DSC examinations of the Al-20wt%Zn sand-cast alloy inoculated with Ti-containing grain refiners

[1,2]D. Tsivoulas, [3]T. Czeppe, [1]W. K. Krajewski

[1] Faculty of Foundry Engineering, AGH University of Science and Technology, 23 Reymonta Street, 30-059, Kraków, Poland

[2] School of Materials, The University of Manchester, Grosvenor Street, Manchester, M1 7HS, UK

[3] Polish Academy of Sciences, 25 Reymonta Street, 30-059, Kraków, Poland

Abstract

The present study continues the research efforts of recent years on the grain-refinement of the sand-cast Al-20wt%Zn alloy. The aim of the current experimental work is to optimise the grain-refining Ti-addition by achieving a balance of all the desired properties for an as-cast alloy; small grain size, high tensile strength, high damping properties and low porosity are targeted.

This paper is focused on the effects of the addition of four master alloys (MAs) containing different amounts of Ti, on the melting and crystallisation behaviour of the Al-Zn20 alloy. Differential Scanning Calorimetry (DSC) was employed in order to compare the base alloy with its four modified variants. These preliminary measurements include the enthalpy/peak area of the phase transformations and the corresponding temperature ranges.

Project background

Regarding the four master alloys of the present work, the (Al,Zn)3Ti has not been studied before, while the ZnTi4 alloy was reported to yield a larger grain size compared to the typical AlTiB and AlTiC additions. The latter two MAs constitute the most common refiner additions, with the AlTiB-type reported to be superior in terms of grain refinement potential compared to AlTiC-type. This is said to occur due to the lower number of nuclei in the latter MA-type. Increasing the amount of Ti and C beyond the standard contents in the AlTiC MAs can give similar, or even slightly superior, performance to the Al5Ti1B alloy.

The DSC technique in this work, will aid to investigate the energy and temperatures associated with the solid-liquid phase transitions in the Al-Zn system during a full thermal cycle. Fig. 1 shows that during the heating-cooling thermal cycle the Al-Zn20 alloy will pass through a narrow two-phase region of aluminium in solid solution and liquid (α+L). This region if found at temperatures between approximately 590-630ºC and is expected to widen the transformation peaks in the DSC curves.

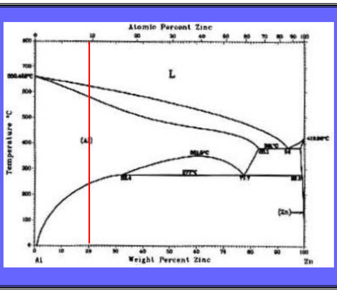

Fig. 1: Binary Al-Zn phase diagram. The composition of the initial Al-Zn20 alloy has been marked with a red line.

Melting curves

Melting takes place over a wide range of temperatures. It is quite obvious that the peak of the unmodified Al-Zn20 base alloy is significantly smaller than those of the grain-refined alloys (Fig. 2a). Also, the peak temperature seems to be slightly shifted towards higher temperatures, but this difference is minor (Fig. 2b). However, the start temperature of melting is increased by approximately 10ºC in the grain refined alloys compared to the initial Al-Zn20 alloy.

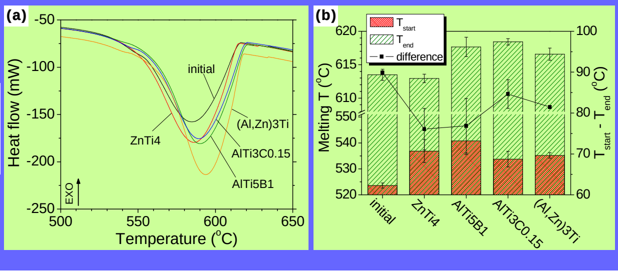

Fig. 2: a) DSC peaks for melting (rate: 10 K/min). **b)** Start and end temperatures of melting for all alloys.

Crystallisation curves

Regarding the crystallisation peaks, again the unmodified alloy exhibited a smaller peak compared to alloys with MA additions (Fig. 3a). The peak temperature is shifted towards slightly lower temperatures compared to the unmodified base alloy Al-Zn20 (Fig. 3b). The initiation temperature of crystallisation in this case is fairly similar in all alloys, while the end temperature is lower for the initial alloy by approximately 4-5ºC. A "shoulder" is obvious on the low temperature side of the peaks, which corresponds to some other phenomenon taking place during crystallisation. The crystallisation temperature range depends quite strongly on the sample dimensions, due to effects from the free surfaces on the nucleation of solidification. On the contrary, the temperature range of melting was not affected by this parameter.

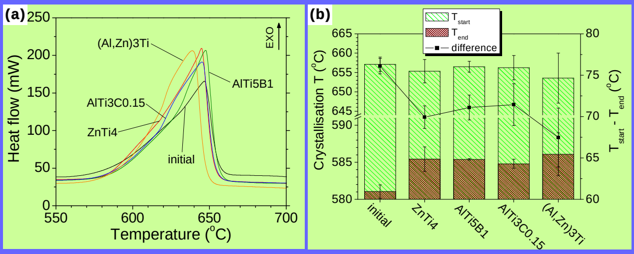

Fig. 3: a) DSC peaks of crystallisation (rate: 10 K/min). **b)** Start and end temperatures of crystallisation for all alloys.

Enthalpies of transformation from DSC curves

The addition of grain-refiners was seen to result in a large increase in the enthalpies of melting and crystallisation (Fig. 4). It is seen that the modification of the initial alloy by grain refiners, yielded an enthalpy of melting at least 65 J/g higher than of the modified alloys and an enthalpy of crystallisation higher by about 100 J/g. This work is at a preliminary stage and no definite explanation can be given on this yet.

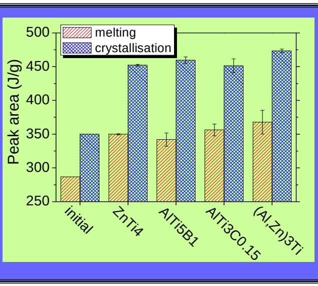

Fig. 4: Enthalpies of melting and crystallisation measured from peaks of the DSC curves.

Conclusions

All master alloy additions to the Al-Zn20 alloy exhibited increased enthalpy of transformation for both melting and crystallisation, compared to the base alloy containing no grain-refiners. In particular, the (Al,Zn)3Ti MA addition yielded the highest enthalpies amongst all alloys and a fairly narrow range of temperatures for melting and crystallisation.

Preliminary thermal analysis results show that the (Al,Zn)3Ti MA is rather promising addition if one also considers its excellent grain refining ability. Further work will reveal more information on the effects of the MAs used here and help optimise the microstructure of the as-cast Al-Zn20 alloy.

Acknowledgements

The authors acknowledge The European Community for financial support under Marie Curie Transfer of Knowledge grant No. MTKD-CT-2006-042468. The provision of laboratory facilities in the Faculty of Foundry Engineering - AGH UST Krakow and Institute of Metallurgy and Materials Science - PAN Krakow is also kindly acknowledged.