Improved Materials for Molten Metal Containment Can Lead to Significant Energy and Production Benefits

Refractory corrosion and wear has always been problematic for materials used in aluminum contact applications. Deterioration of refractory materials leads to decreased thermal efficiency of the aluminum processing unit. These issues lead to production outages resulting in significant energy losses due to reduced product quality/yield prior to shut down and lost product during shut down. Also, large amounts of energy are lost during cooling of the furnace and are then required for reheating of the furnace.

Characterization and analysis of new and currently used materials performed by Oak Ridge National Laboratory (ORNL) and University of Missouri, Rolla (UMR), along with industrial partners, on the ITP project “Multifunctional Metallic and Refractory Materials for Energy Efficient Handling of Molten Metals”, has led to an understanding of the corrosion and wear mechanisms associated with aluminum contact refractories. Mechanisms were identified in the refractory both above and below the melt line. The most severe reactions occur at the metal line triple point where solid refractory is in contact with the molten metal (liquid) and the gaseous species above the melt. Problems associated with these mechanisms included low effectiveness of anti-wetting additives, poor refractory aggregate quality, reaction of micro-silica with cement binder systems, and poor furnace maintenance practices.

Fig. 1. Corrosion and Wear Mechanisms Associated with Aluminum Contact Refractories

Fig 2. Aluminum Melting Furnace Refractory Failures
Metal Line Cut and Corundum Growth (left) and Refractory Expansion (right)
The knowledge gained from this project has enabled the development of two new materials for improved corrosion and wear resistance which also offer better thermal management in molten aluminum contact applications. One material is a castable refractory based on calcium aluminate (bonite) developed with industrial partner Missouri Refractory Company. The other material is an alumina/silicon carbide composite material (TCON) developed with industrial partner Fireline, Inc. These materials have been validated through the exposure of material samples for over 2,000 hours in an industrial setting at Energy Industries of Ohio (EIO).

The materials successfully performed for the extent of the 2,000 hour trial with no detectable signs of aluminum penetration (by optical microscopy or SEM of post-mortem samples) and no mechanical degradation due to surface cleaning of dross above the metal line. Improvements in corrosion and wear resistance (5X improvement in wetting behavior and 3X improvement in corrosion rate) along with improved thermal management are estimated in aluminum contact applications due to these new materials. It is estimated that a total energy savings of over 0.55 trillion Btu per year will result in the aluminum industry from new materials development associated with this project.

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Fig. 3. Bonite and TCON Materials
Fig. 4. Vessel Used for Industrial Trial at Energy Industries of Ohio (EIO) with TCON Plates Embedded in Bonite Castable

Fig. 5. EIO Industrial Refractory Trial