OPEN-HEARTH FURNACE STEEL MELTING BATH REFRACTORY SERVICING

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The reliability of a steel-melting object operation depends to a considerable extent on the state of the furnace hearth refractory lining. Prolonged and partial furnace stoppages lead to loss of integrity of the sintered layer whose restoration requires performance of several necessary operations. Timely repair of the sintered layer reduces hot lost time and periclase material consumption.

Keywords: furnace, hearth, chamotte objects, periclase objects, sintered layer, melting, beam, metal sheet, temperature, infra-red imager, wall.

The hearth is one of the main elements of the workspace of an open-hearth furnace. It consists of a bottom, within whose central part there is steel delivery opening, longitudinal banks over the side of the furnace and transverse in the direction of the front and rear walls. During operation of a hearth it should exhibit sufficient impact strength in order to withstand mechanical damage during loading with charges of categories A and B of form No. 1 – 3 (GOST 2787), and also physicochemical action of a gas atmosphere, slag and metal, hydrodynamic action of poured molten iron, delivered steel, etc. The lining of the hearth should be of rational thickness in order to provide sufficient heat insulation and reliable resistance to possible penetration of liquid metal.

Normally a hearth consists of successively placed layers of refractory material, laid on a metal sheet. The first layer is asbestos board (GOST 2850). A layer chamotte objects (GOST 8693) is placed upon it, and then there is a layer of periclase powder, that is the so-called sintered layer. The design thickness of the furnace hearth with a capacity of 200 – 300 tons is 1080 – 1170 mm, including, mm: sintered layer 225 – 250, layer of periclase objects 690 – 805, chamotte 120, asbestos board about 20 [1]. Laying of the bottom, longitudinal and transverse banks is also made with horizontal rows. The slope of the hearth bottom surface in the direction of the steel-pouring opening is made due to the sintered layer to a value of 0.05. The axis of the steel-pouring opening is arranged at an angle of 7° to the horizontal surface. Transverse banks of the hearth of the rear and front walls to the level of the charging doors is made at an angle of 45°, and the longitudinal banks from the direction of the port are made at an angle of about 35°. Expansion joints are filled with periclase powder grade DMPK-75 with a gap.

Thermal expansion joints in the hearth periclase layer have a thickness of 10 mm per running meter with laying on end and 4.5 – 6.0 mm with laying at the edge. Thermal expansion joints are not considered in the layer of chamotte objects in laying the bottom and banks. In rows of periclase objects in the longitudinal bank from the direction of the port the thermal expansion joints are 9 mm per 1 running meter of laying. Joints are staggered in the banks.

The temperature of the inner surface of the hearth during melting varies within wide limits. On direct contact with molten metal before delivery its rises to 1660°C and on contact with the slag to 1700°C. In the period of repairing banks and the hearth bottom the temperature falls below 1000°C. The heat resistance of the lining should provide a temperature of the outer surface of the hearth metal sheet not above 150°C (PB 11-493–02, GOST 12.2.099, [1]). In open-hearth furnaces with a capacity of 60, 270 and 450 tons the cycle of temperature measurements of the surface of the metal sheet was carried out using an IR-imager grade

SAT-90G. Repeated temperature measurements of the hearth metal sheet surface were carried out when the furnace was in a steady-state operating regime. Analysis of the re-

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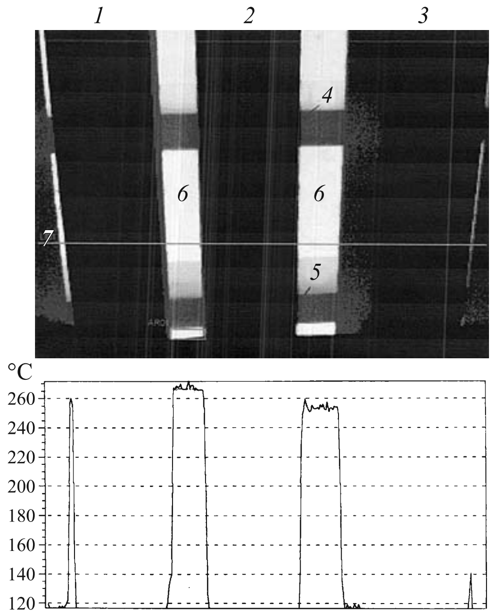

Fig. 1. Hearth left-hand bank: *1 – 3*) longitudinal beams; *4*, *5*) transverse beams; *6*) hearth metal sheet; *7*) surface with maximum temperature 277.8°C.

