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THE SENSITIVITY STUDY OF THE THERMAL STATE MODEL OF THE SYSTEM «MELT–LADLE–ENVIRONMENT»

Abstract: Mathematical model of transient heat transfer through a multilayer lining of the ladle, as well as due to the radiation from the surface of the melt is designed. On the basis of analysis of the influence of structural and thermal factors as the main parameters for the model identification be selected the reduced values of the inner diameter of ladle lining and of the emissivity of melt surface.

Key words: modeling, casting ladle, thermal state, transient heat transfer

Statement of the problem

Limited opportunities for adjusting the physical and physico-chemical conditions of the processes of iron melting in traditional units led to the creation of new steelmaking processes. In those cases where the technological operations, which provide the desired quality of the metal directly in the aggregate, resulting in a loss of productivity of the process, they operate in the auxiliary tank. In today's furnace steel processing the ladle turns from purely transport vessel to the metallurgical reactor. Respectively increased demands on him.

The molten steel temperature is the primary factor that limits the duration of the processing operations with the melt in the ladle. Declines due to the heat loss for heating ladle lining, heat transfer through it, and radiation from the surface of the melt.

When transferring to the casting ladle is necessary to ensure a rather narrow range of steel temperature. Since the production environment to implement operational control of this important parameter with the required precision is not possible, then for control the furnace steel processing it is necessary to forecast of temperature change.

Analysis of publications on the topic of research

The study of the thermal state of the melt in the ladle in the furnace steel processing paid much attention. In particular, in [1] proposed the technology of automatic determination of enthalpy ladle. Using a mathematical model unsteady heat transfer in [2] considered the influence of the thickness of the lining ladle on the melt heat loss. In [3] presented results of a study of thermal state ladle at a variable heat

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load. In [4] investigated the variation of the temperature of the melt, depending on the time of technological operations of the ladle treatment.

The wording of the purposes of Article

Usually when modeling the thermal characteristics of the melt and of the refractory lining materials, the coefficients of convective and radiation heat transfer are not measured, and adopted in accordance with the reference data. In each case of the melt pouring in the ladle, only measured weight of the melt, its initial temperature and the initial temperature of the inner surface of the ladle lining after the thermal treatment. Environment temperature is usually taken as the reference temperature industrial rooms. As a result, the actual values of the model parameters may differ from those of a few percent.

Therefore it is necessary to investigate the effect of variation values of ladle thermal state on results of melt cooling modeling.

The main part

To simulate the ladle is represented as a cylinder with a flat bottom. In the mathematical model [2] takes into account the heat losses through the multilayer wall and bottom of the ladle, as well as radiation from the melt surface, which partially or completely covered with a slag layer.

To calculate the unsteady heat transfer process during cooling of the melt in the ladle, uses the following input data: geometric dimensions of bath and weight of melt; the initial temperature of the melt and the inner surface of the ladle lining, as well as environment temperature; thickness and number of lining layers; thermal properties of melt and lining materials.

The initial temperature field in the wall and a bottom of ladles it is calculated by the given first kind boundary conditions – constant values of temperature on the inner surface of the ladle lining and the outer surface of the armor, that have been adopted in accordance with the data of industrial research.

For this study, is modeled on a 120-ton ladle with an external diameter of 3.6 m and a height of 4.3 m. Ladle lining structure and thermal properties of its components are given in [5]. The initial temperature of the melt in the ladle after the release, according to our observations, the average is 1,620 ˚C, and the initial temperature of the inner surface of the lining prepared ladle – 1100 ˚C. Environment temperature for the calculations is taken to be 30 ˚C. Conditions of simulation corresponded the case of exposure of ladle of the molten steel within 30 minutes.

To calculate the unsteady heat transfer process during cooling of the melt in the ladle, the following nominal values of the model parameters be used: melt weight of 120000 kg; melt density of 7000 kg/m^3; its heat capacity 825 J/(kg·K); coefficients of convection heat transfer: from the melt to the wall of the ladle 5800 W/(m^2·K) and from the melt surface and from the outer wall of the ladle into the environment – respectively, 27 and 12 W/(m^2·K).

The influence coefficients K_e of model parameters calculated by the formula

$$K_e = \frac{(P_{\max} - P_{\min}) / P_n}{(\Delta t_{\max} - \Delta t_{\min}) / \Delta t_n}, \quad (1)$$

where $P_{\max}$, $P_{\min}$, P_n – respectively, the maximum, minimum and nominal value of the analyzed parameter; $\Delta t_{\max}$, $\Delta t_{\min}$, Δt_n – corresponding decrease in the melt temperature during the simulation.

Analysis of simulation results in cooling of the melt variability parameters thermal state ladle showed that the most significant are: thermal properties of liquid steel (density and heat capacity) – influence coefficients K_e are equal to minus 0,89; the initial temperature of the inner surface of the lining (K_e = – 0,66); inner diameter of the ladle (K_e = + 0,74); the degree of the emissivity of the melt surface (K_e = + 0,39). Less influence on the accuracy of the model variations of thermal properties and thickness of the inner lining layer (0,2 > K_e > 0,05). Uncertainty values of the remaining parameters of the “melt–ladle” can be neglected.

Conclusions and prospects for future research

Given the reliability of the data on the thermal properties of the melt and corundum, as well as the initial temperature of the inner surface of the ladle lining, the main parameters of the adaptation of thermal state model of the ladle should be considered redused the values of its internal diameter and the emissivity of the melt surface.

The results can be used to create a reliable forecasting system of the changes in the melt temperature in the furnace steel processing.

References

1. Ageev S.V. Technologiya avtomaticheskogo opredeleniya teplosoderzaniya stalerazlivochnogo kovsha // S.V. Ageev, A.D. Chernopol‘sky, I.A.

Petushkov, V.I. Boikov, S.V. Bystrov, A.A. Blinnikov. – Metallurg, 2011. № 5. P.48–52.

2. Michaylovskiy N.V. Vliyanie tolshchiny futerovki staleraz-livochnogo kovsha na teplovye poteri rasplava // N.V. Michaylovskiy, S.V. Beyzun. – Metallurgicheskaya teplotehnika: Sbornik nauchnych trudov NMetAU. – Dnepropetrovsk: NMetAU, 2010. P.135–142.

3. Oshovskaya E.V. Modelirovanie raboty futerovki stalerazlivochnogo kovsha s peremennoy teplovoy nagruzkoy // E.V. Oshovskaya, I.N. Salmash, D.A. Fomenko. – Naukovi prazi DonNTU: Metalurgiya, 2011. Vyp. 13(194). P.198–210.

4. Beyzun S.V. Teplovoe sostoyanie kovshey pri vnepechnoy obrabotke stali // S.V. Beyzun, N.V. Mikhaylovskiy, V.I. Shibakinsky. – Metallurgicheskaya i gornorudnaya promyshlennost‘, 2013. № 4. P.104–107.

5. Kazanzev E.I. Promyshlennye pechi: Spravochnoe rukovodstvo dlya raschetov i proektirovaniya. – 2-e izdanie, pererab. i dop. – M.: Metallurgiya, 1975. – 368 p.