Research Programs

Slurry-Ready SSM: Structural Refinement Through Mixing of Two Liquids

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Introduction

In the early days of SSM development, it was thought that one had to cool the liquid down into the two-phase region, and to shear off and break the dendrites (i.e. melt agitation via mechanical or, later on, magnetohydrodynamic [MHD] stirring) and thus producing a slurry. However, during the last few years, work sponsored at ACRC - MPI by the Department of Energy, as well as work by the research team at MIT led to the discovery that one did not need to break off dendrites to produce the semi-solid structure of globular primary alpha phase. Instead, if the temperature of the melt was such that one could produce many nuclei ("copious nucleation"), and if the nuclei did not grow past a certain point (i.e. suppression of dendritic growth), nor melt back into the bulk liquid, then one could produce a slurry with the ideal semi-solid structure directly from the melt. This concept is the genesis of commercial processes and methodologies to generate semi-solid slurries from the liquid state. The concept relies on controlled nucleation and growth, as opposed to the previous theory, in which a dendritic structure is modified into a globular structure via shear forces.

Armed with the new understanding, the research team has developed a novel, low cost rheocasting process-termed the Continuous Rheoconversion Process (CRP). The advantages of the CRP process include:

- Continuous conversion of liquid to slurry
- Low cost, commercially viable
- Flexible
    - Thixocasting or slurry-ready
    - Not alloy specific
- Allows for rapid adjustment of solid content
- Recycling of scrap easy to incorporate
- Can be used with one melt as well - design flexibility
- The CRP can accommodate significantly higher levels of superheat than existing slurry-on-demand processes.

Salient Results

Figure 1 illustrates the concept of the CRP process, in which two melts (either of the same alloy, or two different alloys), held at a particular level of superheat, are passively mixed within a reactor. The reactor provides heat extraction and forced convection during the initial stage of solidification, leading to the formation of thixotropic structures.

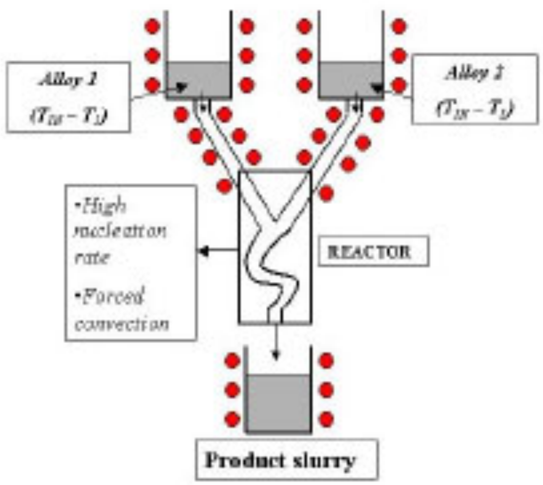

Figure 1: Conceptual schematic of the Continuous Rheoconversion Process (CRP).

Figure 2 illustrates typical semi-solid structures of A356 alloy obtained under different rheocasting conditions. Extensive experimental results with various commercial aluminum alloys indicate that the CRP can generate slurries with near-ideal semi-solid microstructures directly from the molten state; it is highly effective for the manufacture of high quality semi-solid feedstock for both thixocasting and rheocasting applications.

