REFRACTORIES FOR INGOT CASTING VIA BOTTOM POURING

PALLOTTA 1859
Although the percentage of steel produced in the world via ingot casting has decreased to 4,1% in 2012 (World Steel Association Statistical Yearbook 2013), some low-alloy steel grades and steel for special applications can only be produced by this process. Steel casting into the ingots allows even for the production of oversized components weighing up to several hundred tons.

Top pouring is easy to use, but generates many defects both on the surface and internally, which is not suitable for high quality steels.

Bottom pouring is better, especially for intensive deoxidation, high superheat, low turbulence, and casting in a nonoxidizing atmosphere. It is also less damaging to ingot molds but requires additional refractory equipment to direct the steel into the molds.

The presence of such additional holloware determines several necessities, which can only be satisfied with an appropriate choice of lining geometries and materials. The refractory must in fact be able to withstand severe thermomechanical stress conditions: the components are exposed to thermal shocks in the beginning of teeming phase, and for the whole process are eroded by the liquid steel flux.

Some steel grades are quite corrosive (such as high-manganese steel or semikilled grades with high soluble oxygen contents) and this can lead, in association with the above described stresses, to a component failure, which in the worst cases can imply a significant economical damage caused by associated events, and not leastly a notable risk for the surrounding workers.
Problems related to inclusions

Nonmetallic inclusions are a significant problem in cast steels because they may lead to problems in castings that require expensive casting repairs or rejection. The mechanical properties of steel are controlled to a large degree by the volume fraction, size, distribution, composition, and morphology of inclusions and precipitates, which act as stress raisers.

Fracture toughness decreases when inclusions are present, especially in higher-strength lower-ductility alloys. The pronounced property degradation caused by inclusions is observed in tests that reflect slow, rapid, or cyclic strain rates, such as creep, impact, and fatigue testing. The source of most fatigue problems in steel are hard and brittle oxide inclusions.

Large exogenous inclusions also cause inferior surface appearance, poor polishability, reduced resistance to corrosion, and, in severe cases, slag lines and laminations. Inclusions also lower resistance to hydrogen induced cracks. In machining, they produce chatter, causing pits and gouges on the surface of machined sections, frequent breakage, and excessive tool wear.

Since almost 60% of all exogenous inclusions in killed steels are reported to arise from “attacking” of refractories (P.W. Wright: Met. Forum, 1979, vol. 2 (2), pp. 82-86), the application of high quality materials and the individuation of specific design solutions aiming to the limitation or even the elimination
of such negative effects can turn out in a significant improvement of the steel production, with evident positive consequences from the economical point of view.

**Traditional refractory linings**
Traditional linings for ingot casting via bottom pouring generally include refractory pipes and channels composed by about ten pieces in sequence; such lining implies the necessity of a complicated and prolonged installation. Moreover, the pressed and fired material of which the pieces are made tends to exhibit an high consumption rate, and to release fragments in the steel flow, which will become inclusions. The high number of joints, real weak points of the structure, also contribute to this phenomenon, because they are less erosion resistant and will turn out to be the first point of attack by the steel flux.

**Innovations by Pallotta S.p.A.: COMIN® refractory products**
The ever-increasing demands for high quality have made the steelmaker increasingly aware of the necessity for high performance refractory products to meet stringent “cleanliness” requirements.

**Pallotta S.p.A.** has a significant experience in this field, and in order to satisfy steelmakers’ needs has developed the COMIN® refractory product line for bottom pouring, applying technologies for the production of prefabricated column pipes and channels even 1.5 meters long or more.

The length is equivalent to about 5-6 traditional units, and these refractory items are ready to use, since preheating is not necessary. The COMIN® solutions are protected by patents in several European Countries, and significantly contribute...
to raise the qualitative standard of the steel. In fact we are the only ones able to propose pipes and channels in castable concrete, which can be personalized according to customer’s needs regarding geometry, including also curves or small scale details.

