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DEVELOPMENT OF A MELT TEMPERATURE CONTROL SYSTEM FOR INDUCTION CRUCIBLE MIXERS

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The calculation method of the heat and electric characteristics of induction crucible holding furnace with take into account the variable melt level in crucible is developed. The structural model of the mixer is received. The model of the control system of the mixer with indirect estimation of the temperature is developed.

Key words: induction crucible holding furnace, indirect estimation of the temperature, programmable controller.

One of the most important features of induction crucible mixers (ICMs) that distinguish them from melting furnaces consists in the fact that they operate at a variable melt level in a crucible. To calculate the thermal and electrical characteristics of ICMs with allowance for a variable melt level, researchers developed athe special-purpose Overheat software package. The melt level was found to substantially affect the thermal and electrical characteristics of ICMs [1], and changes in these characteristics would substantially affect the melt temperature conditions in a mixer.

Since one of the basic problems of ICMs is the overheating of the liquid metal to the required temperature before casting and the maintenance of constant casting temperature conditions, the role of an automatic control system (ACS) for the melt temperature in order to stabilize the temperature conditions of ICM operation is very important. The operating conditions of the casting unit and the type of metal in an ICM crucible are also important. Indeed, if the requirements for the accuracy of the temperature maintenance are stringent or a metal is gradually poured from a mixer (in the case if the casting weight is smaller than the ICM capacity), it is necessary to monitor and continuously control the temperature, since the electrical and thermal conditions of the mixer operation change continuously.

It should be noted that the traditional thermoelectric means for controlling the melt temperature (immersion thermocouples) have the following disadvantages: periodic control, the necessity of turning off a unit for measurements, and so on. Therefore, it is a challenging problem to design an automatic control system (ACS) for the melt temperature in an ICM that is based on indirect parameters. A structural model should be constructed for an ICM with allowance for a variable melt level in a crucible.

To construct a structural model for an ICM, we used the energy balance equation

$$\left(P(\tau)-P_1(\tau)-P_h(\tau)\right)d\tau = c\cdot m(\tau)\,dt \qquad (1)$$

where $P(\tau)$ is the power consumed by the mixer, $P_1(\tau)$ is the active power losses in the inductor, $P_h(\tau)$ is the total thermal losses, c is the specific heat of the melt, $m(\tau)$ is the melt weight in the crucible, $d\tau$ is the elementary time interval, and dt is the change in the melt temperature in the time $d\tau$.

We performed calculations (numerical experiments) of an ICM filled with 4 t of cast iron using the Overheat software package by designing experiments and obtained the following dependences of the total thermal losses and the inductor losses on significant parameters:

the total thermal losses through the mixer lining (kW) are

$$P_h = -26 + 0{,}081\cdot l + 0{,}05\cdot t - 1{,}32\cdot 10^{-5}\cdot l\cdot t \qquad (2)$$

the inductor electrical losses (kW) are

$$P_1 = 7{,}872\cdot 10^{-6}\cdot I_1^{\,2} - 9{,}607\cdot 10^{-9}\cdot I_1 . \qquad (3)$$

The calculation of the melt temperature in suggested system requires information on the power consumed from athe power supply and the electrical losses in the inductor and the thermal losses with allowance for the metal weight in the mixer and the initial melt temperature.

