Research Programs

AlB_2 Grain Refined Billet Route - SiBloy®

Research Team:

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The permanent grain refinement technology-SiBloy® has been proven very effective for aluminum alloys. This technology circumvents the most important problems encountered in conventional chemical grain refining techniques, namely the lack of grain size uniformity, the fading of nucleating agent, and the agglomeration and settling of the insoluble nucleating particles in the melt. In this process, grain-refining additions containing silicon and boron promote the formation of AlB_2 particles just above the liquidus temperature of the melt, and the solubility of AlB_2 at the typical melt holding temperatures makes it possible to achieve grain refinement effect that is almost independent of the thermal history of the melt. In addition, this grain refiner can be used in conjunction with alloy modifiers to enhance mechanical properties.

The aim of this project was to modify the SiBloy® technology to produce high quality SSM feedstock for rheocasting and thixoforming applications. Specifically, the following objectives were defined and achieved in this project:

- Determine grain-refining characteristics of Si-B additions for 356/357 and other recommended alloys. Effects on grain size to be examined include:
    1. level of addition
    2. cooling rate
    3. holding time, and
    4. casting temperature.
- Characterize rheological properties and microstructure of semi-solid slurries produced via both rheocasting and thixoforming routes.
- Industrial evaluation of SSM feedstock performance to determine robustness of the process.
- Optimize processing conditions and recommend optimum practices.

Salient Results

Figure 1 illustrates various processing parameters investigated. These include casting temperature, cooling rate, B level, convection level (casting process); as well as reheating rate, reheating temperature and isothermal holding time (thixoforming process).

