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DYNAMIC MODELING OF THE THERMAL STATE FOR CASTING LADLE

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On the basis of analysis for construction of casting ladle the mathematical model of its thermal state, which is realized by the set of typical dynamic links at the package of structural modeling of «Matlab Simulink», is worked out. A model allows operatively to forecast the temperature of fusion during the operations of out-of-furnace treatment.

Keywords: casting ladle, thermal state, out-of-furnace treatment, structural modeling, forecasting of temperature fusion

One of basic parameters which limit duration of technological operations with casting ladles is a temperature of fusion [1]. The decline of temperature of fusion is related with the thermal losses at heating of ladle casing, transferrableness of warmth through her and radiation from the open surface of fusion. Methods of calculations for distribution of temperature in relation to a ladle casing during the thermal operating on her of fusion are brought in many works, in particular, in article [2] the mathematical model of non-stationary transference of warmth through heat-resistant ladle casing is worked out, and in article [3] – method of calculations for thermal losses of fusion during his stay in a casting ladle.

For creation of ASM of out-of-furnace treatment of steel it is necessary not only operative prognostication of temperature of fusion but also possibility for research of influence of various factors on the dynamics of the thermal state of casting ladle. A task to work out a corresponding computer model with the use of package of structural modeling of «Matlab Simulink» is stated.

A casting ladle has the cooked case, made from steel sheets by thick to 40 mm in form the truncated cone with expansion up. A bottom of ladle can be flat or have a spherical form. For simplification a ladle was given in a kind of the cylinder with a flat bottom.

For the calculations of non-stationary heat exchange during cooling of fusion in a casting ladle use such initial data: geometrical sizes of bath and mass of fusion (external sizes of ladle are fixed, internal are hesitate); initial temperature of fusion and internal surface of ladle casing and temperature of environment; part of open surface of fusion in a ladle; thickness and quantity of casing layers; thermophysical properties of fusion and materials of casing.

The source field of temperature in a wall and bottom of ladle is calculated on the boundary conditions of the first kind – constant value of temperature for internal surface of ladle casing and external surface of amour, which are acceptable in accordance with these industrial experiments.

Modeling of non-stationary heat emission from fusion through multi-layered a wall and bottom of ladle is executed on an initial data and source field of temperature taking into account change of temperature of fusion.

Change of temperature of fusion Δt_w at every step to time of modeling $\Delta\tau$, temperature Δt_i i-cylindrical and the temperature $\Delta t_{dn,i}$ of flat casing layers for wall of ladle calculate on a formulas

$$\Delta t_m = -\frac{\left(Q_{st} + Q_{dn} + Q_{pov}\right)\cdot\Delta\tau}{C_m \cdot M_m} \; ; \qquad (1)$$

$$\Delta t_i = \frac{\left(Q_i^w - Q_{i+1}^w\right)\cdot\Delta\tau}{0{,}25 C_i \cdot \pi \cdot \rho_i \cdot \left(d_{in}^2 - d_{out}^2\right)\cdot H_m} \; ; \qquad (2)$$

$$\Delta t_{dn,i} = \frac{\left(Q_i - Q_{i+1}\right)\cdot\Delta\tau}{C_i \cdot \rho_i \cdot F_{dni} \cdot \delta_i} \; , \qquad (3)$$

where Q_{st}, Q_{dn} are a convective thermal stream from fusion to the wall of ladle and from fusion to the bottom of ladle, W, accordingly; Q_{pov} is a radiant-convective thermal stream from the surface of fusion, W; C_m, M_m are a heat capacity, Jou/(kg·K), and mass of fusion, kg, accordingly; C_i, ρ_i are accordingly heat capacity, Jou/(kg·K), and density, kg/m^3, material of i-casing layer; d_i, d_{i+1} are an internal and external diameter of i-layer of casing, m, accordingly; H_m is a height of bath of fusion in a ladle, m; Q_i^w, Q_{i+1}^w are a thermal stream through the internal and external surface of i-layer of casing, W, accordingly; F_{dni}, δ_i are an area, m^2, and thickness for i-layer of casing of bottom for ladle, m, accordingly.

A radiant thermal stream from the surface of fusion is determined under the law of Stefan-Boltzmann

$$Q_{rud} = \varepsilon_{rud} \cdot \tilde{N}_0 \cdot S_{\eth} \cdot \left(T_{fus}^4 - T_{env}^4 \right) \; , \qquad (4)$$

where ε_{rud} is reduced degree of blackness for the system «fusion-environment» taking into account part of open (free of slag) surface of metal, C_0 is Boltzmann constant; S_p is an area of open surface of fusion, m^2; T_{fus}, T_{env} are absolute temperatures of fusion and environment, accordingly, K.

In addition, a convective thermal stream goes out from the surface of fusion

$$Q_{conv} = 0{,}25\alpha_{st} \cdot \pi \cdot d_{in}^2 \cdot \left(t_{fus} - t_{env}\right) \; , \qquad (5)$$

where ε_0 is a coefficient of heat emission by a convection from the surface of fusion to an environment, W/(m^2·K); $\varepsilon_0 = \left(\frac{1}{\varepsilon_{fus}} + \frac{1}{\varepsilon_{env}} - 1 \right)^{-1}$, ε_{fus}, ε_{env} are accordingly temperature of fusion and environment.

The computer model of the thermal state of ladle is realized in the package of «Matlab Simulink». A model consists of three subsystems which modeling heat emission from the surface of fusion and transference of warmth through a wall and bottom of ladle. Every subsystem is the set of associate typical dynamic lances which will realize the mathematical model of heat exchange (5). All elements are constrained inter se and represent the dynamics of temperature of fusion and casing layers, and also thermal streams in a casting ladle during time of modeling.

The computer chart of the thermal state for casting ladle, which realized in the software environment of «Simulink», provides the reflection of dynamics of temperature of fusion during time of technological operations and heat exchange between fusion and wall and bottom of ladle, and also by an environment.

As a example for calculations was chosen 120-ton casting ladle with an external diameter 3.6 m and high 4.3 m, the initial temperatures of fusion and internal surface him casing – 1893 and 1473 К.

Results of modeling for fusion which is in a ladle during one hour show that his temperature goes down from an initial value to 1831 К, id est on 335 К. It is set, that thermal stream from fusion through the wall of ladle three times more what stream from fusion through a bottom, by the most loss of warmth fusion is a stream from his surface.

Conclusions. Comparing of the got results of modeling with the real data of cooling of fusion enables to consider the worked out model adequate and well-off for application during researches of casting ladles, and also for creation of ASM of out-of-furnace treatment of steel.

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