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COATINGS

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HEAT-ENGINEERING CHARACTERISTICS OF DIATOMACEOUS-EARTH MATERIALS IN A WIDE TEMPERATURE RANGE

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The ultimate strength of diatomite in compression was studied as a function of temperature in the range 50 – 700°C. The ultimate strength in compression at temperature 450 – 500°C is approximately a factor of 2 greater than the strength under normal conditions. This makes it possible to organize the process of heating diatomite-based lining of high-temperature furnaces more efficiently.

Key words: ultimate strength in compression, diatomite, break-down stress.

The lining (brickwork) comprises a system of barriers of a high-temperature furnace that separates a medium with high temperature (melted material, products of combustion, and others) from the surrounding environment.

According to the rules of industrial operations the surface temperature of equipment must not exceed 45°C [1]. In addition, a series of studies established that the actual flow of heat through the lining (brickwork) of high-temperature furnaces is significantly greater than the recommended values [2, 3].

In high-temperature furnaces thermal stresses appear in the brickwork during the heat-up process. These stresses are due to the non-uniform distribution of the temperature in different parts of the masonry or limited possibilities for the masonry to expand as it heats up. As a rule, excessively rapid heating of furnaces and temperature non-uniformity in different sections of the masonry engendered thermal stresses that break down the material. In addition, compressive stresses σ_c appear in the high-temperature section of the masonry and tensile stresses σ_t appear in the low-temperature section.

In picking the heating rate the magnitude of the thermal stresses arising in the masonry material must be taken into account.

In manufacturing plants calculations of the thermal stresses are performed to adjust the existing heating schedule of a furnace, and when necessary it is replaced by a new schedule for heating equipment so that the lining does not operate at heating rates above admissible values.

Since different materials are used in linings, the heating and cooling rates of all these materials must be different. Nonobservance of the temperature-time parameters of furnace heat-up can result in the appearance of temperature stresses above admissible values and, in consequence, the appearance of micro-cracks and then beak-down of the material.

This process can intensify if the material is exposed to different temperatures simultaneously. For example, too rapid growth of temperature at a cold start usually damages the thermal insulation of a high-temperature furnace. Thermal insulation possesses low thermal conductivity, so that it heats more slowly than a refractory layer or metal.

It should be noted that during downtime (when equipment is not heated) the lining material absorbs moisture from the air. Slow heating is necessary in order to gradually dry the lining and keep the moisture from boiling, which causes refractories to fracture. As a rule, high-temperature furnaces are heated according to schedules that are recommended by the manufacturer of the equipment. In the process many factors are neglected: changes in the properties of the lining materials as a function of temperature owing to permeation of the materials by metal or exposure to aggressive gases, and others. Standard schedules for drying and heating of furnaces are displayed in Fig. 1. Depending on the masonry material the temperature is allowed to rise by no more than 60 K/h [4].

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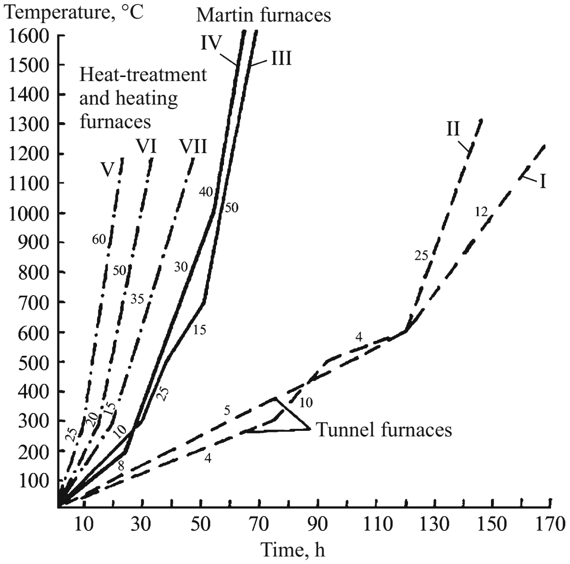

Fig. 1. Drying and heating schedule for furnaces with lining made of refractory materials: tunnel furnaces: I) dinas masonry; II) chamotte masonry; Martin furnaces: III) furnaces with dinas vault; IV) furnaces with chromium-magnesite vault; heat-treatment and heating furnaces: V) chamotte masonry, masonry volume to 20 m^3; VI) chamotte masonry, masonry volume to 50 m^3; VII) chamotte masonry, masonry volume to 100 m^3; the arabic numbers on the curves denote the rate of heating of the lining, K/h.