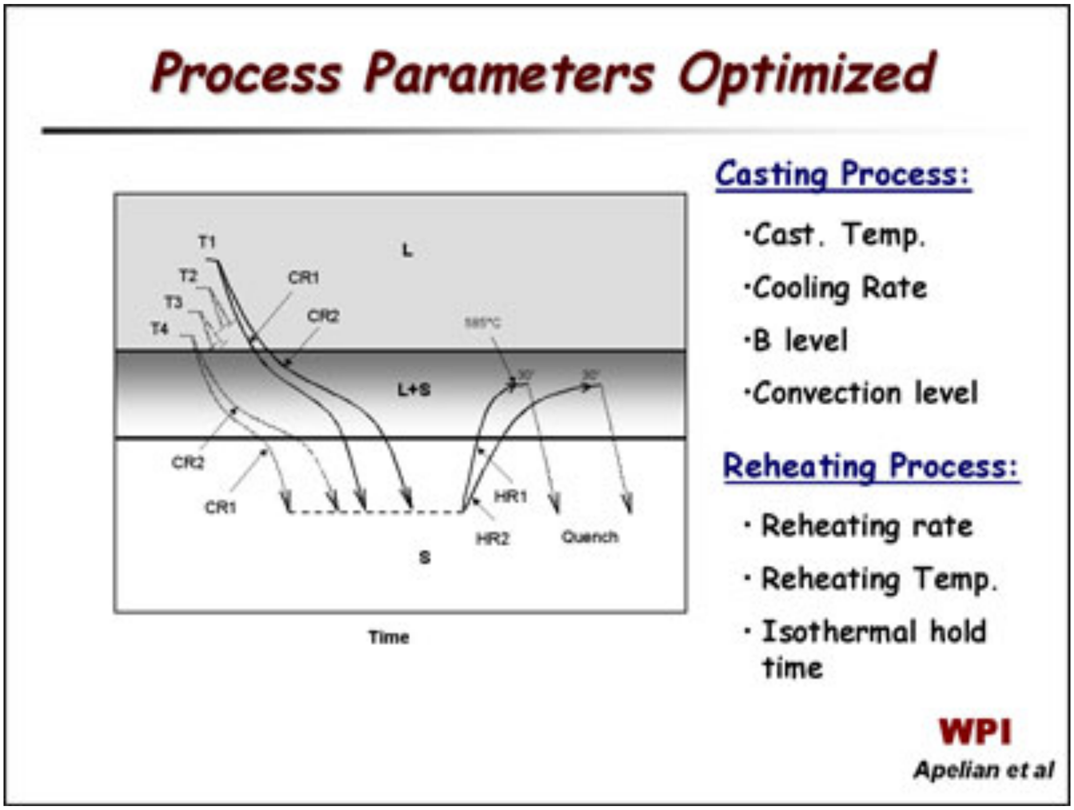
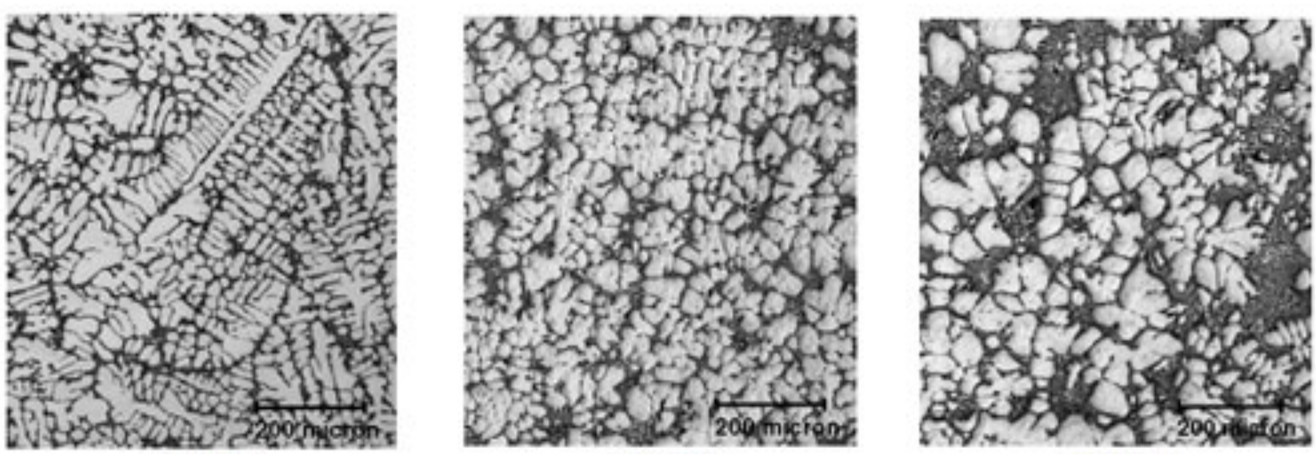


Figure 1: Schematic diagram of the processing parameters optimized.

Figures 2 and 3 show the effect of billet casting temperature on the morphology of the as-cast microstructure, as well as the semi-solid structure of an AlB_2 grain refined A356 alloy. By lowering the casting temperature, one changes the morphology of the billet's as-cast microstructure from a highly dendritic structure (Figure 2a) to a rosette-like structure (Figure 2c). As can be seen in Figure 3, the semi-solid structure of billets cast at a relatively low pouring temperature is characterized by small, round alpha particles with much less entrapped liquid in comparison to those cast at a high pouring temperature.



720°C *Fig. 2(a)* | 650°C *Fig. 2(b)* | 625°C *Fig. 2(c)*

Figure 2: Evolution of as-cast microstructure of an AlB_2 grain refined A356 as a function of billet casting temperature.

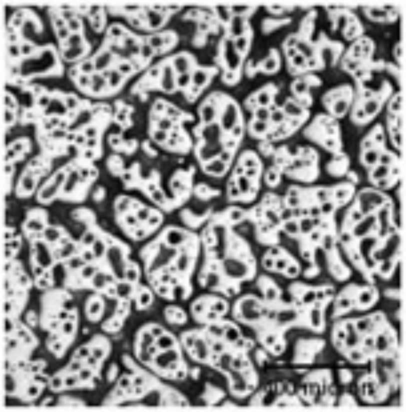


Fig. 3 (a)

