Research Programs

Quantitative Microstructure Characterization of Commercial Semi-Solid Aluminum Alloys

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Introduction

The rheological properties of semi-solid metal slurries are strongly dependent on their microstructure. Specifically, three characteristic microstructural parameters are critical in determining rheological behavior and flow properties of aluminum semi-solid slurries. They are: (1) particle size of the Alpha phase; (2) shape factor of the Alpha particles, and (3) entrapped liquid content within the Alpha particles. In this work, extensive image analyses have been performed to determine evolution of the three parameters as a function of commercial processing conditions and material genealogy. Semi-solid materials evaluated include MHD, GR, SIMA, new MIT, and UBE processed billets, and processing conditions investigated include different processing temperatures during continuous heating, as well as isothermal holding for different times at commercial forming temperatures. In addition, detailed investigations were carried out to reveal the formation mechanism of the entrapped liquid within the Alpha phase.

Objectives

The aim of this project was to establish a comprehensive knowledge base in understanding the effect of processing conditions and material genealogy on the microstructure evolution and rheological properties of various semi-solid metal slurries. Quantitative data have been provided to optimize industrial practice

Salient Results

Salient results of this study are highlighted below:

- During commercial SSM forming temperature range (580-590°C), shape factor values of all the semi-solid billets decrease with increasing temperature, which indicates that higher forming temperature leads to a better spheriodization of Alpha particles.
- As shown in Figure 3, SIMA billets have the smallest shape factor value, corresponding to an "optimum" spheroid Alpha particle shape. Whereas, Si-B refined billets have the highest shape factor value, thus corresponding to the most irregular shape of Alpha particles. This is consistent with microstructure observations (see Figures 1 and 2).
- Higher processing temperature tends to increase particle size, but the effect is not significant for commercial forming temperature range (580-590°C).
- The Alpha particle size in grain-refined billets is much larger than in MHD, SIMA and MIT processed billets. Among them, the SIMA billets have the smallest Alpha particle size, and a uniform size distribution, falling in the range between 50-80 μm in the temperature range investigated.

- Interestingly, processing temperature does not show a significant influence on Alpha particle size of Si-B grain refined billets (SiBloy®). This is most likely related to the permanent grain refinement effect of the Si-B master alloy.
- GR billets have much higher entrapped liquid content than MHD billets. The entrapped liquid content in Ti-B refined billets can account for as high as 36% of the liquid phase at 578°C. During commercial forming temperature range between 580-590°C, the entrapped liquid content in GR billets varies between 15-30%, which is 2-3 times higher than in MHD billets.
- Both processing temperature and isothermal holding time have a significant influence on the entrapped liquid content of GR billets. Increasing processing temperature or isothermal holding time decreases entrapped liquid content of GR billets considerably.

