UDC 685.5.011

V.Yu. Zinchenko, associate professor, c.t.s.
Yu.M. Pazyuk, associate professor, c.t.s.
I.A. Ovchinnikova, associate professor, c.t.s.

TO OPTIMIZATION OF TEMPERATURE CONDITIONS AFTER FORCING THERMAL WORK OF CHAMBER HEATING FURNACES

Zaporozhe state engineering academy, Ukraine

There are considered structure diagrams of control system by the processes of heating of metal at forcing of thermal work for chamber heater furnaces. There are presented optimal temperature regimes of the forced heating thermal thin and thermal massive bodies.

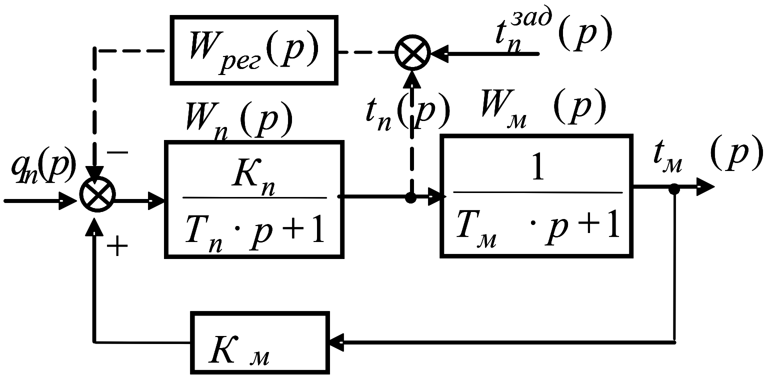
Keywords: chamber heating furnace, forcing of heat work, system of controlling, temperature regime of heating, optimization

Introduction. The necessity of forcing of thermal work for heater furnaces takes place at their operative controlling for the concordance of work, both between them and with other technological equipment. At the speed modes of heating the productivity of thermal aggregates rises, goes down scaling of metal and its decarbonating. However the specific expense of fuel increases here, and rise demands to precision of providing of the set temperature regimes of heating, and also quality of the heated metal.

From position of controlling theory the speed heating behaves to the tasks of optimal performance and decides by the methods of mathematical optimization, in particular, with the use of principle of maximum [1] on the basis of mathematical models of dynamics of the system as differential equations.

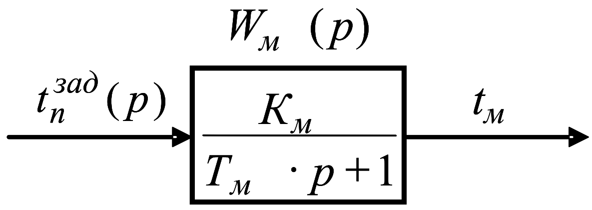
Coming from that chamber heater furnaces mainly are aggregates with the concentrated admission of thermal power and backing-off of products of burning, a controlling of their work is carried out by the change of the thermal burden depending on a temperature, measurable in one (rarer in a few points) working space. The dynamics of metal heating can present as the concentrated model, shown on a fig. 1.a.

At the corresponding choice of law of adjusting and adjustment of regulator on practice, as a rule, satisfactory accordance of the set temperature in the furnace is provided to its fact size, id est. $t_n^{зад}(p) = t_n(p)$. Neglect the dynamics of transitional processes in the system of adjusting of temperature, the structure of the system can be substantially simplified, bringing its over to the kind, shown on a fig. 1,b.



a

$q_n(p)$, $t_n^{зад}(p)$, $t_м(p)$, $t_n(p)$ are parameters of tricked power, task of temperature of furnace, metal and warming gases according



b

Figure 1 - Structure diagram of controlling by heating of metal in a furnace

According to the chosen structure, a temperature regime, as temporal function of temperature of furnace $t_n(p)$, fully determines the eventual temperature of the heated metal $t_м(p)$.

