New family of refractory materials provide exceptional resistance in contact with molten aluminium

This feature provides an insight into the properties of RX-TCON® ceramic/ceramic-metallic matrix materials which provide resistance to wear, corrosion and thermal shock, especially in contact with molten aluminium.

Rex Materials Group and Fireline TCON, Inc. have introduced the new RX-TCON®, materials for tough molten metal handling applications. RX-TCON is a family of ceramic/ceramic-metallic matrix composite materials specifically designed for resisting wear, corrosion and thermal shock. Originally developed for military armour, RX-TCON materials are not only very hard, but are also tough and non-wetting in contact with molten aluminium. The process to make these materials involves reacting silica-based materials in super-heated aluminium to form aluminium oxide with no residual silica, which makes them impervious to the reactivity of molten aluminium at melting and casting temperatures. A special grade of high purity SiC is added to make the material very thermal shock resistant.

RMG integrates RX-TCON plates and shapes into its traditional highly insulating fused silica and ceramic fibre materials to deliver a system that gives very high erosion resistance, while maintaining great thermal control. Applications such as tap-out troughs and block liners, degasser liners, rotor and pump components, furnace linings and others are in development. Initial evaluations have already proven that RX-TCON offers significant performance improvements over traditional refractories.

**Laboratory testing of RX-TCON composites**

In 2004, a US Department of Energy project entitled, “Multifunctional Metallic and Refractory Materials for Energy Efficient Handling of Molten Metals” was initiated with the stated goal of extending the life of molten-metal containment refractories by an order of magnitude through the development of new materials with industrial collaborators. Extensive testing by project researchers at Oak Ridge National Laboratory and the University of Missouri – Rolla found the RX-TCON materials provided excellent performance, as summarised below:

**Static and dynamic corrosion tests:**

Bars of TCON materials were immersed in molten aluminium alloys at 700°C for durations between 500 and 1,000 hr. Cross-sectional samples revealed practically no interaction of the TCON material with the molten aluminium.

**Scale drop testing:**

Static and dynamic sessile drop methods were employed for studying the wettability of RX-TCON materials by molten aluminium. Results showed non-wetting behaviour on a macroscopic scale and only slight wetting on a microscopic level.

**Room and elevated temperature modulus of rupture:**

Four-point bending tests gave MOR values on the order of 50 MPa at room temperature and 25 MPa at 700°C. The project researchers noted that this is an extremely good strength for a refractory material, good enough for the material to be used in a structural application if desired.

**Thermal shock/thermal cycling:**

Testing of an optimised RX-TCON grade showed no measurable drop off in strength due to thermal cycling/shock.

The project researchers considered the laboratory-scale testing of RX-TCON to be a success and initiated an industrial scale test to further validate the material. As shown in Fig 1, arced plates of RX-TCON were inserted into the wall of a 325-lb melting furnace and positioned at the melt line.

Commercial field trials of RX-TCON composites

Fireline and Rex Materials Group have successfully trialled RX-TCON materials in several separate applications. The first was in an automated production cell for casting aluminium-alloy diesel pistons, where iron rings are preconditioned in molten aluminium, prior to being embedded into pistons during casting. RX-TCON parts in the form of hooks were used as holders for the iron rings during the preconditioning process, where they were subjected to corrosion by pure molten aluminium at above 770°C and mechanical wear due to rotation of the hooks in the bath. The RX-TCON hooks were found to last up to ten weeks, as compared with competitive hooks that typically lasted one to three days. Additionally, the RX-TCON hooks were found to fail in a predictable and controlled manner, as compared to the competitive hooks that failed catastrophically and unpredictably.

The second application was in a 500 lb. ladle for the transfer of molten aluminium alloy from a melting furnace to a holding furnace within a foundry. RX-TCON was used as a melt impact pad (located in the bottom of the ladle) to reduce erosion of the refractory lining. Conventional refractory materials located in the bottom of the ladle were found to erode as the aluminium melt was poured into the ladle. This erosion led to the need to remove the ladle from service for repair as the erosion became severe. Previous maintenance practices required patching of the ladle every two to three weeks and replacement of ladles every 18-24 months, adding both cost and the need to have multiple ladles on hand. RX-TCON plates were installed in the bottoms of two ladles while they were being relined. After 17 and 24 weeks of service, respectively, the pads in both ladles showed no observable corrosion or erosion. Further, during inspection, the aluminium skin adhering to the RX-TCON surface was easily peeled away indicating a lack of wetting. Based on the performance of these two ladles, the customer has added RX-TCON plates to all of its transfer ladles.

An early, successful, application was in an induction heating tube for the bottom of a die-cast holding furnace. The tube had two upright channels leading into the bottom of the holding furnace. Connecting these two channels was a straight, square channel that was wrapped with induction wires, creating a magnetic field. When the cooler aluminium travelled down the channel, the magnetic field heated the alu-
Aluminium back up to temperature, the hot aluminium rising back up through the same channel as it came down. This tube was traditionally a castable refractory. Constant build-up made operators “rod” these parts out every shift. When the RX-TCON material was put in, there was no build-up, subsequently eliminating the need for “rodding”. Life of this element went from a few weeks to about a year, saving the end-user a substantial outlay in maintenance costs and down time. All furnaces equipped with this type of heating device have been switched over to RX-TCON channels.

In another application, a tap-out trough at a major secondary aluminium processor was retrofitted with a RX-TCON impact pad by chiselling out a portion of the existing refractory and mortaring in a 12 by 12 by 0.75 in RX-TCON plate. This trough was connected to a reverberatory furnace that was tapped two to three times a day, with approximately 250,000 lb. of aluminium alloy being drained into the trough with each tapping. The plate lasted for over five months with no discernable effect on the RX-TCON pad. (The trial was concluded when the refractory material surrounding the RX-TCON plate eroded away.) As a result of this positive trial, this and other molten aluminium processors will be installing RX-TCON impact pads into tap-out troughs.

Finally, RX-TCON plates were recently installed at the melt line in a degassing trough. The plates have showed no signs of wear; while the surrounding refractory is experiencing severe degradation. This trial is still on-going but the results are significant in that this is a very tough application. RX-TCON’s ability to withstand corrosion by the degassing environment, as well as erosion due to melt velocity demonstrates how exceptional these materials are.

Future trials planned for RX-TCON include holding furnace walls, tap-out block inserts, pump parts and many other challenging applications. As indicated by the previous trials, these materials will cost-effectively extend the operational lifetime of molten aluminium processing equipment. However, by backing RX-TCON shapes with traditional highly-insulating refractories, refractory systems can be designed that not only last a long period of time but also achieve significant energy savings by continuously minimising heat losses.

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