HOT SEAT

Making choices…

In the latest of his exclusive refractory analyses, P.Carlo Ratto* talks to AG about how the choice of refractories for WE and forehearth substructures has been made easier with newly developed materials.

In the last 2013 contribution to AsianGlass, we focus on refractories for working-end and distributors, forehearts. These components of the glassmaking’s hot-end are typical of container and tabletopware, but also, with different characteristics, of almost all types of glass production.

In what follows, we will refer to the largest segment, the container glass. Here, starting from the throat outlet (riser), we have, typically, a working end and distributor that deliver refined glass to one or more channels (substructure of forehearts) where glass is conditioned (temperature, viscosity) up to the point of forming machinery feed (typically using a spout in the container/tableware production).

Depending on the configuration of the furnace (lines/furnace), the geometry of the plant layout and type of products done, this part of the hot-end can have extremely variable complexity and design. Various types of devices such as stirrers and continuous/discontinuous drainage can be used, so as to get the best degree of glass homogeneity and cleanliness from defects such as cords that will immediately translate into finished products rejection.

Whatever it is the configuration of working end, distributor, channels, a number of common considerations can be done:
- Temperatures are lower than in the fusion/refining areas of the furnace. Depending on the type of glass and the articles to be manufactured, the glass temperature is conditioned in the relevant sections of foreheaths so as to get to spout (or other delivering mean) with the proper viscosity for the specific forming process.
- Due to the above, corrosion of refractories at glass contact (understructure of distributor and forehearts) is much lower than in the fusion tank. Refractory corrosion rate, in fact, is exponential to the temperature.
- Due to the above, any refractory-related defect coming from the fusion tank or yielded to the glass in these final sections will be hardly “digested” and will likely get into the forming section, determining defects, potentially leading to rejection of the affected item. Stirrers and drains can attenuate this occurrence but it is obvious that the best approach is reducing upfront the defect generation.

From the above considerations, we infer that materials other than fused-cast can be installed in the distributor and forehearth substructures, due to a reduced corrosive stress.

This fact makes it viable the utilization of AZS fused-cast, α-β alumina fused-cast, sinter AZS (zircon-mullite, typically the 333 formulation, with about 11% ZrO2, sinter alumina (α), In spite of the fact that fused-cast materials, within the same class of chemistry, exhibit a better resistance to corrosion, in this section of the furnace (with a reduced temperature), corrosion resistance performance is not so different and even the difference between alumina and AZS is much less than what could be at higher temperature.

In terms of corrosion, therefore, all the four classes of materials are acceptable and fused cast (in this case AZS) should be preferred only in very special applications, where the temperature of distributor/forehearts is untypically high.

Qualitative issues

Possibly the most concerning type of defect, not easily trackable back to fusion/refining section, is the so-called cat-scratches. These defects, consisting in bands of very fine cords, commonly distributed at the surface of a container (therefore coming from the bottom of a channel/spout), sometime protruding (therefore causing problems to the labeling machine), are always of higher density than matrix, due to enrichment of Zirconia (and often, associated to Alumina).

Several studies have been done to determine whether these cords are originated in the fusion/refining end or in the distributor/channel. Tracking elements (such as Vanadium) typically polluting exudate from superstructure of fusion tank utilizing oil as fossil fuel and other considerations have led to estimate that as much as 90% of cat scratches are originating in the final sections of the furnace, particularly the forehearth substructure (channels).

Since, as told, Zirconia is always present in the cat-scratches cords, and the origin of these defects is very frequently in channels, the obvious fix is to eliminate zirconia from channel refractories. Both sinter zircon mullite and AZS fused cast, in fact, can release Zirconia due to corrosion and, in the case of AZS fused cast, as a consequence of glassy phase exudation. We can safely say that, alumina-based refractories, both fused-cast and sinter, can be installed in channels for quality issues, at least concerning the cat-scratch issue.
Fused cast \(\alpha-\beta\) alumina is, in general, resistant to corrosion and with an extremely low porosity; the only limit is in fact relevant to its density and to the very nature of any fused-cast body: in fact the extremely high density and the scarce presence of plastic phases (at the operational temperature) is the origin of a relatively bad resistance to thermo-shock, while the fact that the liquid ceramic has lower density than the solid, leads to the formation of a shrinkage cavity when the shape (e.g. a channel block) is cast and solidifies through a controlled crystallization process. In the so-called “regular cavity” casting techniques, this cavity is localized immediately under and around the casting gate(s) that, in a regular process, is the area under the bottom of the channel. As a consequence of low resistance to thermo-shock, during the new channel heat-up, a great care must be used to prevent large heating inhomogeneities. At the end of pre-heating, when the channel is completely equilibrated, a great attention must be applied to the mechanical means to contrast any channel block displacements. All this might be considered obvious, but as a matter of facts, when dealing with fused-cast alumina channels, blocks cracking, open joints and (in some unfortunate case) open cracks are not a very rare occurrence, particularly in case of long and curved channels.

