The end of fused-cast refractories in soda-lime glass furnace superstructures?

Fused-cast refractories are the most successful refractories to be installed in glass melting tanks. P.Carlo Ratto* highlights how their application has contributed to the evolution of glass.

Fused-cast refractories (FCR) applications have been extended beyond the use within fusion, refiner, distributor and channels sections of smelters. Traditional bricks have been replaced in the superstructure and, after the advent of oxy-fuel technology, have proved to be technical solutions for the crown (Alumina and AZS), where the replacement of traditional silica is only hampered by financial costs.

'Daring' applications
In an attempt to stretch FCR market volume, products have been introduced in ‘daring’ applications such as regenerative packages, where the major weak point of any FCR (thermo shock sensitivity) is challenged by environment conditions.

While the limits of regenerative package applications are evident in front of a recognised set of advantages versus traditional solutions (typically basic sinter refractories), the application of FCR in the superstructure of the melting tank has become the technical standard; particularly for soda-lime container furnaces. This is where the properties of AZS fused cast provide the durability and stability needed to withstand longer campaign lives and higher temperatures.

The advent of oxy-fuel technology, with its five-fold higher concentration of sodium vapours in the furnace atmosphere, has made the application of acidic sinter refractories critical and pushed the AZS FCR application to the limit in many cases.

Fused-cast alumina, in the latter case, proved to be a suitable solution due to its intrinsic resistance to high sodium vapours.

Drawbacks
Even in traditional air-fuel technology, large (side port) furnaces for soda-lime glass (where atmospheric turbulence is limited to the zone close to the dog-house), are lined with fused cast alumina in the 2/3 downstream of superstructure. This is a typical configuration for float furnaces.

Since alumina fused-cast is not financially competitive compared to AZS fused-cast, the motivation for such a replacement is mostly technical.

AZS blocks have drawbacks that can become critical when the performance demand is pushed to the limit. For float glass, the problem is glassy phase exudation, which is typical behaviour of a AZS fused-cast.

AZS fused-cast is composed of two crystalline phases (baddeleyite and corundum) and an amorphous (glassy) phase. The latter is chemically a sodium silicatic glass saturated by alumina and zirconia, with high viscosity but capable of being extruded from the refractory texture at temperatures above 1200°C. This ‘exudate’ is responsible for the shiny, ‘wet’ appearance of the AZS fused-cast superstructure at operational conditions. This exudate, flowing from the hot face, eventually drops and contaminates the mass of glass produced, with the potential of generating knots, cords, zircon stones, and cat-scratch.

Drips from upstream sections of superstructure are mostly digested, but when the exudate reaches the glass close to the throat (or from the shadow wall), defects can enter the upper throat stream after a short digestion time and eventually generate defects in the finished products.

Defects coming from AZS exudate are not a major problem for most soda-lime container furnaces, but can be an issue for higher quality glass (float) or when relatively small furnaces are exploited at a high pull rate, variable glass colour and variable pull.

Another FCR drawback is they are not homogeneous bodies, with significant structural and compositional inhomogeneity. They usually have an internal void - the shrinkage cavity - as a result of the difference in density between the liquid and solid status of the refractory.

These FCR characteristics are responsible for an inhomogeneous exploitation of the refractory body, and erratic thermo conductivity within a single block. The thermal conductivity

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Refractories

of the FCR body is higher than any chemically equivalent sinter body, as a consequence of the phases composition and low total porosity. This calls for multiple layers of insulation to reach a given overall insulation with respect to the designed energy performance.

FCRs are made through complex ceramic foundry technology, where mould technology is at the core of know-how.

Even with the most advanced technologies, there are limits to the size and complexity of individual blocks that can be commercially produced.

The cost of complex one-way (for AZS) or graphite (for alumina) moulds and the decreased process yields when complexity and size increases, are factors curbing the feasibility range. They determine the minimum amount of single components present in a given furnace section, as a consequence of the largest possible size of single components.

