Effective Controls For Corundum Growth That Improve Quality and Cut Costs

Conquering Aluminum Furnace Corundum

Aluminum processors face constant challenges to their aluminum melt operations. Due to robust demand, processors often operate these furnaces at higher temperatures to maximize production rates. As a result, one of the costliest operational challenges is the aggressive formation of corundum deposits in their furnaces.

There are thermochemical reactions in the melting process that are dependent upon time, temperature, and availability of oxygen.

Corundum growth in a refractory lining of an aluminum furnace occurs due to a reaction between the alumina-silicate refractory and molten aluminum. This leads to a reduction of the oxides in the refractory, creating a ceramic-metal composite, or cermet. The cermet composite consists of a corundum skeleton that fills the pore network of the refractory with metallic aluminum. Corundum nodules typically contain 70%-80% alumina (Al_2O_3), and 20%-30% aluminum metal (Al).

Excessive, damaging, and costly corundum growth can be mitigated with the right refractory materials, coupled with the correct maintenance and watchful operation.

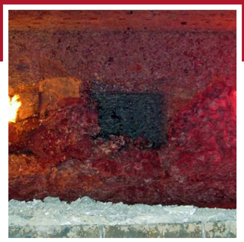
External Corundum Growth

Corundum formation can occur both externally and internally in the refractory lining. External corundum grows above the metal line outward from the hot face of the refractory lining, often appearing as mushroom-shaped corrosion. Heat and atmospheric oxygen feed this reaction in the furnace chamber. Corundum formation begins at the point where the molten aluminum, refractory wall, and atmosphere meet. It then wicks through the wall. As a result, the formation ultimately creates a volume expansion, which causes cracking and reduces mechanical strength. The basic formula for this reaction is:

$$4Al\ (l) + 3O_2\ (g) + Q\ (heat) = 2Al_2O_3\ (s)$$

Internal Corundum Growth

Corundum can develop internally, without atmospheric oxygen, below the metal line, and is formed through a reduction of the refractory



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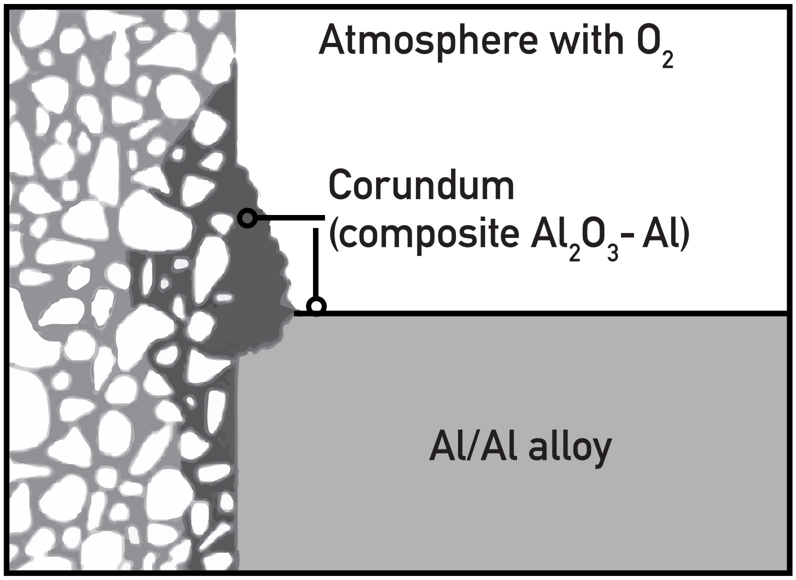
components. This takes place in the pore system of the refractory matrix, primarily through reduction of the silica (SiO_2) as well as iron (FeO). The basic formula for this reaction is:

$4Al\ (l) + 3SiO_2\ (s) + Q\ (heat) = 2Al_2O_3\ (s) + 3Si\ (l)$

Internal corundum growth below the metal line is more insidious as it can't be seen until it's too late, and once it begins to form, it continues to grow. Alloys containing magnesium are especially aggressive in reducing oxygen, producing magnesia alumina spinel:

$4Al_2O_3\ (s) + 3Mg\ (l) + Q\ (heat) = 3MgAl_2O_4\ (s) + 2Al\ (l)$



Corundum forms when molten aluminum is in contact with refractory, accelerated by oxygen.