SSM Related Publications

Related Publications

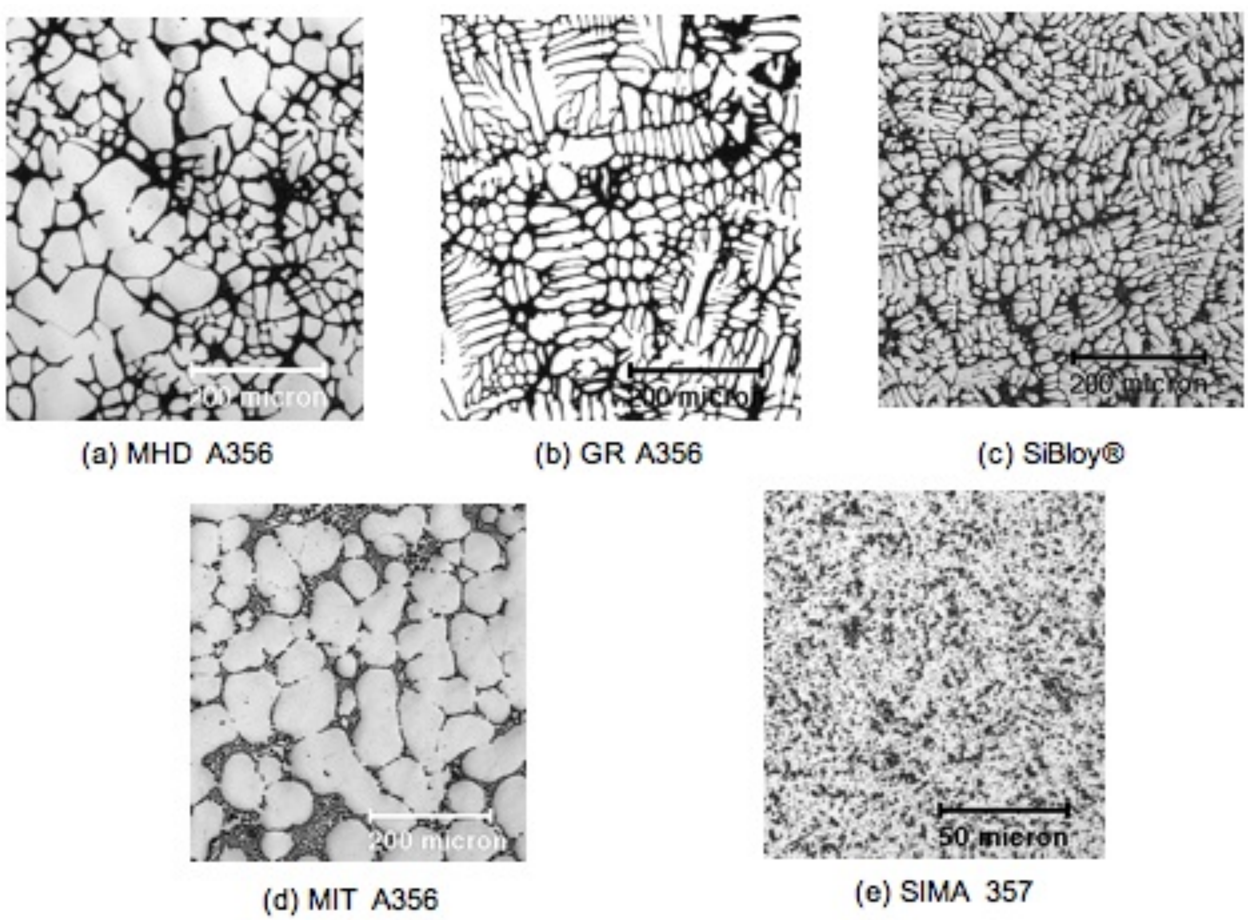

Figure 1: As-cast microstructure of various semi-solid billets.