On the contrary, the largest individual blocks should be limited by the practical manageability of large masses and complex shapes during furnace construction/repair. Plants today are usually equipped to handle weights and shapes larger than what FCR technology can provide, so FCR blocks are usually smaller than desirable.

A larger than necessary number of pieces means more joints, which under several aspects, represents a criticality. This is particularly true when considering multi-piece arches (ports, dog-house and the like), where complex 3D puzzle results in the need to use centring frames and other auxiliary devices to reproduce the tested set-up assembly at the construction site.

It is obvious that, for example, single arch rings in one piece would facilitate the assembly and construction of ports, but this is often unfeasible for FCR technology.

Large and complex FCR shapes, even if feasible, require a proper warm-up due to the poor resistance to thermo-shock so might require an impractical slow heat up schedule.

In summary, in spite of the density and stability of AZS FCR in the superstructure of soda-lime glass furnaces, the refractories have drawbacks due to their peculiar nature:

- The inhomogeneity of their chemical and physical structure and the presence of a shrinkage cavity (common to all fused-cast).
- Relatively high thermo-conductivity (common to most fused-cast).
- The poor resistance to thermo-shock (common to most fused-cast).
- The production of polluting liquid phase exudate at working temperature (for AZS fused cast).
- The technological platform for FCR production and its intrinsic nature do not permit large and complex shapes, in a commercially viable mode (common to all fused-cast).

An unideal solution?
The ideal refractory for a glass superstructure application should have durability and stability comparable to FCR. It should also have a homogeneous body with better thermo-shock resistance and lower thermo-conductivity.

It should not generate exudation of liquid phases nor yield other types of defects to the processed glass.

The manufacturing technology of these ideal refractories should permit production of sizes and shapes optimal for application.

Until a few years ago, this was not an easy solution. As a result, furnace designers have been specifying AZS FCR for superstructure of soda-lime furnaces, and moderate amounts of alumina fused-cast for float furnaces and oxy-fuel powered smelters.

A technological evolution within the mature shaping technology (vibro-casting) domain means today the development of sinter products with moderate porosity, high durability and stability, lower thermo conductivity and improved thermo-shock resistance in a highly homogeneous body is possible.

These refractories, typically in the same AZS range of chemistry, can be produced in a large size and in complex shapes, to the point of being able to cast single-arch-ring blocks that can be cast, dried and fired-up to a great deal of stability and a minor permanent linear change (PLC) at service temperature; permitting better control of dimensional changes during furnace warm-up.

These sinter 'large pre-cast shapes' exhibit a thermo conductivity coefficient considerably lower than the AZS FCR equivalent in application, as a consequence of the sinter texture.

For the same reasons, these refractory bodies include only a minor amount of glassy phases that, due to textural porosity, does not exude under operational conditions. This feature is a major advantage versus traditional AZS FCR in the same application.

Competitive
These ‘new’ materials are rapidly expanding their presence in specific application niches, as soon as their viability is validated through long-lasting operational campaigns. For soda-lime container furnaces these last more
These new pre-cast large shapes have enough thermo-shock resistance to be suitable for superstructure hot repairs or replacement of consumable parts such as peepholes, cameras and pressure blocks. Few specialised manufacturers are capable of handling the technology and know-how needed to get consistent results. Very few have enough experience with major global glassmakers, which are installing this new class of refractories in the described way.

In spite of several attempts to produce ‘special types’ of AZS FCR for a specific application (generally marketed by major Western players as ‘low-exudation AZS’), these new sinter products are one of the success stories of tomorrow. Since these materials have been marketed as a technological improvement (and not under the usual cost-reduction stance), it is good to know they represent a rare opportunity for Western players to develop something new, even outside the oligopoly of the few historical large players, whose know-how is sufficiently protected from early commoditisation.

These products, using a combination of mature forming technology and advanced formulation expertise, do not require huge infrastructure investments for specialised equipment (that is the case for FCR production). They are perfect for de-localisation of medium-small units (with a relatively modest break-even point) close to customers, to reduce logistical costs and to take advantage of specific, medium-short term, low-cost opportunities.

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