Root Causes of Corundum Growth

There are four identifiable root causes that promote corundum growth:

1. High temperature
2. Presence of oxygen
3. Alloy composition
4. Use of fluxes and fluoride salts

High temperatures accelerate the reduction of oxides in the refractory. The higher the temperatures, the more quickly non-wetting agents lose their effectiveness. Aluminum begins to penetrate into the refractory matrix because of decreases in aluminum viscosity and surface tension. Excessive furnace temperature can be the result of several causes: overfiring, improper furnace control, or inaccurate thermocouple placement. For example, a thermocouple that is recessed into the refractory lining by 2 inches may underreport temperatures by several hundred degrees.

Oxygen drives the reaction process in two ways: as an atmospheric gas, and as a reducible oxide in the refractory. Minimizing oxygen by controlling negative pressure sources such as doors, windows, and well openings reduces the potential for reaction. Proper flue sizing and burner stoichiometry also reduces excess oxygen and improves furnace energy efficiency.

Alloy composition can be a factor. Some aluminum alloys contain elements that reduce the silica as well as iron oxide, zinc oxide and other oxides in refractories. Careful attention is necessary in choosing an appropriate refractory for more aggressive aluminum alloys to reduce the potential for reaction.

Use of **fluxes and fluoride salts** like cryolite Na_3AlF_6 in aluminum melting accelerates the reduction of oxides in the refractory. Their alkaline properties also reduce the local melt temperature of the refractory at the bellyband and then infiltrate the furnace lining. Over time, with lack of regular maintenance, the corundum buildup will reduce furnace performance and increase aluminum loss.

Trouble Spots

The spread of corundum growth occur, most common in areas where its formation mechanisms of heat and oxygen are present. Typical problem areas include doors, openings, flue areas, and burner cones due to the potential for excess oxygen. Negative furnace pressure can also lead to leakage from the outside. Other common areas of formation include rear walls and bellyband areas, where regular cleaning and maintenance are more difficult.

Corundum Costs

In the effort to meet growing demand today, aluminum processors are increasing their production rates where possible by running their furnaces hotter and longer. To meet this demand, some have made strategic decisions to delay regular maintenance or repairs. These strategies can have a detrimental effect on the life of the refractory lining and need to be weighed against the costs:

Corundum under heat expansion cracks the refractory.

- Downtime of the furnace leading to lost production revenues
- Material and labor repair
- Aluminum melt loss and possible alloy contamination
- Possible structural damage due to high thermal expansion
- Reduced burner performance and efficiency
- Possible business relationship strain among the refractory supplier, installation partner, and end user

Control and Avoidance

The key to fighting corundum starts with choosing the proper refractory material for molten aluminum contact. Plibrico pioneered the development of effective refractory additives that combat corundum, including non-wetting additives, dense oxide barrier formers, and pore-size reducers. These additives can be found in Plibrico products, including the following:

- The Plicast Al-Tuff® system, which increases wetting resistance and reduces the potential for oxidation-reduction of the refractory

- Plibrico's Al-Shield® refractories, which form a reactive layer to resist molten aluminum penetration up to 2000°F
- Plibrico's Al-Rezist™ series, combines the Al-Tuff and Al-Shield technologies into a single package. The refractories non-wetting additives resist aluminum wetting up to 1500°F, by forming a dense corundum barrier to withstand penetration and reducing pore growth size over a wider temperature range.
- Phos-bonded castables like Plibrico's Exo-set Uno™, which offer good resistance to metal slag penetration, especially in higher temperatures, and adhere well to the existing refractory for repairs

In general, PliPartner refractory contractors tell us that they find phos-bonded plastic refractories to be excellent repair materials for aluminum processors. They are usually low in free silica and non-wetting. The material bonds chemically to existing refractory, making them easier to install, and phos-bonded plastic refractories are an excellent solution for corundum growth at the bellyband.

Best Practices That Will Help

A regular maintenance plan can go a long way to increasing refractory life; a schedule is essential. A knowledgeable refractory expert with genuine experience in aluminum heat processes can help with ideal schedules and checklists.

Corundum buildup is a common concern among aluminum furnace end users. Optimally, longevity of a furnace lining depends on best practices in refractory materials and installation methods, knowing the past refractory performance history to evaluate future performance, managing expectations of furnace production output, and monitoring regular maintenance and operation of the furnace.

These factors are measurable key performance indicators that will help decision makers design and build good refractory linings for the demanding needs of aluminum producers today Considering these factors and balancing them according to the producers' needs can deliver a higher-quality product for longer life.

Additional Resources

Plibrico offers additional resources you can use to help you conquer your aluminum furnace corundum. You can find more information online, including short video material at www.plibrico.com.

To talk to a knowledgeable expert with genuine experience, please contact us at: contact@plibrico.com or 312-337-9000.

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