UDC 519.2(075)

FEATURES OF MODELLING DYNAMICS FOR HEATING PROCESSES OF CYLINDRICAL CAST IRON PRODUCTS IN GAS OVENS

I.G. Gulina, A.A. Martynenko, O.I. Simonenko
(Ukraine, Dnipro, National Mining University)

Formulation of the problem. The process of heating the billets of rolling mills from cast iron in gas heating ovens (both in covalent and casting floors) has clear requirements for temperature heating regimes.

Compliance with the requirements of technology is possible with the use of automatic control devices. Programmable logic controllers are commonly used as a temperature control device. Correct operation of automation is possible because of a definite model of the heating process dynamics.

The purpose of this work is to select a rational structure of the model for the heating process dynamics, taking into account existing control systems of the heating furnace. In the end of the work, we determine the requirements for temperature measurement devices as regulated quantities.

Presentation of research materials. To determine the mathematical model of the heat treatment process of a roll in a chamber furnace with gas heating in the form of a transfer function, it is necessary to determine the influence that we will use as the input. Chamber furnace has 18 gas burners, each of which has a capacity of 190 kW. The burner system is equipped with all necessary combustion control devices, control systems that control all necessary parameters. It is expedient to regulate the temperature by changing the task of the burner capacity brought to the furnace. Considering that, the burner control system linearizes the static characteristic of the system "task - thermal power of gas burners". The generalized structure of the control object has the following form:

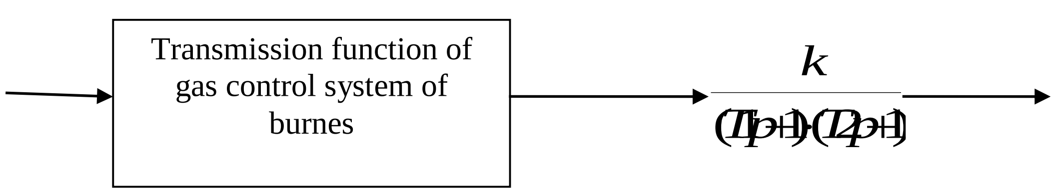

Fig. 1. Simplified structure of the control object model

The control of the heat treatment process of rolls is carried out using the number of control systems, one of which is the gas burner control system. Control system functions are as follows:

- the temperature of the exhaust gases

- signaling the normal operation of each burner
- alarm signal for each burner
- pressure/dilution in the furnace space
- gas pressure in front of the burners
- air pressure in front of the burners
- display the operation of the smoke exhaust and fan

Also using the system:

- impulse control of gas burners
- smooth or step-by-step regulation of burner power
- frequency controlled fan motors and smoke exhausters
- heating/cooling the furnace according to the heat treatment
- control of the density of gas valves on the gas supply to the furnace
- control of the minimum and maximum gas pressure

The gas oven is equipped with a complete set of sensors that control all important parameters such as:

- temperature,
- gas consumption,
- temperature and flow of heated air,
- completeness of combustion of fuel.

The system for controlling the power of gas burners is included into the control curve of the roller temperature. Since this system is modern and digital, it normalizes all nonlinear properties of used sensors and control valves. Therefore, the transfer function of this system can be defined as an ideal enhancement link. The inertia of heat transfer processes in the considered roller does not take into account the inertia of relatively fast-acting sensors and actuators that provide control over the operation of the furnace.

The coefficient of enhancement of the transfer function of the heating process of a roll in a chamber furnace should be determined as the ratio of the temperature of the roll to the power supplied to the furnace by gas burners. In total, the chamber furnace provides a power of 3420 kW. The transmission coefficient will have a dimension ºC/kW and its value is 0.292 ºC/kW.

The gas burner control system allows you to use different control methods, we can supply the input of the microprocessor system as the relative power values (for example, in percentages) and the numerical temperature values that meet the requirements of the technological process. For modeling and calculation for a gas burner control system, the transmittance ratio of kW/ºC. Then its value is 3.42 kW/ºC. The resultant gain $K = 1$.

The heating of the casting to a temperature of 1000 ° C at a nominal burner capacity is 33 hours. The heating rate is 7°C/hour. However, the temperature control zone is in the range of approximately 100-900°C. Within these limits, the dependence of the casting temperature on time is practically linear [1].