Problem formulation. Be task of this work is study of chamber hear furnaces as object of controlling from position of theory for optimal system/

Basic part of researches. There is examined a task of heating thermal thin body the dynamics of which is described by linear differential equation with permanent coefficients. Neglect the inheritance of warming environment, the transmission function of object $W_{об}(p)$ looks like

$$W_{об}(p) = \frac{t_м(p)}{t_n(p)} = \frac{C_1 \cdot p + C_0}{a_2 \cdot p^2 + a_1 \cdot p + a_0}\ , \qquad (1)$$

where $C_1 = T_{кл}$; $C_0 = K_n$; $a_2 = T_{кл} \cdot T_м \cdot (1 - K_м)$; $a_1 = T_м \cdot (1 - K_{кл}) + T_{кл} \cdot (1 - K_м)$; $a_0 = 1 - (K_м - K_{кл})$.

This function can be rewritten as

$$W_{об}(p) = \frac{K \cdot (T_3 p + 1)}{T_1 \cdot T_2 \cdot p^2 + (T_1 + T_2) \cdot p + 1}\ , \qquad (2)$$

where T_1, T_2 are polynomial roots of denominator for function (1), T_3 is polynomial root of its numerator; K is a coefficient of transitivity, $K = C_0 / a_0$.

The presence of operator p in the numerator of function (1) is hampered application of maximum principle, because the decision of right part of equation suffers breaks, and maximum principle is applicable for a continuous function. At the analogical classic tasks of optimization this obstacle is overcame by a transition from the real object to fictitious one, formed by two multiplied links with continuous output sizes $Y_1(p)$ and $Y_2(p)$ [2].

According to the accepted presentation of object

$$t_м(p) = Y_1(p) + Y_2(p) \qquad (3)$$

in the set regime we have

$$t_м^{кін} = t_n^{кін} \cdot (K_1 + K_2) \qquad (4)$$

where $t_м^{кін}$, $t_п^{кін}$ is an eventual temperature of metal and furnace accordingly.

In such problem formulation of optimization is decided with the use of maximum principle. Then control influence on the first area of controlling U_1 will be a relay, and it is described by equation

$$U_1 = \left|t_п^{\max}\right| \cdot \operatorname{sign}\left(t_м^{кін} - t_м\right) , \tag{5}$$

id est. we will realize one interval of controlling.

On the second area of controlling control influence U_2 can be defined as [2]:

$$U_2(p) = U_1(p) \cdot \frac{T_1 - T_2}{T_3 \cdot p + 1} , \tag{6}$$

Then, applying reverse transformation of Laplace, we get

$$U_2(f) = U_1(f) \cdot \frac{T_1 - T_2}{T_3} \cdot \exp\left(-\frac{\tau}{T}\right) , \tag{7}$$

Consequently, after achievement of a parameter $t_м(\tau)$ calculation value control influence must be diminished on exponential dependence from the thermal capacity of feting of furnace, characterized by a parameter T_3.

The optimal chart for change of temperature of warming gases depends on numeral values K_1, K_2, T_1, T_2 and T_3, however the type of controlling remains general for objects, containing a derivative from control influence (fig. 2).

Change of controlling $U_1 = \left|t_п^{\max}\right|$ takes place at reaching the temperature of metal to certain calculation size $t_м^{розр}$ in moment $\tau_{пер}$, determined from the decision of differential equation, corresponding to the transmission function (2).