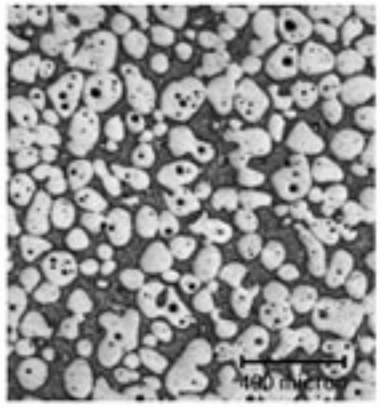


Fig. 3 (b)

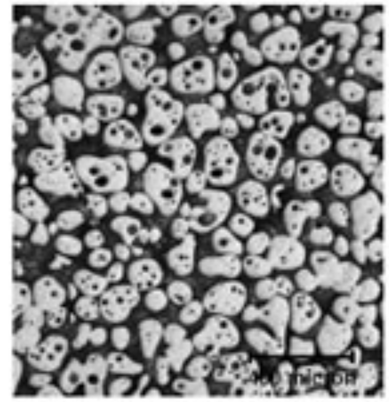
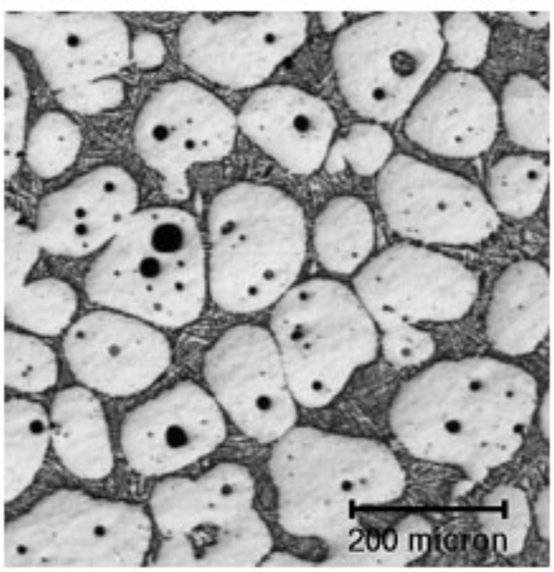


Fig. 3(c)

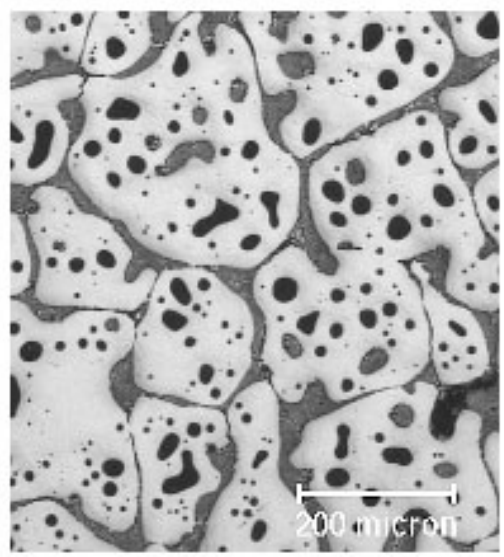
Figure 3: Evolution of semi-solid structure of an AlB_2 grain refined A356 as a function of billet casting temperature: (a) 720°C, (b) 650°C, and (c) 625°C. The billets were all partially remelted at 585°C.

Figure 4 compares semi-solid structure of optimized AlB_2 grain refined Al-Si alloys with that of commercial Ti-B grain refined SSM alloys. Image analysis pointed out that the semi-solid structure of SiBloy® SSM billets has about 4 times less entrapped liquid content, a smaller alpha particle size (90μm versus 128μm), and a better morphology of the alpha phase (shape factor: 1.35 versus 1.40) as compared to commercial TiB_2 grain refined semi-solid A356 billets.



SiBloy® SSM

Fig. 4(a)



GR A356

Fig. 4(b)

Figure 4: A comparison of semi-solid structures of SiBloy® SSM billets (Fig. 4a) with those of commercial TiB_2 grain refined A356 semi-solid billets (Fig. 4b). (Reheated Temperature: 585°C).

