REFRACTORIES AT THE USER

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EFFECT OF THERMAL SHOCKS ON CORROSION AND EROSION PROPERTIES OF LININGS

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It has been established that linings of batch heating units fracture predominantly due to the thermal stresses that appear in them in operation. The elastic-mechanical properties of the articles of a lining are shown to depend on the heating rate and temperature, which makes it possible to predict the parameters under which the lining fractures. It is established that by protecting the articles of the lining from thermal stresses by a nonshrinking mortar or a protective coating the service life of the lining can be increased by a factor of 1.5–2 with reduction of the laboriousness of the technology and the consumption of expensive refractories.

Refractory linings in high-temperature metallurgical batch units (converters, wells-furnaces, rotary furnaces, ladles, etc.) mostly wear by spalling after operation due to thermal stresses that appear in the lining. When a converter is started without preliminary heating of the lining, the size of spalls due to the primary thermal shock attains 150 mm.

The traditional lining of joints in high-temperature batch units for nonferrous metallurgy is made using dry refractory powders and is inefficient because it lacks the requisite elastic-deformation, adhesion, and heat-insulating properties. In operation, dry powders float up because of their low density and the absence of adhesion to the lining; the reagents of the melt penetrate the bald joints of the lining.

When a slag-matte melt cools, it expands due to the quite high temperature coefficient of linear expansion, causing internal stresses in the lining. Such multiple cyclic stresses cause rapid disruption of the lining in each cycle. Simultaneously with filling of the lining joints with the slag-matte melt the functional surface of the lining is impregnated with the melt to a depth of 30–100 mm, as a result of which various zones are formed in the refractory. In heating and cooling of the lining thermal stresses exceeding the strength of the refractory appear on the boundaries of these zones (Fig. 1), which also leads to spalling of the impregnated layer. Our study of the endurance of linings has shown that thermal stresses greatly the resistance of the refractories to the chemical aggression of the processed product. The slag resistance (dynamic) of refractory specimens subjected to preliminary action of a thermal shock is several times lower than in specimens heated slowly before the test.

Fig. 1. Stress σ as a function of the deformation ε in a chromomagnesite refractory before and after service in a copper-melting converter at different temperatures (indicated at the curves, °C): — — — before service; — — — the least changed zone; — — — the functional and transition zones.

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The structure of periclase-chromite specimens tested for slag resistance after a thermal shock at the contact with the slag is dense; a well-defined boundary of the chemical interaction of the refractory components with the reagents of the slag can be observed.

In periclase-chromite specimens subjected to preliminary action of a thermal shock the structure is porous, the refractory components are markedly separated, and the space formed is filled with silicates. The erosion processes predominate over the corrosion ones, which increases the wear rate of the refractories correspondingly.

We have established that the disruption of the initial continuity of the refractories depends on their geometric size, their thermophysical and elastic-mechanical properties, and the intensity of the variation of the temperature field.

The effect of the disruption of the continuity of the structure in refractory articles was studied by means of nondestructive testing on a UKB-1M ultrasound device. The method is based on the fact that the denser and more uniform the medium, the higher the speed of propagation of ultrasound. When the temperature acts on one side, the appearance of temperature stresses is accompanied by the formation and growth of microcracks. Then the speed of the ultrasound increases markedly. A comparison of the speed of the ultrasound in the article before and after the temperature effect characterizes indirectly the degree of disruption of the initial continuity.

As the heating rate is increased, the continuity of the refractory articles is disrupted intensely (Fig. 2), and the zone of the highest microcracking is positioned at 1/3 - 1/5 of the length of the refractory from its functional surface.

We have studied the modulus of elasticity, the ultimate compressive strength (at 20 - 1200°C), and the dependence of the modulus of elasticity on the heating rate of refractory specimens (Fig. 3).

Acceleration of heating of molten refractories of a periclase-chromite composition affects the increase in the modulus of elasticity, making the specimens break at a certain temperature (see Fig. 3a). Therefore, articles based on molten materials are the most sensitive to thermal shocks, and linings from these materials should be heated to the operating temperature at a lower rate than refractories from sintered materials, or should be coated with a protective cover that decreases markedly the thermal stresses that appear when the furnace is started (Fig. 4).

The elevated content of silicates typical for chromomagnesite articles produced by the Panteleimonovskii Refractory Plant makes them more "rigid" at low temperatures and causes more rapid softening even at 1100 - 1200°C. An increase in the heating rate of the lining has a strong effect on the decrease in the modulus of elasticity, i.e., makes the refractory lining less strong.

In batch furnaces characterized by rapid heating and cooling of the lining, mortars and protective coatings (gunning and ramming mixtures) should be used, depending of the service conditions of the lining articles, because they decrease the thermal stresses quite considerably.

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Fig. 2. Disruption of the continuity of the structure of a chromomagnesite refractory, expressed in terms of the decrease in the speed of ultrasound passing through the article, as a function of the heating rate m (in °C/min).

Fig. 3. Variation of the modulus of elasticity $E$ of refractories with the test temperature $t$ and the heating rate $m$: a) fused periclase-chromite refractory; b, c) chromomagnesite refractory produced by the Kombinat Magnezit JSC (b) and the Panteleimonovskii Refractory Plant JSC (c).