The combined presence of thermal cracks concerning the channel bottom, and the existence of a underlying shrinkage cavity can create a situation where hot glass can infiltrate some minor or major cavity, particularly in case of heavy insulated channels. This infiltrated glass can react with impurities localized at the surface of large \(\beta\) crystals upholstering the cavity walls. The reaction do generally produce gases and alumina enriched glass that, eventually, will pollute the glass stream in the channel, with gas bubbles and aluminous cords, stones.

This type of accident has been observed particularly in cases where a glassmaker decided to install \(\alpha-\beta\) alumina channel for the first time, having previous experience with sinter channels that, due to their texture, are far less sensitive to thermo-shock (and obviously an homogeneous structure without shrinkage cavity).

When installing \(\alpha-\beta\) alumina channels, a technically clever way to eliminate this risk is installing blocks without cavity. These materials are produced with a technology called “DCL” (diamond cut lug) where, similarly to what happens for AZS EPIC3 (RT, PB and other brand names) the cavity is located in an area that is sawn away with a diamond blade tool. The major difference, here, is that the saw surface is the external bottom surface that is, generally, a relatively large surface: the cost of such channel blocks, therefore, is generally very high, some time considered prohibitive for regular container glass applications. It is often used in applications like lead crystal and other special glasses.

Another peculiar characteristic of \(\alpha-\beta\) alumina channel blocks is the low electrical resistivity that at a temperature of 1300°C is of an order of magnitude lower than for a 41% AZS fused cast. It is recommended that channels equipped with Moly electrodes for conditioning are not equipped with this type of materials.

While alumina is the first choice for quality issues, it is clear that fused-cast \(\alpha-\beta\) alumina channel have some potential for issues, if not very carefully handled and that a much safer option implies a substantial premium in price, not always acceptable.

A more generally acceptable option among the aluminous refractories (not containing Zirconia) is the utilization of high purity, high alumina, sinter refractories. Various materials like so have been introduced in the market during decades, with alternate fortune; materials based on alumina and a ceramic multilic bond can have a weak point in the bonding matrix; preventing intense nephelitic attack, release of alumina and alumina stones is extremely important to prevent aluminous defects cession to the matrix glass.

More recently, the advent of single phase \(\alpha\)-alumina, direct bond, has determined the marketing of a new generation of materials with a corrosion resistance comparable to the \(\alpha-\beta\) fused-cast alumina (at the operational channel temperature) and, meanwhile, preserving advantages in the structural homogeneity, the thermo-shock resistance, the reversible thermal expansion and the thermo conductivity typical of sinter bodies vs. fused-cast. These materials are generally vibro-cast or slip-cast formed and fired at appropriate temperatures so as to reach the needed bond.

In addition to the above mentioned advantages, offered nowadays by a very few specialized suppliers, there is an additional feature available from a supplier mastering the capability of casting very large shapes: in complicated channel geometry, one critical point is 90° curves that, for technological reasons, cannot be produced in a single piece as fused-cast or as a traditional slip-cast; these segments of a curve represent an issue for stability of joints during the channel heat up.

The capability of producing 90° (and other angles) curved channel segments in a single piece, as well as producing longer channel blocks allows reducing the number of joints and their criticality, so as to reduce construction time and improve the quality of job during heat-up and equilibration. The same company recently mentioned for superstructure large sinter shapes, has combined the technology relevant to material quality (single phase high purity sinter alumina) with the capability of producing large shapes (larger channel blocks and single piece curves), bringing the substrate forehearth technology to a new level of quality.

Special Shapes Refractory Co. of Bessemer, Alabama, is marketing such solution, mostly for the large and complex container forehearth, with a convenient combination of phases, offering a solution potentially useful for a large portion of container glass industry, allowing some more margin for imperfections in the warm-up operations and, in most cases, simplifying the insulation package for the forehearth substructure.

It is good to remark that, in spite of the unfavorable cycle of the economy, good companies are still investing in the continued search for better refractory for glass, preparing ground for improved operations; developing innovative solutions is, for western companies, the only way to succeed in a globalized world, riding the wave before commoditization.

*CP Carlo Ratto is the owner of fused_cast@technologist.com, San Vito al Tagliamento, Italy. For additional information, call (39) 0434-82742, fax (39) 0434-876158, e-mail info@fusedcast.com or visit www.fusedcast.com