Characteristics of Cast Magnesium Alloys – Microstructures, Defects and Mechanical Properties

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Magnesium is the lightest of all structural metals. As such, and combined with good mechanical and physical properties, it forms the basis for commercial alloys that have found successful use in a wide variety of applications. The work presented in this thesis has aimed to investigate the characteristics of microstructures and defects in cast magnesium alloys, as well as how they influence the mechanical properties.

The microstructural features of binary Mg-Al alloys with various Al concentrations were investigated under a range of cooling conditions. The experiments were done by using a gradient solidification technique to achieve homogeneous and nearly defect-free magnesium alloy specimens, through which the isolated effect of microstructural parameters on the mechanical properties could be evaluated. Some models were developed to describe the relationships between the microstructure and mechanical properties in the Mg-Al alloys. In this work, it was also found that the mechanical properties of cast Mg components were affected by some non-structural factors. It is proposed that mould constraints in the die during cooling can have a significant effect on the yield strength of die-cast magnesium components.

Investigations were also done concerning the characteristics of the microstructure, especially the so called pre-solidified crystals, as well as two common defects, segregation bands and hot-tears, in die-cast Mg components. The effects of process parameters on the formation of the microstructure and these defects were thoroughly investigated in some high pressure die cast commercial components. Applying a high intensification pressure was found to have a strong effect in minimizing the segregation band formation, however at the same time promoting the formation of hot tears. A new theory describing the mechanisms for segregation band formation is proposed. The theory was confirmed by simulations of solidification process during die casting, and by experimental verification. The tensile stresses built up in the residual liquid due to the solidification (and cooling) shrinkage of the casting, which causes a pressure drop and viscous flow of enriched liquid inside the mushy zone, is believed to be the main reason for segregation band formation.

In order to be able to produce premium quality and cost effective Mg components, a new semi-solid casting process was developed. The process, called Rapid Slurry Forming (RSF), is based on a rapid but precise control of the enthalpy of the metal, thereby permitting the operator to obtain the desired solid fraction in the slurry. By using this process, large amounts of high quality semi-solid slurry can be produced in some minutes. This new technology opens up possibilities for producing Mg-components with well described microstructures, low defect contents and good mechanical properties.

Keywords: Mg alloys, microstructure, mechanical properties, defects, modelling, segregation bands, hot tear, mould constraint, semi-solid casting