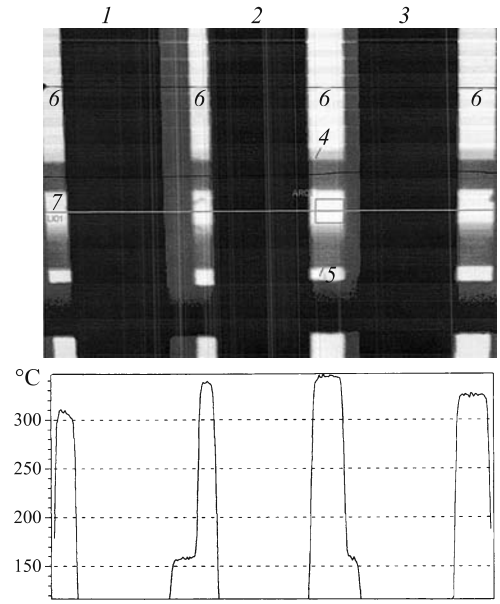

Fig. 2. Central part of hearth: *1 – 3*) longitudinal beams; *4*, *5*) transverse beams; *6*) hearth metal sheet; *7*) surface with maximum temperature 348.8°C.

sults obtained at different times of a furnace campaign and melting periods showed that the temperature field is inhomogeneous and varies both over the longitudinal and transverse directions of the bath.

An increased temperature level is noted over almost the whole hearth metal sheet surface after 50 – 70 melts. In the initial period of a furnace campaign there is a typical temperature distribution from the front wall to the rear over the left-hand bank from 165 to 255°C at the center, and up to 160°C at the rear wall. A similar temperature distribution has been observed over the center of a furnace, over the site of the third window and steel delivery opening 165 – 275 – 195°C, and over the right-hand bank: 160 – 255 – 180°C.

Towards the end of a furnace campaign the state of the hearth lining differs considerably in a worse direction (Figs. 1 – 3). The results obtained fro recording the temperature field of the hearth metal sheet directly point to the intense wear of the sintered layer and the unsatisfactory state of the bath surface. A local increase or reduction in sheet temperature signifies a local change in refractory lining thickness. In contact areas of the surface of the sintered layer presence of lining wear was noted in the from of depressions (pits) or swelling in the form of bumps (build-ups).

Information about the temperature state of the outer surface, obtained by means of IR-imager recordings, is reliable for operational action during hearth repair. In recent years emergency situations have been recorded with an increase in the amount of hearth repair work, that is caused by occurrence of unevenness of the hearth surface and development of pits as a result of partial separation of the sintered layer,

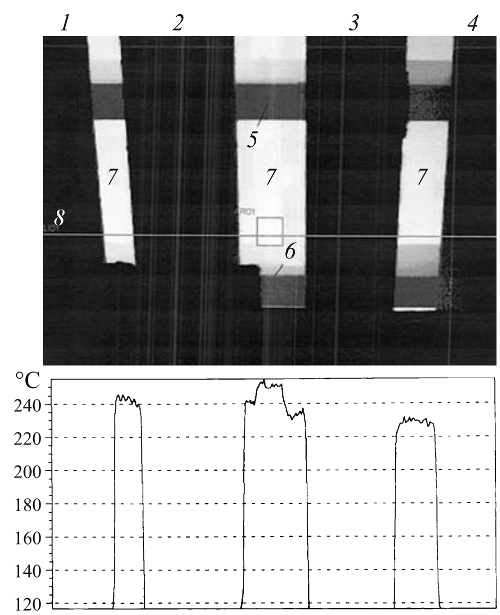

Fig. 3. Hearth right-hand bank: *1 – 3*) longitudinal beams; *4*, *5*) transverse beams; *6*) hearth metal sheet; *7*) surface with maximum temperature 256.6°C.

and cases have been noted of emergence of metal though banks below the level of the threshold of the charging doors. Emergency situations are possible with conditions of disruption of sintered layer integrity, for whose ramming various periclase materials were used. For example, [2, 3], for a hearth with nitrogen blowing the firm RHI proposes use in ramming the bottom of magnesite powder grades

Fig. 4. Bank over rear wall.