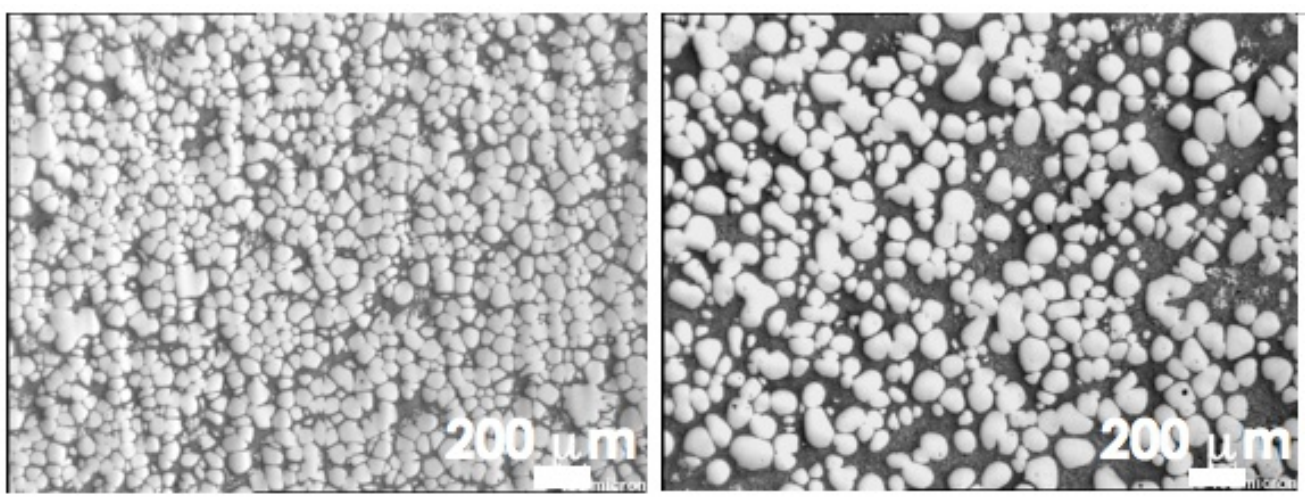

Figure 2: Microstructures of A356 slurries sampled at two different temperatures in the two-phase region, (a) 605°C (left), and (b) 585°C (right).

In addition, the CRP is capable for alloys that are not "castable," or which are known for their poor castability. Figure 3 shows such a structure from an A206 alloy (Al-4.5wt%Cu). Experimental results point out that the CRP can improve the castability of the alloy significantly. The reason for this is that the CRP changes the morphology of the primary phase from coarse dendrites to fine globules, which eliminates the feeding problem during solidification that is associated with traditional casting methods. Therefore, this alloy is actually "castable" using the CRP, and this holds true for various other wrought alloys as well.

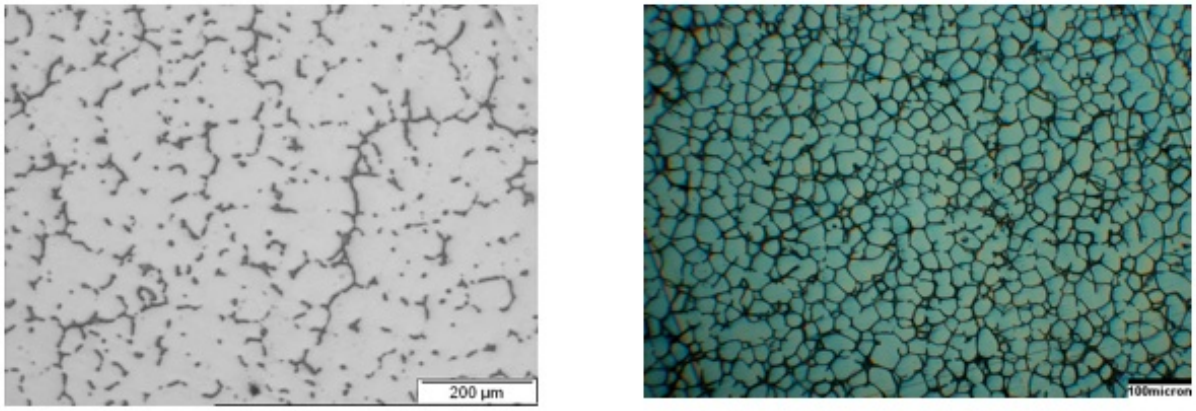

Figure 3: Microstructures of an A206 alloy: (a) Air-cooled from the liquid state (left), (b) As-solidified structure obtained with the CRP (right).

SSM Related Publications (2002-Present)

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