Research Programs

Removal of Hydrogen and Solid Particles from Molten Aluminum Alloys in the Rotating Impeller Degasser: Mathematical Models and Computer Simulations

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Introduction

Aluminum alloy cleanliness has been in the limelight during the last three decades and still remains as one of the top concerns in the aluminum casting industry. In general, cleaning an aluminum alloy refers to minimizing the following contaminants: 1) dissolved gases, especially hydrogen, 2) alkaline elements, such as sodium, lithium, and calcium, and 3) unwanted solid particles, such as oxides, carbides, and a variety of intermetallic compounds. Extensive research has resulted in significant improvements in our understanding of the various aspects of these contaminants, and in many foundries, melt-cleansing practices have been established and are routinely used. However, with the ever-increasing demands for improved casting properties, requirements for molten metal cleanliness have become extremely stringent. Rotary degassing is one of the most efficient ways of cleansing molten metals, thus removal of unwanted particles and dissolved hydrogen from molten aluminum alloys by rotary degassing has become a widely used foundry practice. Rotary degassing (shown schematically in Figure 1) involves purging a gas into the molten alloy through holes in a rotating impeller. Monatomic dissolved hydrogen either diffuses into these gas bubbles or it forms diatomic hydrogen gas at the bubbles' surface; in any case, it is removed from the melt with the rising bubbles. Simultaneously, solid particles in the melt collide with one another due to turbulence created by the impeller and form aggregates. These aggregates either settle to the furnace floor, or are captured by the rising gas bubbles and are also removed from the melt.

Objectives

The objective of this work was to understand the physical mechanisms underlying the removal of dissolved hydrogen and unwanted solid particles from molten aluminum alloys by the rotating impeller degasser, and to develop a methodology for the effective use of the degassing process by providing mathematical models and computer simulations of the process.

A robust model for removal of solid particles and hydrogen from molten aluminum has been developed. The process is divided into three interdependent subsystems that are modeled by (1) a computational fluid dynamics module, (2) a particle dynamics module, and (3) a hydrogen diffusion module. The commercial code (Fluent5.5) was used to solve the computational fluid dynamics equations, a particle population balance equation with special discretization was used to model particle collision and particle removal, and a conservation of hydrogen mass balance was used to model hydrogen removal.

The model provides insight into the effect of the various process parameters on the removal of solid particles and hydrogen gas from aluminum melts, and provides useful information for robust design and efficient operation of industrial rotary degassers. Figures 2 and 3 show results of model simulations compared to measured values.

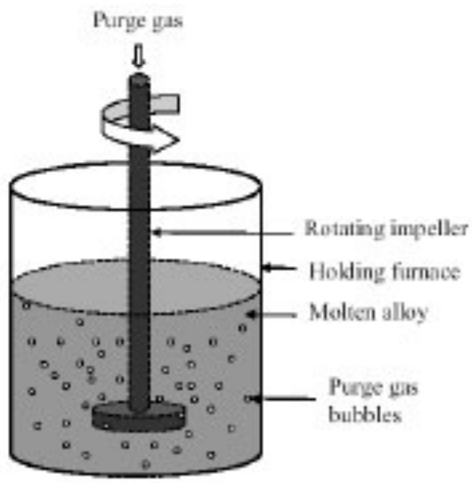

Figure 1 Schematic representation of the rotary degassing process.

