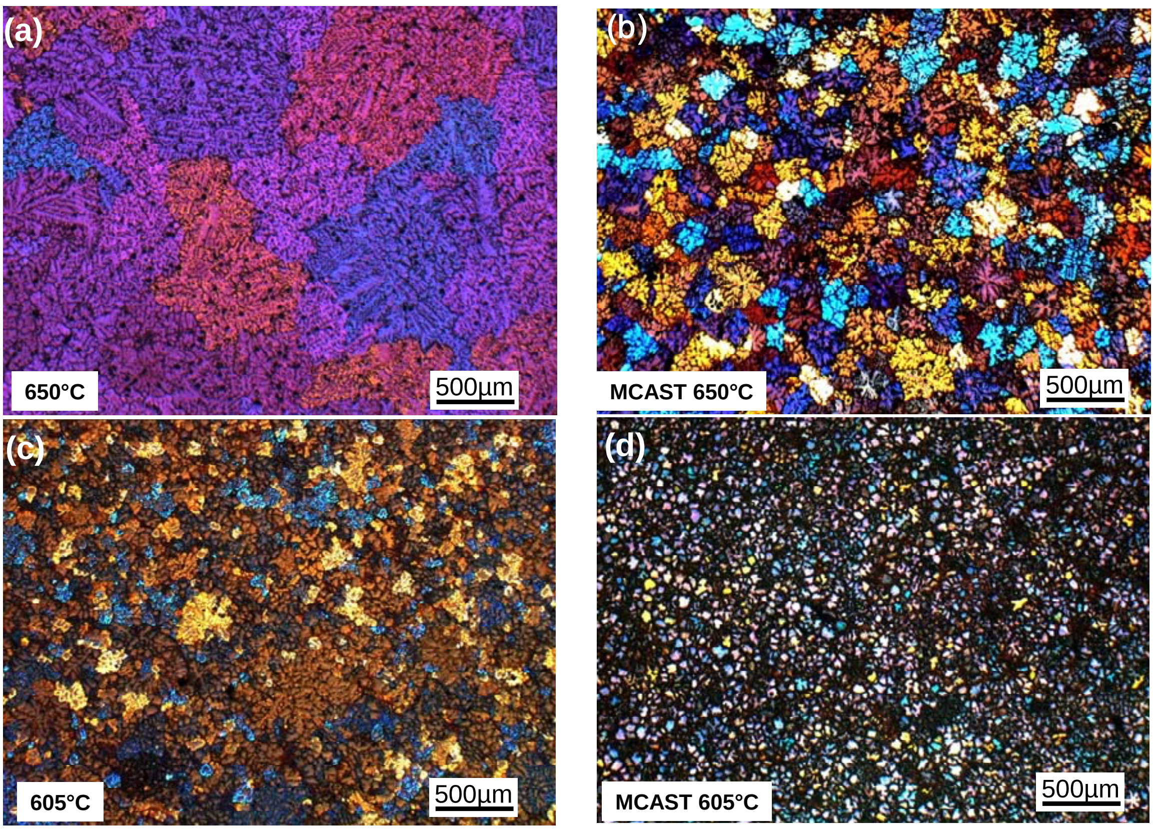

Fig. 2 Optical micrographs of typical microstructures of AZ91D castings showing the significant grain size reduction and after melt conditioning at 650°C (a) conventional, (b) MCAST and at 605°C (c) conventional, (d) MCAST

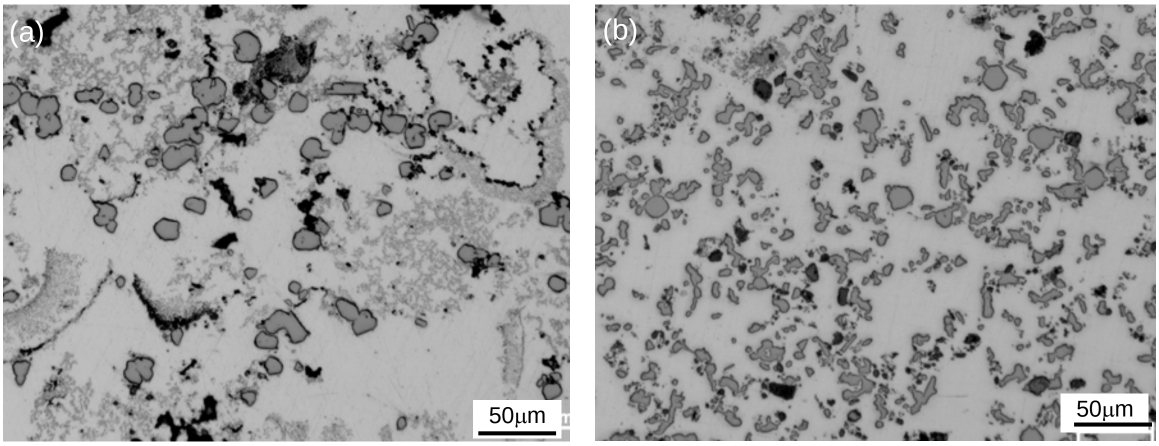

Figure 3: Optical micrographs showing the morphology of oxide and intermetallic Al8Mn5 particles collected by pressurised filtration from (a) a conventional non-sheared melt and (b) a melt conditioned AZ91D alloy melt. Note the smaller particle size and the lack of oxide films in the conditioned melt