In 'Instructions for drying the brickwork of stationary boilers', in drying brickwork made from heat-resistant concrete or refractory masonry the maximum measured rate of growth of the temperature of the brickwork must not exceed 20 K/h when heating to 150°C, 30 K/h from 150 to 500°C, and subsequently 60 K/h in order to avoid crack formation and loss of strength [5].

Optimization of the factors impacting thermal stresses arising in the lining makes it possible to extend the run time of furnaces and avoid increasing heat losses to the surrounding environment. Significant results can be obtained even without changing the lining material, improving only the conditions of operation (temperature regimes).

In summary, it is recommended that the process of heating assemblies be conducted with the highest possible temperature rise rates for which the appearing thermal stresses will be below the ultimate strength of masonry materials at given temperature and stress relaxation rate.

In picking the rate of heating, aside from the magnitude of the thermal stresses, the ultimate strength of the employed material at different temperatures is also important.

The aim of the present work is to investigate the temperature dependence of the ultimate strength in compression of diatomite in order to organize the process of heating up the lining of a high-temperature furnace more efficiently.

Diatomite is one of the most commonly used molded thermal insulation materials. PD-350 brick was used in the present studies.

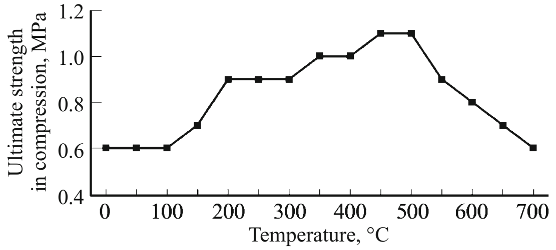

Fig. 2. Ultimate strength of foamed diatomite in compression versus temperature.

According to the manufacturer's data the ultimate strength in compression of this brick is at least 6 MPa at temperature 20°C. These data do not include the character of the change of the parameter as a function of temperature, and in the manufacturer's calculations performed to determine the rate of heating of furnaces containing this material the ultimate strength is assumed to be constant, i.e. temperature independent.

A review of the literature showed that insufficient attention is given to the temperature dependence of the ultimate strength. Meanwhile, the experimental data obtained for periclase-carbonaceous materials make it possible to talk about an increase of the ultimate strength in compression in the temperature interval 150 – 300°C (up to 20%), which gives an additional safety margin for increasing the heating rate and decreasing the time and energy expenditures on the heating process [6].

In these studies the ultimate strength of materials at high temperatures was measured by the method presented in the patent [7]. The measurements were conducted on a special bench.

Samples made from PD-350 foamed diatomite brick, whose composition is presented in [8], were used for the tests. In addition, the declared ultimate strength in compression of this brick is at least 0.6 MPa.

The studies on determining the ultimate strength and compression were performed in the temperature range from 50 to 700°C. For the tests a brick was sawed into cubic samples with 20 mm edges.

The obtained temperature dependence of the ultimate strength in compression of PD-350 foamed diatomite (correlation coefficient is equal to 0.97) is displayed in Fig. 2.

This dependence exhibits the following trends: the initial value of ultimate strength in compression of a sample, equal to 0.6 MPa, remains unchanged as the test temperature is increased to 100°C. As temperature is raised above 100°C the strength increases and at 450 – 500°C reaches its maximum value 1.1 MPa. Subsequently, the ultimate strength decreases to 0.6 MPa at temperature 700°C.

In this case the increase of ultimate strength of the samples in the temperature range 100 – 500°C can be explained by a reduction of the total porosity without chemical transformations. The subsequent reduction of ultimate strength upon heating above 500°C is explained by the onset of chemical reactions. The obtained data on strength reduction are consistent with the results obtained in [9, 10]: investigations of the structure of microsilica by x-ray structural analysis revealed structural rearrangements of polymorphic modifications of silicon dioxide at temperature near 500°C.

In closing, it should be noted that our studies showed that the ultimate strength at temperature 400 – 500°C is approximately a factor of 2 greater than the value under normal conditions. This makes it possible not only to conduct the process of heating up the masonry (lining) at rates where it will not fracture but also to reduce the time and energy expended on the heating process.

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