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EFFICIENT LINING FOR STEEL-POURING LADLES

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An analysis was made of the reasons for the short service life of the lining of steel-pouring ladles and malfunctions of fountains used for bottom-pouring. A high-temperature adhesive was developed and the most chemically stable refractory materials were chosen for it. The operating regime of steel-pouring ladles in the open-hearth shop at the Revda Hardware-Metallurgical Plant (in Revda) was studied, and based on the study results the shop replaced its fireclay bricks with MKRAP refractories. The authors used those results to also develop a mortar that has increased the life of the lining 30 – 50%. Use of the highly stable high-temperature adhesive in fountains has reduced metal loss during bottom-pouring operations.

Keywords: spalling of refractory bricks, refractory adhesive, layer of a lining, heat resistance, alumochromophosphate binder.

A project was undertaken in the open-hearth shop at Revda Hardware-Metallurgical Plant (in Revda) to lengthen the service life of its steel-pouring ladles. The lining of the walls and bottom of the 22.98-m^3 ladles at the plant are made up of three-four layers of refractory bricks. The refractory materials are fireclay bricks of grades ShB-9 and ShKu-32/16, fireclay mortars MSh28 and MSh31, refractory clay, and chromium-bearing concrete. The service temperature of the working layer of the lining is 1600 – 1650°C, slag basicity CaO/SiO_2 is 1.5 – 2.2, and the FeO content of the slag ranges from 10 to 25%. The lining is rapidly dried and heated over a 1 – 2 h period during the beginning of use of the ladle. The horizontal joints of the walls are coated with a fireclay mortar on a sodium-silicate binder. There are no vertical joints in the linings of the walls.

Study of wear of the lining of ladles after service showed that the wear takes place due to spalling of the bricks as a result of thermal shocks which occur during the entry and discharge of molten metal and the heating that the lining undergoes after a repair. The refractory of the lining also reacts chemically with reactants in the melt, particularly in the region of the vertical joints. There, reactants in the slag penetrate the lining to depths of up to 50 mm. In addition, the working layer undergoes abrasive wear in the bottom of the ladle when incoming molten metal strikes the lining. The large amount of wear of the lining in the slag zone is due to oscillation of the melt during use of the ladle.

In our opinion, a lining such as that described above has several shortcomings. The presence of three-four layers in the lining creates too many joints. Also, the use of short (230 mm) bricks in such linings creates 3 – 4 mm of taper in the working layer, which makes it more likely that some bricks will fall out of the layer during operation of the furnace. Another problem is the use of a fireclay mortar on a sodium-silicate binder, which has poor physico-mechanical properties that do not meet the requirements for the given metallurgical conversion. The fireclay bricks operate at the limit of their physico-mechanical properties during use of the ladle. The vertical joints are not coated with the fireclay mortar during repairs to the lining, which allows reactants in the slag and metal to penetrate the joints and thus cause greater corrosive wear. Such penetration also creates thermal stresses in the lining during each introduction and discharge of molten metal due to the large coefficient of linear expansion of the metal and slag compared to the refractory products. In addition, not enough time (1 – 3 h) is provided for drying and heating the lining after the repair and use of a ladle. The use of water to cool the lining after metal is cast produces severe thermal shocks that crack the working layer after 4 – 5 castings, i.e. after 2 – 3 heats. Such cracking occurs because, in accordance with their specifications, fireclay refractories need to undergo 3 – 4 water-cooling cycles (1300°C - water) and 20 – 25 air-cooling cycles (1200°C – air at 20°C) to perform properly. Cooling of a hot lining with water can cause accidents with ladles as a result of local disintegration of the lining during service.

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The technical and technological services at metallurgical plants do monitor the "erosion" of the linings of steel-pouring ladles during use, which makes it difficult to successfully introduce measures that could make them more durable. The rate at which the temperature of the lining increases during drying and heating is not monitored, which can result in increased vapor formation in the lining. Vapor formation under such conditions is especially a problem in the joints, where the fireclay mortar has an initial moisture content from 40 to 50%. The increased vaporization leads to premature rupture of the bonds between granules in the structure of the refractory products and a consequent deterioration in the durability of the lining. Metallurgists in the open-hearth shop clean slag out of the ladles when they are idle - an operation that is not stipulated by shop regulations. Cleaning of the ladles removes a portion of the working layer of the lining as well, since part of the refractory that is impregnated with slag to a depth of 15 – 20 mm comes out together with the slag. This accelerates the wear of the lining.