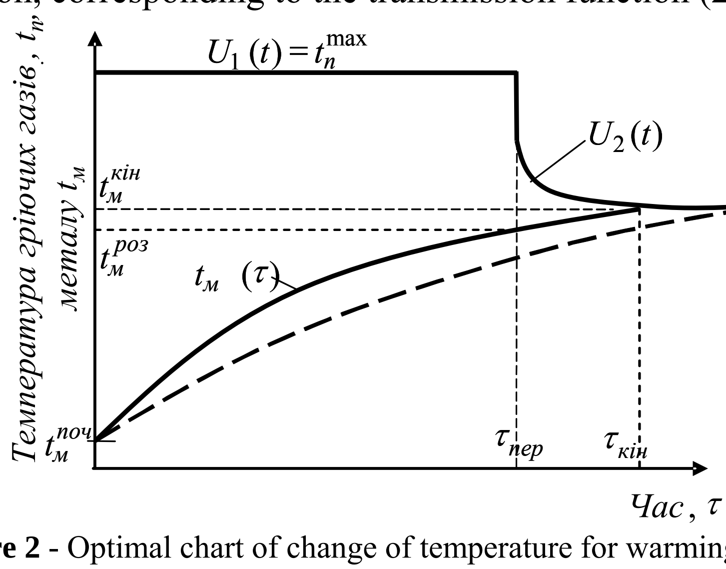


Figure 2 - Optimal chart of change of temperature for warming gases and temperature of metal

Because a decision (7) appears by transcendent equation, then analytical determination of temperature $t_м^{розр}$ and $\tau_{пер}$ is impossible and defining of their required sizes is possible only by graphic or numeral methods.

During practical realization of such algorithm overshoot is possible, that reduces controlling efficiency. In this connection apply the chart of heating at the stationary set temperature of warming gases (shown on a fig. 3 by the dotted line, corresponding $t_n^{зад} = t_м^{кін}$) or two-stage chart with the anticipatory change of controlling is a continuous line $t_n(\tau)$. Such two-stage algorithm is near to optimal and it's simpler to realize.

Coming from that the process of heating of metal flows with absorption of warmth from working space of furnace and compensated at automatic control of temperature due to the tricked thermal power, we determine dependence of thermal power in time from the temperature of metal.

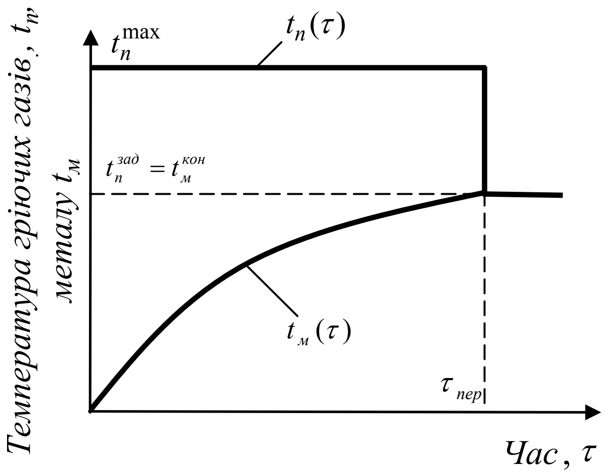


Figure 3 - Temperature regime of the forced heating of metal

Accepting, that relation

$$\frac{W_{екв}(p)\cdot W_{рег}(p)}{1+W_{екв}(p)\cdot W_{рег}(p)} = \frac{t_n(p)}{q_n(p)} = 1 \ , \tag{8}$$

from a flow diagram (fig. 1) the transmission function of the closed system on a channel $q_n(p) - t_n(p)$ we get in a kind

$$q_n(p) = \frac{W_{рег}(p)}{W_м(p)} \cdot t(p) \ , \tag{9}$$

Thus, neglect the inertance of regulator in the closed systems of automatic control of temperature furnace, a function $t_м(\tau)$ fully characterizes the accumulation of warmth in the heated metal. After reaching equality of temperature in furnaces t_n and temperatures of metal $t_м$ the thermal burden of furnace is expended only on indemnification of losses of its lost motion. Consequently, the moment of completion of period of heating of metal can be fixed on the moment of stabilizing of the thermal burden at minimum level.

Temperature charts of heating thermal massive bodies, at least are two-stage: have a period of heating (first) and period of isothermal equalizing (second) [3], thus reduction of duration of the first period of heating is accompanied by lengthening of its second period.