The abrasion resistance of the material is significantly higher compared to traditional shaped linings, and this implies a drastic reduction of the number and dimension of exogenous inclusions, also thanks to the low number of joints. Moreover the lining placement is considerably easier and faster, thus contributing to a more efficient management of the plant and reducing in the meanwhile the possibility of misalignments. The failure risk is considerably reduced thanks both to the mechanical resistance of the material and to the integration of steel needles in the refractory mass, which efficiently prevent crack propagation.

A demonstration of these advantages is given by Figure 8., in which it is possible to appreciate the high performance level of COMIN® products: the steel residuals (“roots”) extracted from the COMIN® channel after stripping have a considerably lower diameter compared to the one extracted from a conventional hollow brick. This clearly indicates a lower wearing, obtained...
thanks to the excellent abrasion resistance of the applied material. The confirmation of the above remarks is also given by the extensive studies conducted by Pallotta S.p.A. for the quantitative determination of the quantity of released material of each one of the refractory elements, basically conducted by measuring the mass consumption, and comparing the results among sets of traditional holloware and COMIN® solutions.

As an example, we can consider an average uphill teeming apparatus for stainless steel having the following characteristics:

1. Ladle capacity: 35 tons
2. Casting speed: 0.8÷1.2 ton/minute
3. Working temperature: 1500°C
4. Average casting time: 35 minutes
5. Vertical pipe inner diameter 80mm
6. Horizontal channel inner diameter 80mm
7. Horizontal curved channel (spider zone) inner diameter 40mm

In such a case the verified consumption rate is considerably lower for COMIN® solutions; in fact the released material is normally <0.08 Kg of refractory per ton of molten steel, and the wear rate can be estimated as in the following table:

<table>
<thead>
<tr>
<th>Refractory article</th>
<th>Traditional element wear rate $\cdot 10^{-4}$Kg/m·s</th>
<th>COMIN® element wear rate $\cdot 10^{-4}$Kg/m·s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical pipe</td>
<td>12.0</td>
<td>8.6</td>
</tr>
<tr>
<td>Horizontal channel</td>
<td>13.0</td>
<td>9.2</td>
</tr>
<tr>
<td>Horizontal curved channel (spider zone)</td>
<td>2.7</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Table 1. Comparison between wear rates measured for traditional refractories and COMIN® solutions

Figure 7. “Spider” of horizontal channels in 4 way configuration; traditional lining with bend in 3 pcs. (left) and COMIN® solution with bend in a single piece (right).

Figure 8. Comparison between steel residuals from a conventional channel (left) and from a COMIN® one (right).
Taking into account the difference in the material density (traditional: 2100Kg/m$^3$; COMIN®: 2600Kg/m$^3$), we therefore have that the COMIN® vertical pipe and horizontal channel are consumed **23% less in terms of volume**, and this can reduce significantly the risk of retrieving inclusions in the ingot. In addition, concerning the smaller diameter channel, it is possible to evidence that the difference in even larger, because the COMIN® refractory is consumed **51% less in terms of volume**. Since the small curved channels in the spider zone are often a critical point due to the reduced wall thickness, the application of a COMIN® element drastically reduces the possibility of failure, thus minimizing the safety and economical risks connected to a steel breakthrough.

The main features of COMIN® refractories for ingot casting via bottom pouring can therefore be summarized as follows:

- **HIGH MECHANICAL RESISTANCE**
- **HIGH THERMAL SHOCK RESISTANCE**
- **EXCELLENT EROSION RESISTANCE**
  - Normal Released Material (NTM) < 0.08Kg/ton
  - Maximum consumption rate < $1.0 \cdot 10^{-3}$Kg/(m · s)
- **LOW STEEL INCLUSION INDEX**
- **LOW JOINT NUMBER**
- **EASY AND FAST INSTALLATION**
- **BROAD POSSIBILITIES FOR GEOMETRICAL CUSTOMIZATIONS**