To make the lining of steel-pouring ladles more durable, its wear resistance must be made the same in different zones of the ladle. The following measures were proposed to create uniformly durable linings:

– the working layer of the bottom should be lined with mullite bricks;

– the working layer of the lining of the walls should be made of No. 9 and No. 16 MKRAP mullite-silica bricks with the use of high-refractory mortar MML-62 (TU 6137–80) to line the joints;

– an alumochromophosphate binder (ACPB) should be used in the joint lining;

– the wall lining should be composed of two layers, which would make it more durable by increasing the taper of the lining; also, a smaller amount of refractory should be used in the working layer in order to increase the working volume of the ladle by 20 – 25%;

– the new joint material should be used in both the horizontal and the vertical joints;

– the lining should be cooled with a gas-air mixture;

– no slag should be removed after discharge of the melt.

Experimental linings passed field tests in three steel-pouring ladles. The tests were performed using refractory bricks and mortar produced by the OAO "Ogneupory" in Bogdanovich.

No emergency situations arose during use of the experimental ladles. Their campaign was ended due to local wear of isolated sections of the working layer of the walls and bottom. The second course of the lining contained small cracks 10 – 20 mm deep and 30 – 50 cm^2 in area. The campaigns of the ladles were 16, 15, and 14 heats, while the statistical average service life of the ladle linings made by the traditional methods has been 10.6 heats. The durability of the linings of the steel-pouring ladles was increased by 38%.

Steel is bottom-poured in the open-hearth shop. Seepage of molten metal through the joint between the stool and the fountain is a fairly common occurrence. This necessitates rejection of the cast metal, interrupts the casting operation, and creates an emergency situation. The cast metal is unfit for further use because it has been contaminated by various materials in the channels of the fountain. To reduce the incidence of such leaks 30 – 40%, we have proposed the use of a high-refractory adhesive based on a corundum filler, ACPB, and refractory clay. The composition of the adhesive: 50% corundum filler of the 0.5 – 0.063-mm fraction; 40% ACPB diluted with water to a density of 1.25 g/cm^3; 10% refractory clay containing at least 28% Al_2O_3 [1 – 3]. To give the binder the required density, the ACPB that was supplied to the plant was diluted with water in a 1:1 proportion. The physico-mechanical properties of the adhesive: refractoriness no lower than 1770°C; heat resistance 24 heating cycles in air; ultimate strength in shear at least 6.5 MPa; spreadability no less than 70 – 90 mm; cone shrinkage no less than 11 cm; linear shrinkage 0 at a service temperature of 1230°C, 1.6% at 1400°C, and 2.0% at 1600°C; apparent density no lower than 1.8 g/cm^3; open porosity no less than 23%; ultimate strength in compression no lower than 35 MPa. The amount of adhesive used is 5 – 6% for each 1 m^3 of fountain tubing.

The sequence is followed in preparing the adhesive: first, 80% ACPB is poured into a mixer, and this is followed by the addition of separate calculated amounts of filler and clay. The components are then mixed for 6 – 8 min. The preparation of the adhesive is completed by addition of the remaining binder.

The adhesive is mixed in a forced-action mixer (solution mixer, concrete mixer, or turbulent mixer). Manual preparation of the adhesive does not give the desired results because the use of a viscous binder and a powder which has a high content of dust-sized particles causes balling of the powder. It is not possible to obtain a uniform, homogeneous mass under such conditions.

Either electrocorundum — which is fairly expensive — or wastes from abrasives factories (the Kosulino Abrasives Plant or the Chelyabinsk Abrasives Plant) can be used as the filler. The wastes do not require additional comminution and are inexpensive, but they do contain iron and silicon carbide as impurities. These impurities do not significantly harm the physico-mechanical properties of the adhesive, but they do necessitate the use of a certain technology for preparation of the solution of the adhesive. A reaction that takes place between the iron and silicon carbide impurities causes the adhesive to begin to expand 5 – 10 min after all of the APCB binder has been added. Thus, after the adhesive solution has been formed, it must be held for 2.0 – 2.5 h and periodically mixed until the reaction ends. The adhesive must then be used within 7 – 8 h after it has been made. The time required for the adhesive to harden can be controlled by introducing activating additives such as caustic magnesite. The butt end of the fountain tubes are dipped into the adhesive. Tests of individual sections of the fountain with the adhesive showed an increase in service life of more than 30%.

CONCLUSION

When steel-pouring ladles are provided with linings composed of a large number of layers and no mortar is used in the lining's vertical seams, the lining undergoes local fracture after 4 – 5 heats. Also, the dimensions of the butt ends of the tubes used for bottom-pouring vary over an unacceptably large range, which results in leakage of molten metal and creates emergencies during casting operations in the open-hearth shop. The measures that have been proposed by the authors make it possible to lengthen the service life of the lining of steel-pouring ladles by 20 – 40% and eliminate leaks of metal through the butt joints of the tubes in the fountain assembly. The experimental linings have passed factory tests in steel-pouring ladles used at the Revda Hardware-Metallurgical Plant.

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