This heating process is characterized by the fact that the heat flux density, starting from zero, increases by a convex curve and asymptotically approaches its limit value:

$$q^{\infty}_{surf} = \frac{C_{hs} \cdot R \cdot \rho \cdot C}{K_1}, \tag{1}$$

where C_{hs} - heating speed, K/hour; R - radius of heated body, m;
ρ - material density, kg / m^3; C - Specific heat capacity, J / (kg K);
K1 - coefficient of body shape.
The upper index q^{∞}_{surf} shows that this value is achieved when $\tau \rightarrow \infty$.

For technical calculations with an accuracy of 1%, it can be assumed that the heat flux density reaches its limit value q^{∞}_{surf} for the time interval τ^* and then the heating occurs under the condition q^{∞}_{surf} = const.

$$C_{hs} = \frac{dt_{surf}}{d\tau} = \frac{q_{surf} - q_{T;X=R}}{dx\,\rho\,C} \tag{2}$$

where q_{surf} - the density of the heat flux on the surface of the heated body;
$q_{T;X=R}$ - the density of the heat flowing through the thermal conductivity from the surface layer inside the body; dx - thickness of the surface layer;
ρC - specific volumetric heat capacity of a body substance.

In the initial period of heating, $q_{T;X=R}$ = 0, the heat is concentrated from the outside in a surface layer of thickness dx and, since the C_{hs} is the finite value, then, the density of the heat flowing from the furnace to the surface must be infinite [2].

We accept F_o=1, because the heated product is a cylinder. Determine the coefficient of temperature conductivity:

$$a = \frac{\lambda}{\rho C} = \frac{23}{[illegible]} = [illegible] \tag{3}$$

Time to return to the constant heat flux density:

$$\tau = \frac{R^2 \cdot F_o}{a} = 5\ ho \tag{4}$$

The surface temperature at the end of the first period is determined from the formula:

$$t_{surf} = t_0 + C_{hs}\,\tau = 20 + 30\ 5 = 170\ °C. \tag{5}$$

The density of the heat flow, starting from 170 ºC, stabilizes and determines the linear dependence of the heating temperature from the power supplied to the furnace. At the initial and final heating stage, there is a certain nonlinearity of the dependence, but it can be offset by the organization of the system of control of the temperature of the roll on the principle of control for the deviations of the controlled value. The roots of the characteristic equation of the second order transfer function are valid, and we can bring the transfer function to the form (6).

In this case, the time constant T1= 5357 s^{-1}, and T2 = 19800 s^{-1}

$$W(p) = \frac{k}{(T_1 p + 1)(T_2 p + 1)} \tag{6}$$

The implementation of the furnace temperature control algorithm requires the use of a typical PID control law. Given that the process of regulation is quite long, then the control device can be used to perform additional control or control functions, which uses the capabilities of multitasking [3].

For example, the problem of the effectiveness of control in the framework of the creation of a system of automation can be solved by means of predicting the values of technological variables for their obtained in the past values [4].

Conclusion. Development of the model of the process of heat treatment of large-sized castings in gas ovens should take into account: existing on the object of control and automation system; the temperature control zone is within the stable heat flux density; model parameters are mainly determined by the diameter of the casting.

REFERENCES:

1. Румянцев В. Д. Теория тепло- и массообмена: Учебное пособие / В. Д. Румянцев. – Днепропетровск: Пороги, 2006. – 532 с.

2. Похилько А.С. Румянцев В.Д. Расчет нагрева метала в камерной печи с выдвижным подом, при условии постоянства изменения скорости нагрева на поверхности тела (Снп = const). Металлургическая теплотехника. Выпуск 2 (17), 2010, с.165-170.

3. І.А. Шедловський Реалізація дискретної системи автоматичного керування обладнанням пункту пропуску автотранспорту з використанням механізму багатозадачності ПЛК. Проблеми використання інформаційних технологій в освіті, науці та промисловості: XII міжнар. конф.: зб. наук. пр./ Нац. гірн. ун-т.-Дніпро: НГУ, 2017.-№2.-с.83-86

4. І.Г. Гуліна, І.М. Удовик, А.А. Мартиненко Інтелектуальна оцінка стану об’єктів керування на основі прогнозуючих фільтрів. Проблеми використання інформаційних технологій в освіті, науці та промисловості: XII міжнар. конф.: зб. наук. пр./ Нац. гірн. ун-т.-Дніпро: НГУ, 2017- №2- с.55-57