Fig. 5. Bank over front wall.

ANKERHEARTH-TLS2 and ANKERHEARTH-NN25 at the level of the steel delivery opening, grade ANKER-HEARTH-SB25 in banks above the steel delivery opening, and grade ANKERHEARTH-TLS 2-3-8 in the outer surface of the blowing element and grade ANKERHEARTH-CP30 in the inner volume of the element.

This variety of magnesite powder materials requires strict application with respect to purpose. These recommendations relate to planned decisions that should be made with deviation. However, in carrying out current post-melting repairs for a furnace hearth during hot and cold repair wit prolonged delays in operation in idle time a long delay without warm-up and with the required urgent restoration work there are structural changes in the material throughout the whole volume of the hearth lining. For example, a prolonged furnace shutdown, for intermediate and cold repair leads almost to breakdown of the sintered layer integrity. At its surface transverse and longitudinal cracks of different width appear (Figs. 4, 5). The monolithic nature of the surface of the sintered layer is disturbed due to metal of iron oxide reduced with carbon [2, 4], most intensively at the end of the period of charge melting and at the time of deoxidation. It has been established [4, 5] that during melting of a charge and bath boiling there is a progressive reduction in the content of magnesia-ferrite, magnesia-wüstsite and monticellite within the sintered layer composition. Over the working surface of the hearth metal droplets are distinguished with a size of 1 – 2 and 0.3 – 0.4 mm at a depth of 10 mm or more. The structure of the sintered layer at the end of these periods is presented in Fig. 6. Mainly it is the final residual structure that points to periclase grain refinement.

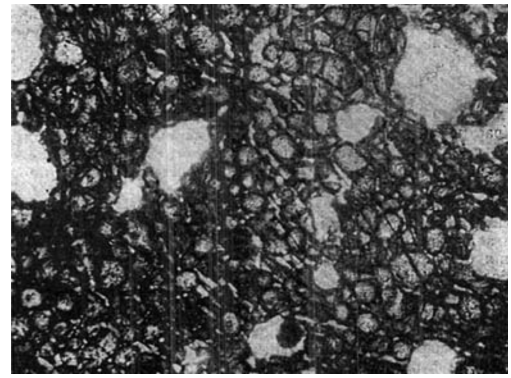

Fig. 6. Structure of sintered layer sample towards the end of bath boiling: light-grey and grey grains are periclase; dark background is glass and metal droplets; white spots are pores. × 100. Reflected light.

The sintered layer has considerable porosity (40 – 50%). The pore size reaches 2 mm. Metal droplets with a size of 0.75 – 1 mm are arranged in the form of chains along the working surface of the hearth and with a size 0.15 – 0.25 mm at a depth of 5 – 8 mm. Consequently, during bath boiling alongside reduction of iron oxide there is formation of metal and pores. In some cases these pores are of gas origin, and in others the nature of their formation is apparently connected with transfer of metal into the bath and floating of readily-melting compounds in the slag. Restoration of the hearth sintered layer after stopping a furnace for planned repair requires performance of several mandatory and successive operations. The profile of the bath should be given the design dimensions with careful collection of rubbish and metal scrap, penetrating into the lining. Then all visible defects are removed with fine dressing powder of the same composition, as the initial sintered layer material.

This is connected with the fact as material for the sintered layer uses different grades of OAO Kombinat Magnezit magnesite powder and also from producers in Germany, Slovenia and China. On an uneven continuous layer of periclase powder, laid to the level of the threshold of the charging doors, a layer of scale is added calculated at 5 – 50% of the total powder weight. Scale from rolling production previously ground and dried is used for this purpose. Scale $FeO \cdot Fe_2O_3$ contains a wüstite component, i.e. the FeO is always greater than Fe_2O_3, and its melting temperature is 1370 – 1410°C. During warming scale and its reaction with periclase powder forms a melt that fill hearth cracks and promotes adhesion of the newly poured powder layer with the main part of the sintered layer. The restoration method in question for the sintered layer has undergone successful testing and shown reliable results.

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