According to Fourier law, the transfer of warmth in a metal is determined by not only ifs thermophysical properties but also size of temperature gradient in its. At the forced heating the temperature of surface of metal rises, gradient of temperatures and also speed of distribution of warmth increase.

The dynamics of change of temperature on the thickness of metal is described by differential equation in partials (equation of heat conductivity) and residual-differential equation. The tasks of optimization of heating of massive bodies behave to the class of tasks of optimization of the systems with the dispersed parameters. At the existent charts of heating of chamber heater furnaces a controlling is carried out on information about a temperature in a furnace. In this connection approximation of the system with the up-dispersed parameters by the system with the concentrated parameters is possible, in which the heated metal is presented as quantity of the consistently included aperiodic links of first order, characterized by permanent to time of heating of elementary layer. This structure corresponds to the mathematical model, described in work [4], when the heated body is presented as n layers with the concentrated parameters, that corresponds to the engineering model of distribution of warmth, offered by Semikin [5]. At heating of massive body there is the successive activation in heating of the conditionally distinguished layers. Distribution of thermal streams and temperature in a body at any moment of time depends from character of distribution of superficial thermal stream in a period, proceeding to the examined moment of time. Time of delay of heating of middle of body determines the inertance of body.

Such model is described by usual differential equations of second order, for which the theory of optimal processes is enough worked out. For these systems there is optimal on a performance and besides only decision of equation, transferring the system from one (initial) state in other (eventual).

What anymore quantity of layers on which break up the heated body, the more so exactly close equations describe the real transitional process. In such presentation of model of heating the task of optimization becomes classic.

According to a theorem about n intervals [6], an optimal controlling will be a relay with n intervals, id est. a temperature in a furnace must *n* one times step to change from $t_n^{\max}$ to $t_n^{\min}$ or vice versa. At such controlling the brief overheats of surface of metal (within the limits of possible size) are possible, however due to a temperature gradient into a body conditions for more rapid smoothing of temperature on the thickness of body are created.

Imposing restriction on the maximum temperature of surface of the heated metal $t_{пов}^{\max}$ and speed of its heating $C_{\max}$, according to a theorem about n intervals, increases the necessary quantity of controlling intervals. On the other hand, at heating of massive bodies, when general duration of heating makes a few hours, duration of transitional processes in a furnace, at the change of temperature in its working space from a minimum size to maximal and back, any far less interval of optimal controlling. It is set [7,8], that first two-three intervals of adjusting make basic part of optimal process of controlling.

By the result of heating for this time, because of eventual speed of distribution of warmth in a massive body, the even warming up of body serves. What more thermal is massive body, the slower a warmth from his surface to the middle spreads and the anymore required controlling intervals. First two-three controlling intervals create temperature gradients for the further independent smoothing of temperature of metal, and subsequent intervals provide even distribution of temperature near by its surface.

At presence of limitations for massive bodies the first two-three intervals can be insufficient for the receipt of satisfactory quality of heating presence of, id est. it is required to enter additional intervals.

On a fig. 4 there is shown optimal temperature chart of heating thermal massive body at laying out on two thermal thin layers and presence of limitation on the temperature of surface $t_{пов}^{max}$ and speed of heating C_{max}. Apparently, a controlling t_n has four levels of constancy, and change must be executed in moments τ_{n_1}, τ_{n_2}, τ_{n_3}.