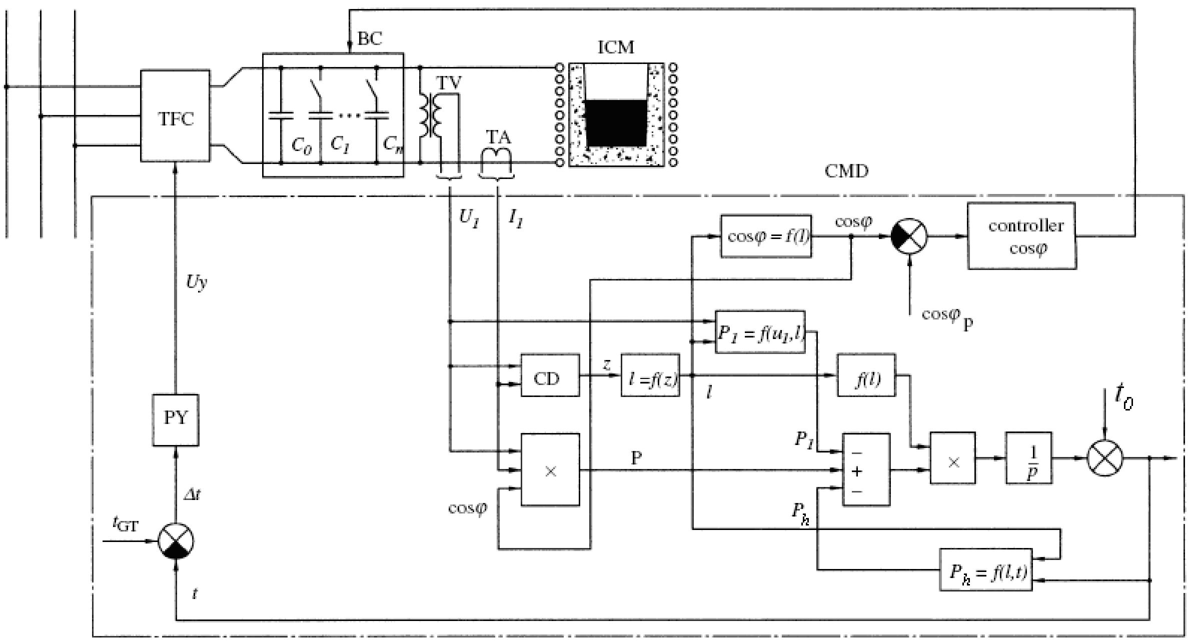

Fig. 1. Functional scheme of the system of controlling the melt temperature in an ICM using indirect parameters.

Our method of an indirect estimation of the melt temperature in an ICM is based on the measurement of electrical parameters (the inductor voltage and current, $\cos\varphi$ of the inductor–charge system) and the metal weight in the mixer.

Controlling the metal weight in the mixer is a separate problem, and it can be solved by indirect methods or the application of tensoresistive transducers. The indirect method of measuring the melt weight in the mixer implies the measurement of the inductor–charge system parameters that are in a direct relation to the metal level in the crucible and, on the other hand, change insignificantly when the melt temperature ACS operates. Such parameters can be represented by $\cos\varphi$ without compensation ofor the electrical resistance (active, reactive, or impedance) of the inductor–charge system. The simplest method is the measurement of the impedance, which represents the ratio of the rootmean-square voltage to the root-mean-square current.

Figure 1 shows the principle of operation of the ICM melt temperature control system using indirect parameters. The mixer is powered from by a static thyristor frequency converter (TFC). A bank of capacitors (BC) connected parallel to the inductor is used to compensate for the reactive power: some of the capacitors are connected all the time, and the others are switched on and off to compensate for the changes in $\cos\varphi$ during operation. From the voltage and current sensor signals, a divider (D) calculates the impedance z of the inductor–charge system, which is used to determine the melt level in the mixer crucible. Using the control system error $\Delta t = t_{GT} - t$, a controlling device (CD) forms a controlling voltage uy(τ), which can be used in, e.g., the vertical pulse-phase control system (PPCS) of the thyristors in the rectifier unit entering into the composition of a frequency converter with a pronounced dc stage.

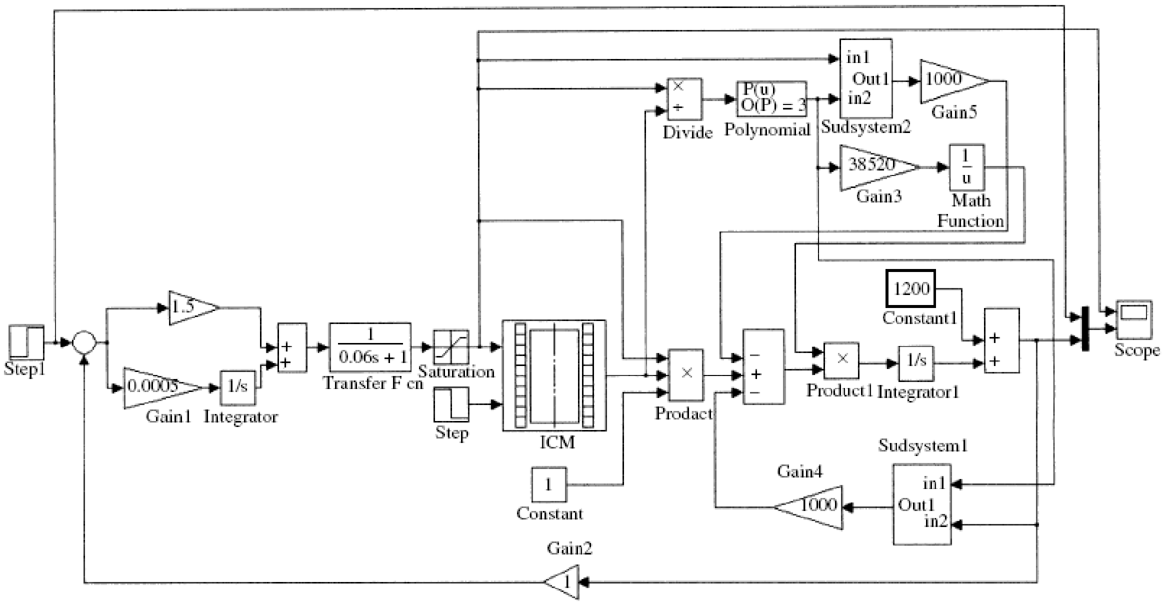

Fig. 2. Block scheme for the structural model of the system of controlling the melt temperature in an ICM using indirect parameters for the Simulink medium.