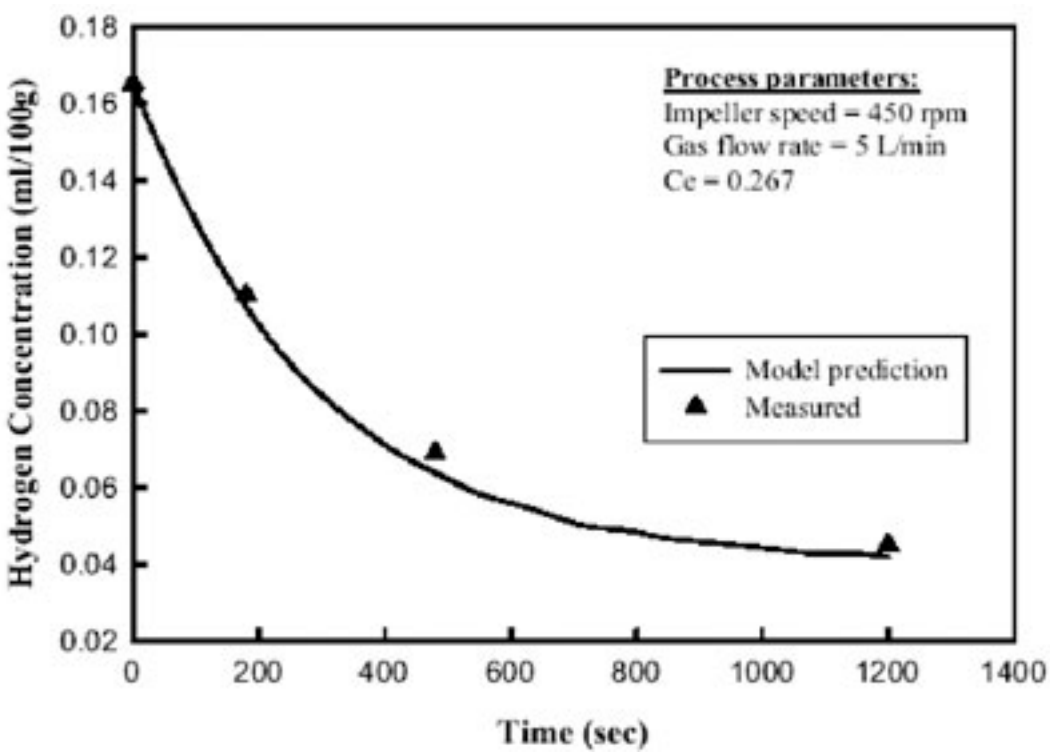

Figure 2 Computer simulation and measured hydrogen content of an aluminum melt after rotary degassing.

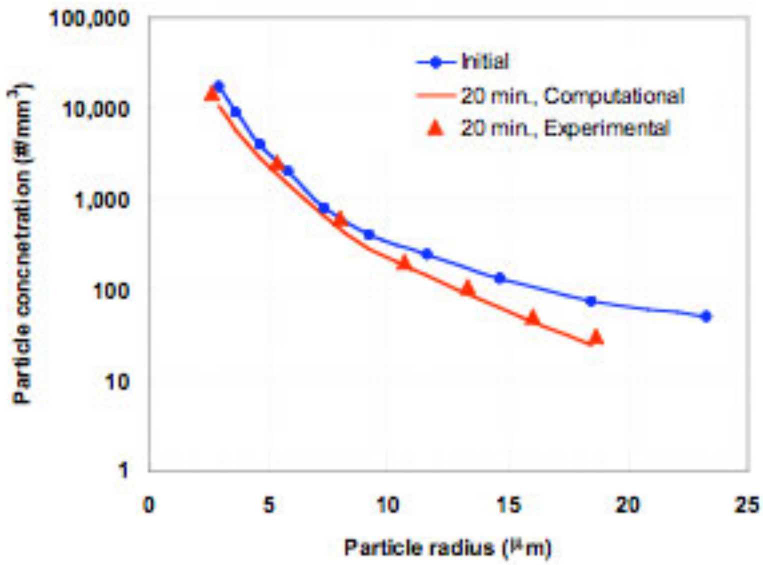

Figure 3 Computer simulation and measured solid particle content of an aluminum melt after rotary degassing.

Publications

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2. V.S. Warke, G. Tryggvason, and M.M. Makhlouf, "Mathematical Modeling and Computer Simulation of Molten Metal Cleansing by the Rotating Impeller Degasser: Part I. Fluid Flow," *J. Mater. Process. Tech.*, vol. 168, no. 1, pp. 112-118, September 2005.
3. V.S. Warke, S. Shankar, and M.M. Makhlouf, "Mathematical Modeling and Computer Simulation of Molten Metal Cleansing by the Rotating Impeller Degasser: Part II. Removal of Hydrogen Gas and Solid Particles," *J. Mater. Process. Tech.*, vol. 168, no. 1, pp. 119-126, September 2005.
4. M. Maniruzzaman and M. Makhlouf, "Mathematical Modeling and Computer Simulation of the Rotating Impeller Particle Flotation Process - Part I: Fluid Flow," *Metall. Trans.*, vol. 33B, pp. 297-303, April 2002.
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