Based on the optimal processing window, a brand new AlB_2 grain refined A356 alloy (the material is termed SiBloy® SSM) was manufactured using Elkem's production unit. Thixoforming Beta trials of SiBloy® SSM billets were conducted using the thixoforming cell of Madison-Kipp Corporation. Figure 5 illustrates the thixoforming cell and the casting produced. The casting (named "gear shift lever bracket") is an integral part in the steering column for GMT-800 series trucks, which requires good internal integrity and a relatively high strength.

In parallel, rheocasting Beta trials of SiBloy® SSM slurry were carried out in March, 2004 at THT Presses using a 200T SLC casting cell. For comparison, the die used for thixocasting at Madison-Kipp Corp. was also used in this study. Figure 6 illustrates the casting cell and SiBloy® SSM castings produced.

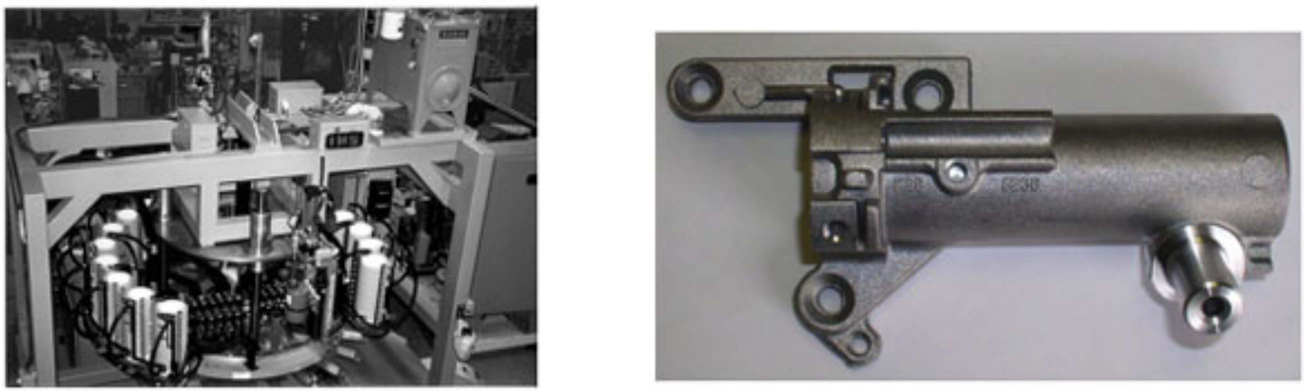


Figure 5: Thixoforming cell at Madison-Kipp Corp. and SiBloy® SSM castings produced.