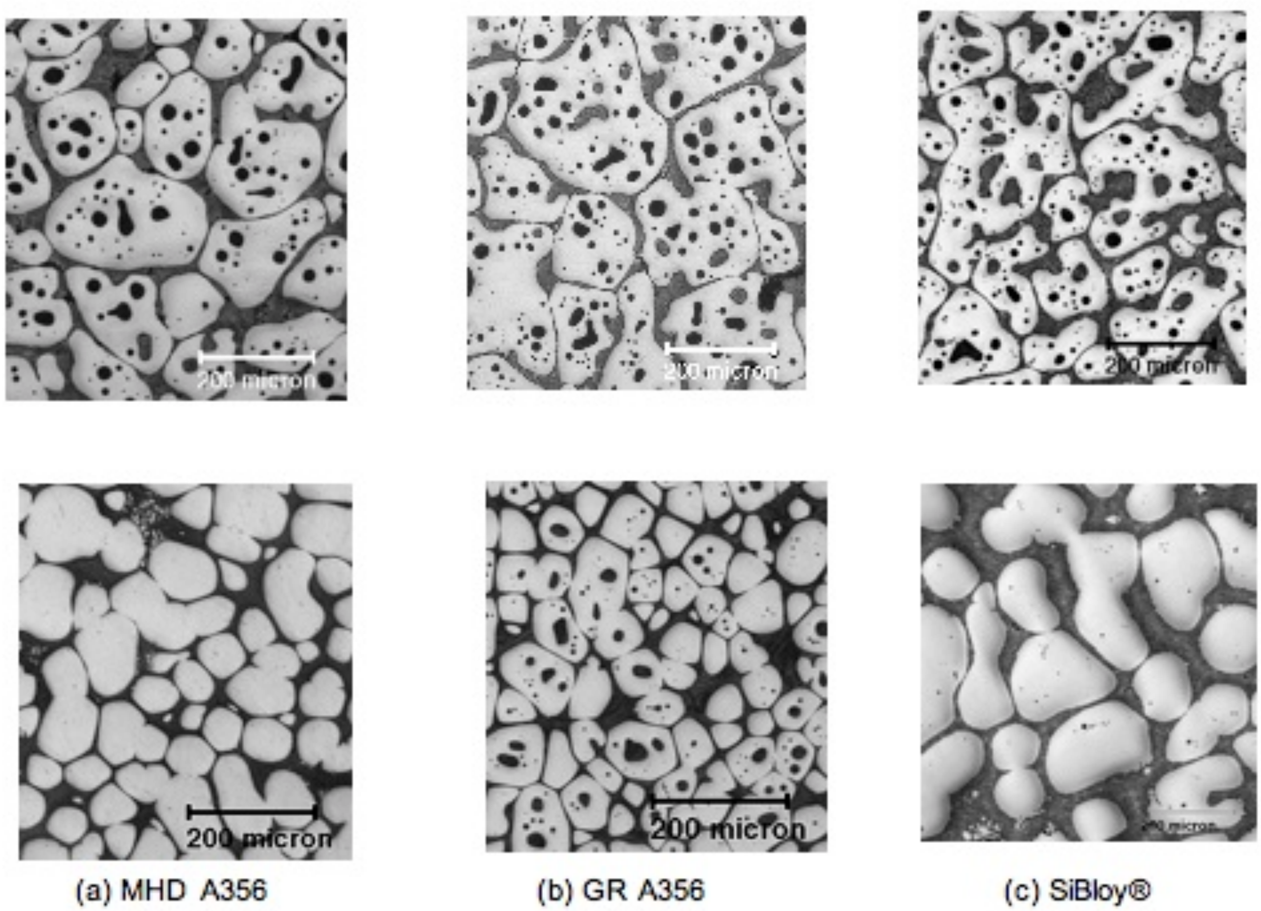

Figure 2: Semi-solid microstructure of various semi-solid billets at 580°C.

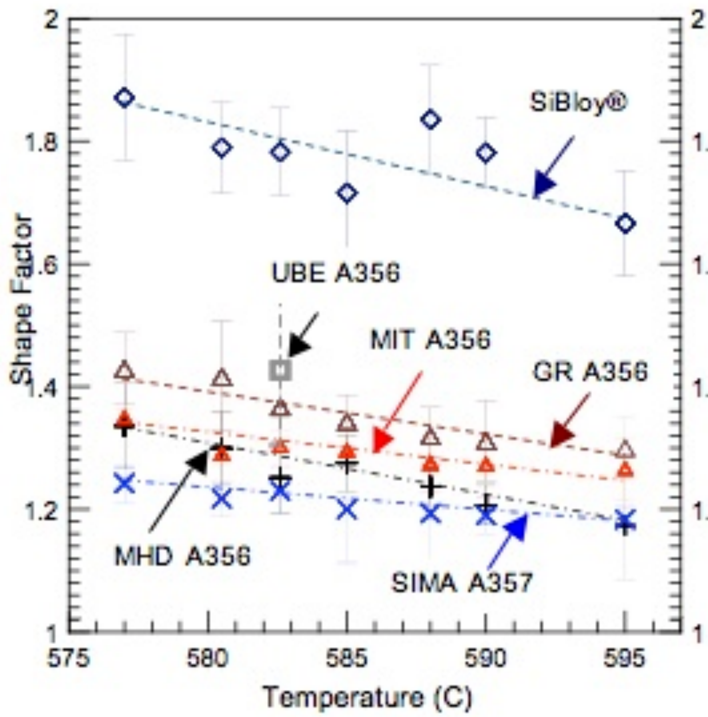

Figure 3: Evolution of shape factor as a function of processing temperature and material genealogy.

