REFRACTORIES IN USE

INSULATION OF REFRACTORY LINING IN SINTERING ZONE
OF ROTARY CEMENT-FIRING KILNS

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The aim of increasing the strength of linings in the sintering zone of rotary cement-firing kilns has led to the use of refractories with high thermal conductivity. The thermal conductivity of magnesite brick, which has been used for a long time for lining the sintering zone, is $\lambda = 1.2 \text{ kcal/m \cdot h \cdot deg}$, and of the periclase-spinel refractory, also an effective lining material, $\lambda = 3-3.4 \text{ kcal/m \cdot h \cdot deg}$. The thermal conductivities of chrome-magnesite refractories, $\lambda = 1.7-1.8 \text{ kcal/m \cdot h \cdot deg}$, and of spalling-resistant magnesite-chrome brick, $\lambda = 2.2-2.9 \text{ kcal/m \cdot h \cdot deg}$, are also much greater than those of previously used refractories. Consistent with the increase in thermal conductivity of the refractories is an increase in the temperature of the kiln casing and loss of heat into the surrounding medium, which can be determined by Eq. (1):

$$Q_k = \alpha (t_k - t_a)D_0\Delta L,$$

where $\alpha$ is the coefficient of heat transfer by radiation and convection determined experimentally and found to be $\alpha = 3.5 + 0.062 t$; $t_k$ and $t_a$ are the temperatures of the kiln casing and surrounding air; $D_0$ is the outer diameter of the kiln; $\Delta L$ is the length of the kiln sector.

Heat losses by a kiln 3.6 m in diameter over a sector of sintering zone 25 m long at 200°C constitute $77 \cdot 10^4$, at 300°C, $169 \cdot 10^4$; at 400°C, $294 \cdot 10^4$; at 500°C, $457 \cdot 10^4$; and at 550°C, $550 \cdot 10^4 \text{ kcal/h}$.

On account of the increase in thermal conductivity of the refractories, the temperature of the casing rose from 220-250 to 400-450°C. When periclase-spinel brick was used without insulation at the Novo-Amvrosievskii Cement Plant, the temperature of the casing reached 550°C. When using a refractory with a high $\lambda$ and intensifying the firing process, it is not possible to select a rational lining for rotary kilns without solving the problem of reducing heat losses into the surrounding medium.

A rise in the temperature of the casing to 450-550°C may result in deformation of the kiln body and in cracking.

It is therefore advisable to reduce the thermal conductivity of the brickwork, but attempts to reduce a refractory's thermal conductivity must be combined with preservation of its refractoriness, spalling-resistance, and wear-resistance.

Frequent references have been made [2-4, 9, 10] to the advisability of using heat insulation when lining kilns with highly conductive refractories (chrome-magnesite and magnesite). Several linings have been tried out in Soviet plants with a layer of insulating material [4-7]. In most cases, however, the strength of these linings was inferior to those without the insulation. Sometimes the destruction of the lining laid with an insulating layer occurred only a few days after the kiln was started up [6].

In other cases the use of insulation did improve the strength of the linings [4,7]. At the Sukhoi Log Cement Plant a lining laid over insulating material with iron crosspieces lasted one and a half times as long as an ordinary one without insulation, and at the Volhobskii Plant the lining lasted twice as long.

Information is available that in other countries linings with insulation have lasted five years.

Despite this fact, in the Soviet cement industry, through the difficulties caused by employing two-layer linings, no insulation of the sintering zone is being practiced.
Characteristics of Refractories [6, 20]

<table>
<thead>
<tr>
<th>Refractory</th>
<th>Refract. under load, °C</th>
<th>Refract. under load, 2 kg/cm², °C</th>
<th>Spalling resist. (1300°-water), heating-cooling cycles</th>
<th>Porosity, %</th>
<th>Compres. strength, kg/cm²</th>
<th>Mean coeff. of linear expansion, α-10⁶</th>
<th>Thermal conductivity, kcal/m · h · deg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chamotte</td>
<td>1770</td>
<td>1380</td>
<td>11</td>
<td>18.9</td>
<td>600</td>
<td>6-8.5</td>
<td>1-1.2</td>
</tr>
<tr>
<td>Clinker-concrete</td>
<td>1750</td>
<td>1360</td>
<td>-</td>
<td>1</td>
<td>&gt;200</td>
<td>13.5</td>
<td>1.35</td>
</tr>
<tr>
<td>Talc</td>
<td>1640</td>
<td>1360</td>
<td>8</td>
<td>0.6-1</td>
<td>120-300</td>
<td>-</td>
<td>0.6-1.2</td>
</tr>
<tr>
<td>Chrome-magnesite (KhM)</td>
<td>&gt;1900</td>
<td>1480-1520</td>
<td>5-6</td>
<td>20-25</td>
<td>250-400</td>
<td>10.5</td>
<td>1.7-1.8</td>
</tr>
<tr>
<td>Spalling-resistant</td>
<td>&gt;1900</td>
<td>1500-1520</td>
<td>5-7</td>
<td>20-22</td>
<td>300-400</td>
<td>-</td>
<td>2.2-2.9</td>
</tr>
<tr>
<td>magnesite-chrome</td>
<td>&gt;1900</td>
<td>1580-1600</td>
<td>7-8</td>
<td>15-17</td>
<td>500-800</td>
<td>14-14.5</td>
<td>3-3.4</td>
</tr>
<tr>
<td>Periclase-spinel (PSh)</td>
<td>&gt;1900</td>
<td>1620-1710</td>
<td>3-5</td>
<td>22-27</td>
<td>200-350</td>
<td>-</td>
<td>2.2</td>
</tr>
<tr>
<td>Forsterite (F)</td>
<td>1850</td>
<td>1620</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 1. Arrangement of brickwork made with periclase-spinel refractory at the Ambrosievskii Cement Plant over an insulating layer. 1) PSh periclase-spinel brick; 2) the same; 3) chamotte brick; 4) magnesia-iron mortar; 5) kiln casing.

A number of investigators have pointed out the disadvantages of using insulation [5, 6, 11, 12]:

1. The use of thermal insulation layers leads to more severe temperature conditions for service of the refractory;
2. The use of thermal insulation greatly increases the compressive loads on the lining through different degrees of expansion of the casing and refractory lining;
3. The use of thermal insulation enlarges the reaction zone in the refractory and promotes deeper penetration by the alkalis;
4. The use of thermal insulation in the sintering zone creates conditions hampering the formation of a coating on the lining surface since heat transfer to the surface is sharply reduced and the surface of the refractory does not reach the temperature necessary for the liquid phase formed to thicken.

As a result of these undesirable effects, investigators have pointed out that there is a decline of the lining's strength when thermal insulation is used.

Thus, by rejecting insulation of the lining in the sintering zone, investigators have given their consent to ever increasing heat losses into the surrounding medium as the conductivity of the refractories used is increased. To prevent high temperatures affecting the metal casing of the kilns, use has been made of water cooling, but this has led to even greater heat losses. From 1951 on, this method began to be introduced with great intensity at a large number of cement plants [12].

It is pointed out in the literature [5, 13-19] that with water cooling the refractory operates under more favorable conditions, the coating forms on it more easily, and, as a result, its strength is higher than in one laid with a layer of insulating material, or without insulation and without artificial cooling.