CASTINGS FROM A CORUNDUM MELT

V. A. Rakhmanov, A. G. Marants, and D. N. Poluboyarinov

Refractory products are sometimes manufactured by casting from a melt. The method makes it possible to obtain products of complex configuration and dimensions from refractory and super-duty refractory materials which melt to a sufficiently liquid state at a high temperature. The apparent density of these products is normally higher than in products processed by the ceramic method but the casting method suffers from an important disadvantage, viz. the high degree of shrinkage of the product during hardening. Often the shrinkage flaws extend through half the thickness of the product so that it is useless.

Plants in the USSR use electrically molten refractories for baddeleyite-corundum products for the glass industry, and corundum and mullite-zirconia products for the metallurgical industry. It is well known [1, pp. 292-293] that a corundum melt shrinks much more than mullite and baddeleyite-corundum melts so that casting good-quality high-density products from the former presents problems.

In this article the writers explain the technological aspects of casting refractory products from a melt of *Kor-95* corundum which contains 95-96% Al₂O₃ and 2-3% SiO₂. The apparent density of corundum castings produced under industrial conditions varies 2.9-3.2 g/cm³. Casting proceeds through a feeder head of a volume of 20% of the mold volume. The head is filled with the melt 30-40 seconds after the mold.

A statistical evaluation of the production data for finished products measuring 600 x 300 x 200 mm has shown that the apparent density fluctuates within the above limits primarily as a result of voltage fluctuations during melting and also as a result of quality differences in the alumina grades. These findings were verified from the apparent density of series of industrial products and of model castings produced to a scale of 1:2. The temperature of the melt poured into the mold was measured in both cases.

It was shown elsewhere [3] that in the case of model castings from Hungarian alumina the apparent density increased with the temperature of the melt from 1900 to 1960°C (measured inside the casting with a VR 5/20 thermocouple). An increase in the apparent density is achieved under production conditions normally by an increase in the voltage and melting time. The results were similar with industrial castings (Fig. 1, curve 3). In the latter case the temperature of the melt in the mold was measured with an optical pyrometer.

The appreciable deterioration of the casting behavior of the melt with a decrease in its temperature from 1950 to 1900°C is evidently connected with the fact that the melt crystallizes over this temperature range. The casting properties are affected to a considerable extent, moreover, by the proneness of the melt to carburization. Carbon enters the melt from the graphite-coated electrodes and colors it gray.

The carbon in the melt (up to 0.1%) greatly reduces its fluidity (notably at the crystallization temperatures) and, consequently, impedes the feed of the casting with melt from the feeder head so that, other conditions being equal, the apparent density of castings from a carburized melt is lower.

### TABLE 1. Chemical Composition of Alumina, %

<table>
<thead>
<tr>
<th>Alumina</th>
<th>Loss on calcination</th>
<th>SiO₂</th>
<th>TiO₂</th>
<th>Al₂O₃</th>
<th>Fe₂O₃</th>
<th>CaO</th>
<th>MgO</th>
<th>K₂O</th>
<th>Na₂O</th>
</tr>
</thead>
<tbody>
<tr>
<td>UAP</td>
<td>1.86</td>
<td>0.27</td>
<td>0.05</td>
<td>96.78</td>
<td>0.03</td>
<td>0.32</td>
<td>0.21</td>
<td>0.02</td>
<td>0.18</td>
</tr>
<tr>
<td>Hungarian</td>
<td>1.00</td>
<td>0.35</td>
<td>0.05</td>
<td>97.70</td>
<td>0.04</td>
<td>0.37</td>
<td>0.02</td>
<td>0.02</td>
<td>0.40</td>
</tr>
</tbody>
</table>

These findings apply to melts of Hungarian alumina but the casting behavior was similar in the case of a melt of alumina from the Ural Aluminum Plant (UAP) containing the normal proportion of quartz sand and produced at a voltage below 150 V (Fig. 1, curve 1). With an increase in the voltage above 160 V the carbon content of UAP alumina decreases to less than 0.01% with the result that the apparent density of castings from a melt at 1910–1940°C increases by 5–7%. With a melting voltage of 190–230 V the melt contained almost no carbon at all and the apparent density of the castings tended to increase with a reduction in the temperature of the melt (Fig. 1, curve 2).

The decrease in the carbon content can be attributed to the decrease in the contact area of the electrodes with the melt when the voltage is raised. A melt of Hungarian alumina failed to clear to an appreciable extent with an increase in the voltage to 190 V, the current remaining constant at 2300 A.

Analyses showed that the main difference between the two brands of alumina lies in their chemical (Table 1) and mineral compositions, viz. UAP alumina contains slightly less Na₂O and α-Al₂O₃ (density 3.56 g/cm³) than Hungarian alumina (density 3.815 g/cm³). This difference may to some extent explain the greater carbon-retention capacity of the Hungarian alumina since the proportion of carbon increases with that of Na₂O and the vitreous phase in the corundum. A simple device for measuring the melt temperature in the furnace was used for determining the variation of the density of the melt over the temperature range 1900–2300°C (Fig. 2). The results must be regarded as approximate, however, since the degree of carburation of the melt was not monitored in the experiments.

The temperature of the melt was measured with a VR-5/20 tungsten–rhenium thermocouple inserted through a steel sheath provided with a graphite nose-piece (Fig. 3). The latter terminates in a 25 mm deep cylindrical cavity 25 mm in diameter provided with a cover. When the nose-piece is immersed into the melt it is filled through two 7 mm holes in the cover without appreciable gas entrapment. The melt hardens in three to five seconds. The temperature at the center of the cavity is recorded automatically by means of a potentiometer.

The density of the melt was calculated from the volume capacity of the cavity and the weight of the specimen. This method gives satisfactory results only at a melt temperature above 1940°C.

The results of the experiment (see Fig. 2) show that over the temperature range 1900–2300°C the density of the corundum melt varies by 11%. The bulk shrinkage of the melt, which equals its density to the

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Fig. 1. The technological parameters (melt temperature, melting voltage, and alumina brand) as factors in the apparent density of the castings: 1 and 2) UAP alumina; 3) Hungarian alumina.

Fig. 2. Temperature-dependent variation of the density of a corundum melt: 1) UAP alumina; 2) Hungarian alumina.

Fig. 3. Graphite nose-piece of immersion type thermocouple for measuring the melt temperature inside the furnace.