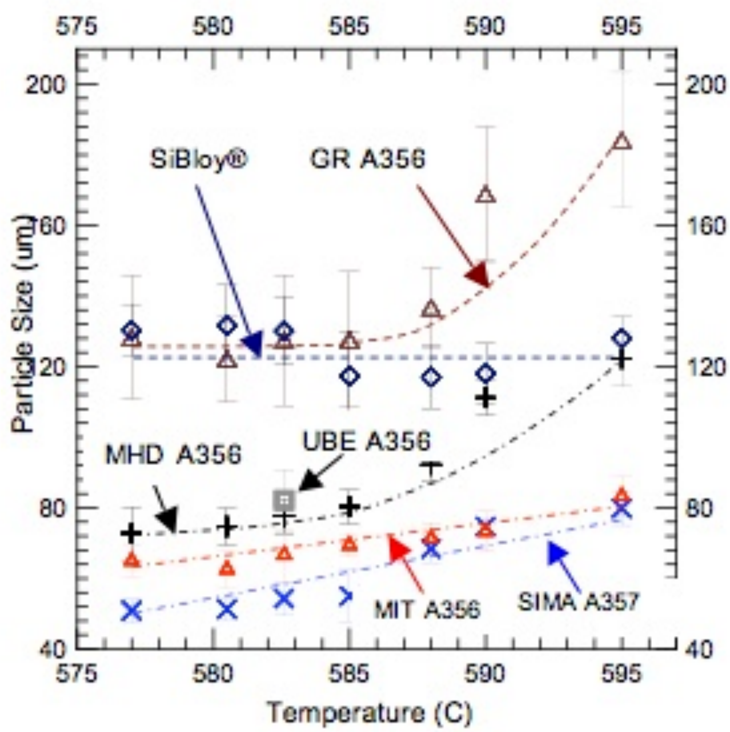

Figure 4: Evolution of particle size as a function of processing temperature and material genealogy.

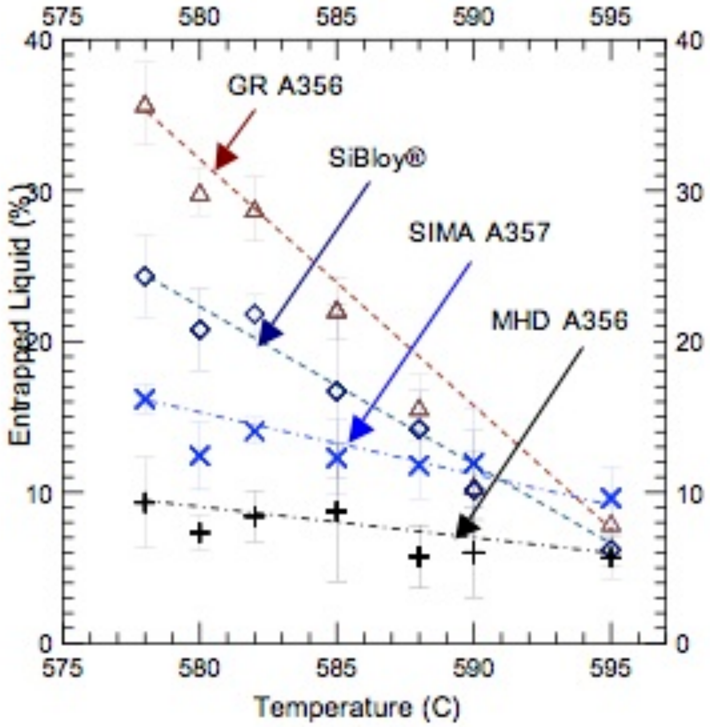

Figure 5: Evolution of entrapped liquid as a function of processing temperature and material genealogy.

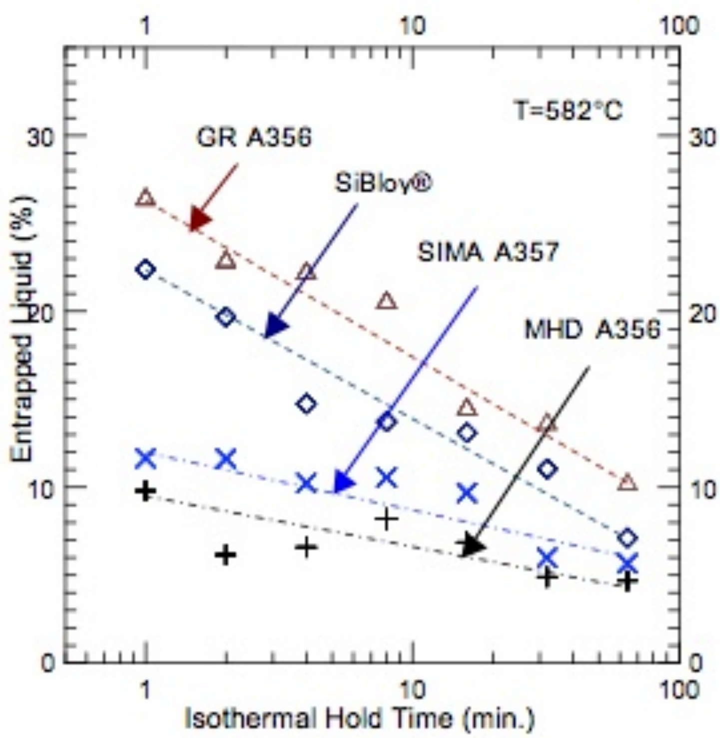

Figure 6: Evolution of entrapped liquid as a function of isothermal holding time and material genealogy.