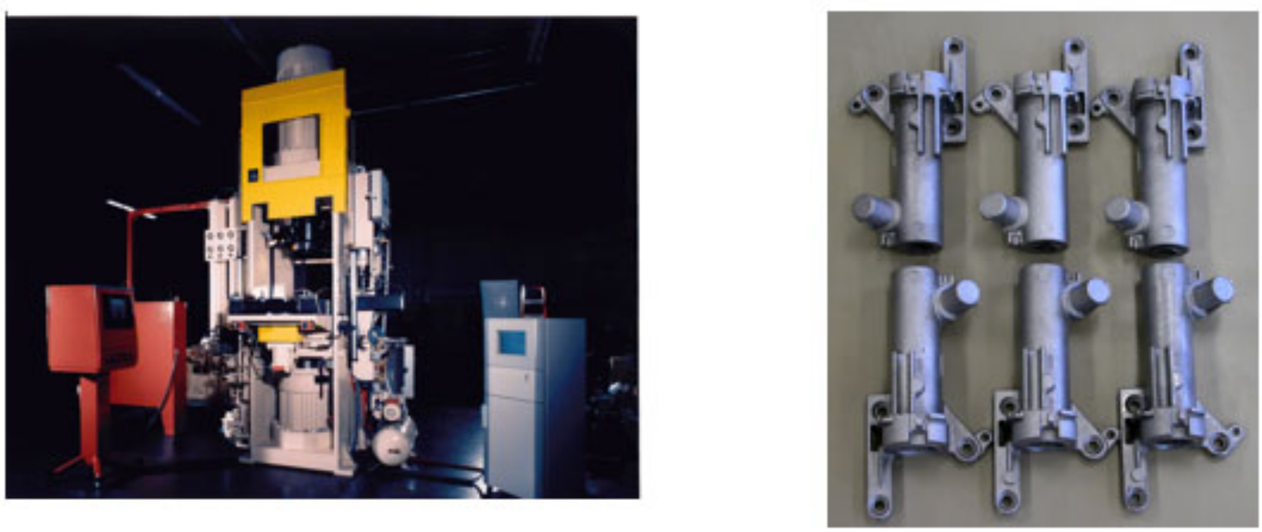


Figure 6: A 200T THT SLC casting cell and SiBloy® SSM castings produced.

Table 1 gives tensile testing results of SiBloy® SSM castings under as-cast, T5 and T6 conditions. From Table 1, one can see that SiBloy® SSM castings have excellent mechanical properties. Processing route (thixo vs. Rheo) does not show a significant influence on the mechanical properties of castings. Another important finding was that SiBloy® SSM castings show an exceptional high ductility under T5 condition, which can give a significant energy saving.

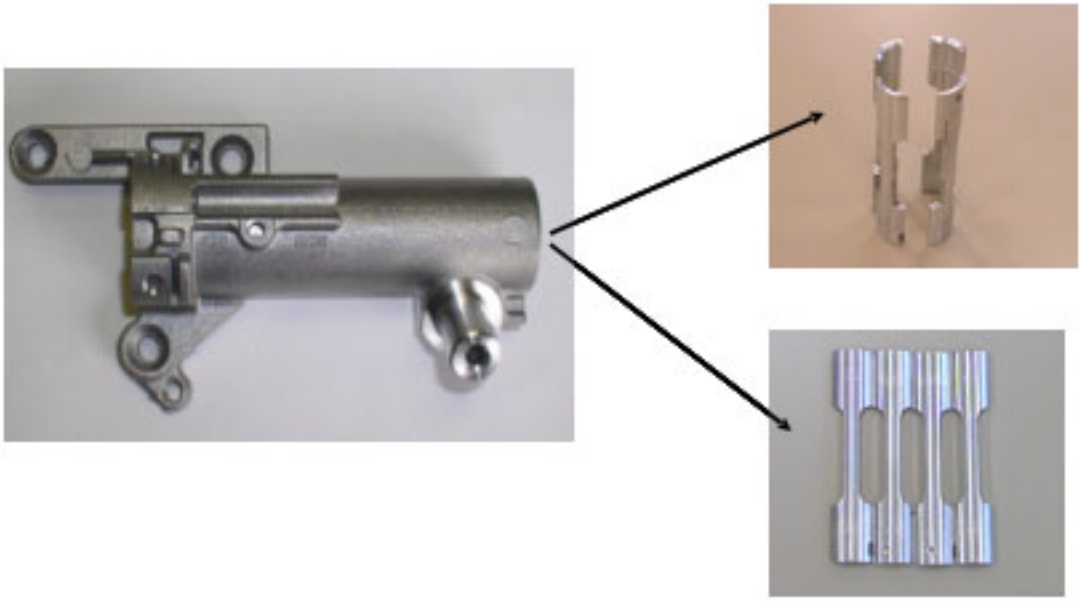


Figure 7: Showing tensile test samples cut from SiBloy® SSM castings.

	Thixo			Rheo		
	UTS (ksi)	YS (ksi)	EL(%)	UTS (ksi)	YS (ksi)	EL (%)
As-Cast	36.0	26.0	9.0	33.0	24.0	8.0
T5	42.0	32.0	8.0	40.0	30.0	8.0
T6	48.0	43.0	12.0	45.0	40.0	11.0

Table 1: Tensile test results of SiBloy® SSM castings

SSM Related Publications (2002-Present)

2009

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