This system uses information on the current values of the electrical parameters, determines the metal weight in the crucible, calculates the electrical losses in the inductor (with allowance for the inductor voltage), the total thermal loses (with allowance for the current information on the melt temperature), and the melt temperature from the obtained energy balance in the mixer.

To calculate the melt temperature from the indirect information from the sensors of the parameters to be measured and to implement the control algorithms in the ACS, we have to use a controlling microprocessor device (CMD, Fig. 1).

Figure 2 shows the block diagram of the structural model of the ICM melt temperature ACS using indirect parameters implemented in the Simulink medium.

When a perturbation action (a change in the melt weight in the crucible) is introduced into the system, the statistical error increases. Figure 3 shows the transient changes in the inductor voltage and the melt temperature when the system processes control are controlled (t_{GT} = 1400°C) and perturbation actionts (pouring 70% melt from the mixer) at the system parameters corresponding to those in Fig. 2. The introduction of an integral component into the control law is shown to eliminate the statistical error; however, it can degrade other direct control quality indices. In particular, the character of the transient processes becomes oscillating. An increase in the integral component increases the overshoot and decreases the time of achieving a given melt temperature. The best (close to aperiodic) character of the transient processes is achieved when the propor-

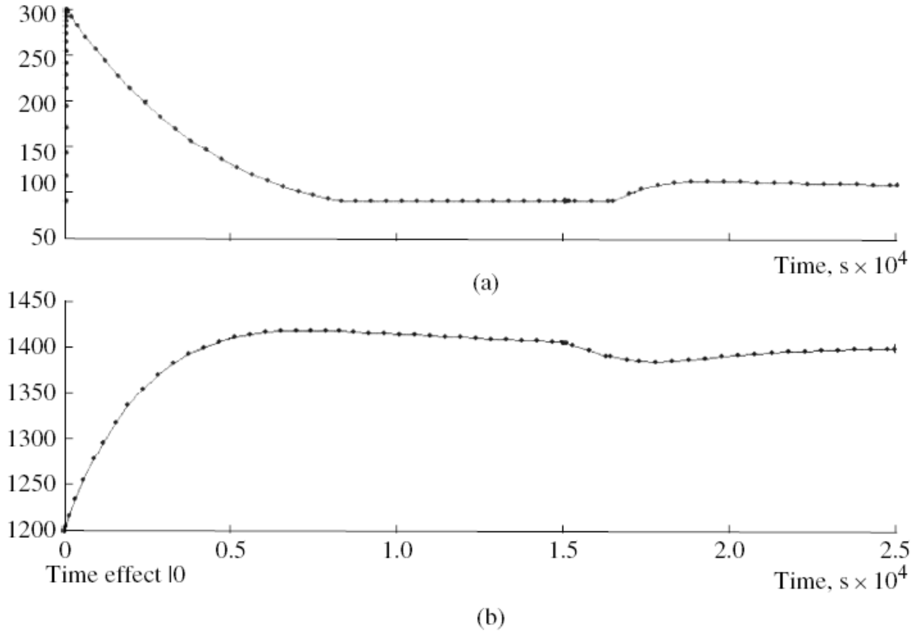

Fig. 3. Transient changes in (a) the inductor voltage (V) and (b) the melt temperature (°C) when the system processes are controlcontrolled and perturbation actions.

tional component significantly exceeds the integral component.

The developed control system is characterized by the relative simplicity of the related calculation and control algorithms, which do not impose stringent requirements on the electronic computer power. Since the change in the melt temperature is inertial, a highspeed control device is not required. Thus, almost any modern programmable microprocessor controller produced by Siemens, Allen Bradley, etc., can be used as the controlling device in the ICM melt temperature ACS using indirect parameters.

The controllers can be programmed with both highlevel languages (e.g., the C language) and special-purpose object-oriented media.

The programmable controller can be connected to an upper level computer, which that visualizes and records the technological process and serves as a control console, by means of computation networks. The controller can also be connected to a multilevel control system of a technological process.

CONCLUSIONS

We propose to control the melt temperature in an ICM using indirect parameters by calculating this temperature from the energy balance of the mixer, which is determined from the measured electrical parameters, the melt weight, and the initial melt temperature. It is reasonable to use regression polynomials that take into account the dependences of the electrical and thermal conditions on the metal level in the mixer.

The proposed system of controlling the melt temperature can be realized with programmable microprocessor controllers.

References:

[1] A. B. Kuvaldin, M. Ya. Pogrebisskii, and M. A. Fedin, “Calculation of the Thermal and Electrical Characteristics of Induction Crucible Mixers,” *Elektrometallurgiya*, No. 12, 18–26 (2007).