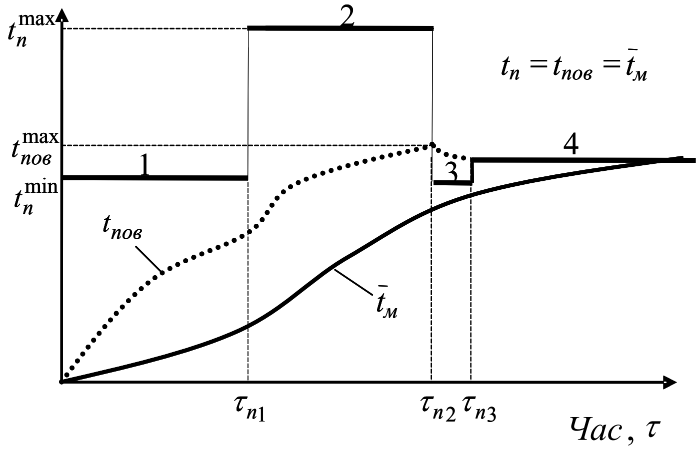


Figure 4 - Temperature chart of the forced heating of metal

The modern theory of the optimal systems with the dispersed parameters clearly determines the temporal function of control influence; however it not determines the necessary quantity of controlling intervals and change moments strictly. Change moments are determined depending on the accepted mathematical model of heating (equations of heat conductivity), so, in work [9] the series of nomograms are offered for the calculations of change moments of control influences.

Conclusions. The chamber heater furnaces as controlling object can be presented as in kind of aperiodic links of first order, in the drip by positive backcouplings, which is determined by correlation of heat transfer to the heated metal and losses of warmth with products of burning, and also through feting of furnace, and changes during heating. At condition of equality of thermal streams to feting of furnace and metal the system «warming gases - feting of furnace - metal» can become astatic, id est. in the set regime dependence disappears between arrival of warmth, temperature of gas environment in a furnace and temperature of metal.

REFERENCES

1. **Кузин, Л. Т.** Основы кибернетики [Текст] : учеб. пособие / Л. Т. Кузин. – М. : Энергия, 1973. – 584 с. – Библиогр.: с. 574-576. – 27000 экз.
2. **Олейников, В. А.** Основы оптимального и экстремального управления [Текст] / В. А. Олейников. – М. : Высшая школа, 1969. – 296 с. – Библиогр.: с. 293-294. – 11000 экз.
3. **Климовицкий, М. Д.** Оптимизация работы нагревательных печей [Текст] / М. Д. Климовицкий. – М. : Металлургия, 1965. – 164 с. – Библиогр.: с. 161-163. – 1990 экз.
4. **Малый, С. А.** Некоторые оптимальные режимы нагрева металла [Текст] / С. А. Малый // Известия вузов. Черная металлургия. – 1966. – № 9. – С. 175-179. – Библиогр.: с. 179.
5. **Бутковский, А. Г.** Теория оптимального управления системами с распределенными параметрами [Текст] / А. Г. Бутковский. – М. : Наука, 1965. – 474 с. – Библиогр.: с. 467-474. – 8000 экз.

6. **Свинолобов, Н. П.** Инженерная модель в теории теплопроводности в трактовке И.Д. Семикина [Текст] / Н. П. Свинолобов // Металлургическая теплотехника : сб. научн. трудов государственной металлургической академии Украины. – 1999. – Т. 2. – С. 226-235. – Библиогр.: с. 235.
7. **Фельдбаум, А. А.** Основы теории оптимальных автоматических систем [Текст] / А. А. Фельдбаум. – М. : Наука, 1966. – 623 с. – Библиогр.: с. 594-618. – 13000 экз.
8. **Маковский, В. А.** Алгоритмы управления нагревательными печами [Текст] / В. А. Маковский, А. А. Лаврентик. – М. : Металлургия, 1977. – 183 с. – Библиогр.: с. 182-183. – 2300 экз.
9. **Бутковский, А. Г.** Методы управления системами с распределенными параметрами [Текст] / А. Г. Бутковский. – М. : Наука, 1975. – 568 с. – Библиогр.: с. 548-565. – 6000 экз.
10. **Ревун, М. П.** Адаптивные системы управления процессами нагрева металла [Текст] / М. П. Ревун, А. К. Соколов. – Запорожье : ЗГИА, 1998. – 352 с. – Библиогр.: с. 346-351. – 300 экз.