WEAR OF THE PERICLASE—LIME LINING OF STEEL TEEMING LADLES IN LADLE DESULFURIZATION OF STEEL

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In the Converter Shop of Azov Steel Combine periclase—lime refractories previously heat treated using a special cycle are used for lining the working layer of the walls of steel teeming ladles. In this shop the method of ladle treatment of steel includes desulfurization of the metal in ladles by treatment with liquid slag synthetic or solid slag-forming mixtures and in some cases with both simultaneously.

The liquid synthetic has a composition of (%)* 40-45 CaO, 35-40 Al₂O₃, ≤5 SiO₂, 4-6 TiO₂, and < 1 iron oxides. The temperature of the liquid synthetic slag during pouring into the ladle is 1680-1720°C (superheated, that is, 160-200°C over the liquidus temperature).

Lime and fluorspar in a 4:1 ratio are used as the solid slag-forming mixture. Freshly fired lime containing not less than 92% CaO + MgO and fluorspar containing not more than 10% SiO₂ are used. The grain size composition of the solid slag-forming mixture is 40-50% 15-30 mm fraction, 30-35% 5-15 mm fraction, and ≤30% finer than 5 mm.

The liquid synthetic slag is poured into the steel teeming ladle immediately before tapping of the metal from the converter into it. The weight of metal in the ladle is 340-360 tons. The specific consumption of liquid synthetic slag is 10-20 kg/ton of steel treated (3.4-4.0 tons/heat). The time of the liquid synthetic slag in the ladle before tapping of metal from the converter is 10-20 min and the metal is in the ladle for 1.5-2.5 h from the start of tapping of it from the converter to the end of teeming of it. Recently for the purpose of economy in scarce and expensive liquid synthetic slag and electric power for production of it a portion or all of the liquid synthetic slag has been replaced by solid slag-forming mixtures.

The results of investigations and operating experience showed that in degree of desulfurization the use of 1 kg of solid slag-forming mixture per ton of steel on the average is equivalent to the use of 4 kg of liquid synthetic slag per ton of steel with a basic lining of the ladle. The solid slag-forming mixture is placed in the steel teeming ladle at the time of tapping of the steel from the converter directly under the stream of metal, which significantly accelerates melting of the solid slag-forming mixture and desulfurization.

The method of ladle treatment of steel includes holding back of the melting slag in turning down of the converter by covering the tap hole with a plug.

The steel is deoxidized in the ladle. A portion of the aluminum is added at the start of tapping of the metal from the converter. Upon reaching 1/3-1/2 of the height of filling of the ladle the solid slag-forming mixture is added with subsequent addition of ferroalloys and the remainder of the aluminum. In treatment of steel only with the solid slag-forming mixture the slag formed from the mixture contains 50-60% CaO, 7-13% SiO₂, 20-28% Al₂O₃, 1.0-2.0% FeO, 0-1.0% MnO, 0.01-0.08% P₂O₅, and 0.2-0.9% S at the end of ladle treatment.

The metal is deoxidized in the ladle in tapping based on calculation of obtaining a silicon content at the lower allowable limit. Each heat is blown in the ladle with argon for 10-15 min with lances submerged in the metal.

*Here and subsequently wt. % is given.
Fig. 1. Disposition of cracks in the zones of the refractory: 1, 2, 3) working, transition, and least changed zones.

Fig. 2. Schematic distribution curve of temperature in a ladle lining with a steady heat flow ($l$ is the distance from the working surface).

Type PIBS-50 (TU 14-8-171-89) tar-bonded periclase-lime refractory parts used on the working layer of a steel-teeming ladle lining contain 60% dolomite, 40% finely ground magnesite powder, and 5-7% (over 100%) of refined tar including up to 70% pitch. These refractory parts were produced at II’ich Mariupol’ Metallurgical Combine by pressing under a pressure of 95-100 MN/m² and not more than 12 h later delivered to Mariupol’ Azov Steel Combine for subsequent heat treatment and use in the working layer of the ladle wall lining. In heat treatment the refractories are rapidly heated to 250-350°C, held for a short time at this temperature, and then cooled. Experience in use of periclase-lime refractories showed that under existing conditions and in the absence of breakdowns in the method of preparation, shipment, heat treatment, and service used hydration processes of the refractories do not develop significantly.

The ladle wall lining is a two layer one including a 200 mm thick working layer and a 100-120-mm-thick safety layer. The 220 mm thick slag belt and working layer of the bottom lining are lined with PKhKU periclase-chromite refractories (TU 14-8-270-78) or Lovinit type Czechoslovakian parts. The chemical composition of the periclase-lime parts used was 50-55% MgO, 30-35% CaO, ≤3% SiO₂, and ≤5% RₓOᵧ and the compressive strength 30 N/mm².

Determination of the mechanism of wear of the periclase-lime lining of steel teeming ladles in ladle treatment with liquid synthetic slag and solid slag-forming mixture with argon blowing of the metal determines the measures for increasing the operating life of the lining and the economic effectiveness of the ladle treatment method as a whole. In this case in it necessary to take into consideration the processes related to deoxidation of the steel in the ladle.

Many theoretical investigations and experience in the production of killed steel have convincingly showed the possibility of processes of reduction of calcium and magnesium from highly basic slags or refractories in high-temperature contact of them with reducing agents such as metallic Al according to the reactions [1, 2]:

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\begin{align*}
\text{CaO} + \frac{2}{3} \text{Al} & = \text{Ca} + \frac{1}{3} \text{Al}_2\text{O}_3, \\
\text{MgO} + \frac{2}{3} \text{Al} & = \text{Mg} + \frac{1}{3} \text{Al}_2\text{O}_3.
\end{align*}
\]

(1) (2)

However, it should be noted that reduction of calcium and magnesium from oxides by metallic aluminum is observed only with a quite high concentration of it in the phase in contact with these oxides (not less that 0.5%) [1], which occurs in deoxidation and alloying of steel in the ladle. Deoxidation in the ladle is done with 1-2 kg large lumps of solid aluminum. It