G. SHLOMCHAK, G. SHVACHYCH, B. MOROZ, E. FEDOROV, D. KOZENKOV

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AUTOMATED CONTROL OF TEMPERATURE REGIMES OF ALLOYED STEEL PRODUCTS BASED ON MULTIPROCESSORS COMPUTING SYSTEMS

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Development features and use of multiprocessor computing system with its mathematical support and software for heat treatment modes simulation of metal billets are considered. The application of modern multiprocessor computing technologies is proposed for increasing the speed and efficiency of computation, which enables to effectively control technological processes. Through the special software the multiprocessor system is able to set and control necessary temperature conditions on all plane of cross-sectional of standard at heating and self-control of metal, and if necessary maybe began to control the thermal mode of treatment in the interval of temperatures of annealing.

Key words: alloyed steel products, heat treatment, automated control, technological parameters, multiprocessor computing system.

INTRODUCTION

Over the last few decades, increasing attention has been paid to the spheroidization processes of the carbide phase with the granular perlite structure, which is considered to be an alternative to long-lasting traditional processes of spheroidizing annealing of a steel billet. These include methods and technologies for combining various types of spheroidizing treatments of metal products [1, 2]. Significant reduction in the duration of spheroidizing annealing is achieved by electroheat treatment of a steel billet [3].

However, high-speed heat treatment processes (HT) require further research, first of all, to control the basic technological parameters for their optimization.

However, both improvement of existing and creation of new technological processes of metal HT require significant costs for conducting a large number of field experiments in laboratory, experimental and industrial equipment, as well as production conditions. Therefore, there is a need to research high-speed modes of steel for development of automated control system of technological parameters of process using computer programs and mathematical simulations.

At the same time, solution of these problems by known standard approaches is a complex problem, where overcoming is only possible via modern multiprocessor computing technology. At the same time, one of the main features of such technologies application is to increase the speed and performance of the computattions. High performance computing allows solving multidimensional problems, as well as the problems that require a large amount of processor time. Speed control allows controling the technological parameters in real-time and, therefore, effectively control technological processes.

These paper developments are different at the point that those focuse on multiprocessor computing systems use. It should be noted that today in the world there is a rapid increase in the number of multiprocessor computing systems and their total productivity. This is due to the fact that such systems have become publicly available and cheap hardware platforms for high-performance computing. Thus, the development and use of multiprocessor computing systems with the mathematical support and software is an actual problem that allows obtaining necessary information for creation and implementation of various technological innovations.

RESEARCH PROBLEM STATEMENT

The problem of the automation system development to control the technological process parameters of high-speed HT of a long product is considered in the paper by use of a multiprocessor computing system [4, 5]. The application of the automated control system for the technological process parameters of the product heat treatment is aimed at improving technological properties of a billet by ensuring a high dispersion and homogeneity of the sample structure in the entire cross-section area. At the same time, the technological process

G. Shlomchak, (e-mail: shlomchak@i.ua),
G. Shvachych, D. Kozenkov, National Metallurgical Academy of Ukraine, Dnipro, Ukraine, B. Moroz, University of Technology, Dnipro, Ukraine, E. Fedorov
Cherkasy State Technological University, Cherkasy, Ukraine

should acquire such advantages as high efficiency, reduced power consumption, and improved performance. The specified properties of technological process are obtained by a multiprocessor computing system. The multiprocessor computing system is mounted as a separate module and special software allows setting and controlling the necessary temperature regimes in the entire cross-section area of a sample while heating and stretching.

PRESENTATION OF THE MAIN RESEARCH MATERIAL

The HT installation of a long steel product [6] was developed to solve the above-stated problems. Figure 1 shows the contours block diagram of the automated control system for the HT installation of a long steel product, where the following notation is taken: MPCS - multiprocessor computing system; EM EM - executive mechanism of extending mechanism; EM ITHU - executive mechanisms of isothermal temperature holding units; EM CDU - executive mechanism of the coling-down unit; EM HU is the executive mechanism of the heating unit of billet. Such a control system has the units that allow obtaining the information about current parameters of the managed processes. Its peculiarity is in the fact that at each of the five stages of the sample technological processing, the two-dimensional heat conduction problem is solved. In this case, the MPCS software allows controlling the temperature regimes, as in the entire cross-section area of a sample, and along its length. Control of such temperature regimes is carried out in the center of the cross-section area of a sample.

MPCS with special software, as a single base, includes mathematical simulations as a heat conduction equation, that is,

$$\frac{\partial T}{\partial \tau}=\frac{\partial^2 T}{\partial z^2}+\frac{\partial^2 T}{\partial r^2}+\frac{1}{r}\cdot\frac{\partial T}{\partial r}+W \quad (1)$$

with the Fourier criterion $\tau=\frac{at}{R^2}$, if $\tau>0$, W is specific power as heat sources, W / m^2.

The equation boundary conditions are as follows:

$$T(0,r,z)=f(r,\tau);$$
$$T(\tau,1,z)=var;$$
$$\frac{\partial T(\tau,0,z)}{\partial r}=0;$$
$$T(\tau,0,z)\neq 0$$

The last two correlations in the boundary conditions indicate that the temperature value in the area of the cylinder axis during the entire heat transfer process must be finite. According to the z coordinate the boundary conditions, depending on the features of the solvable problem, can be of the first, second or third kind. By solving the problem (1) by splitting methods that reduce the molecular operator (1) to the simplest one. This approach allows integration of this equation as an integration sequence of one-dimensional equations of a simpler structure. With regards to the significant complexity of the mathematical simulation (1), the economic algorithms development for the control functions effects calculation of the proposed installation becomes of great importance. Consider the process of creating such algorithms by constructing the equation (1) splitting schemes. At the descriptive level, the idea of constructing splitting schemes along the length and radius of a sample can be described as follows.

The differential problem formulated by the expression (1) is given as:

$$\frac{\partial T}{\partial \tau}=A\cdot f, \quad (2)$$

wherein A is a certain operator of spatial variables, for instance:

$$Af=\frac{\partial^2 T}{\partial z^2}+\frac{\partial^2 T}{\partial r^2}\,. \quad (3)$$

Valuations $f(z, r, t_p)$ for already known values $f(z, r, t_{p-1})$, if $t_p = p \cdot Dt1$ ($Dt1 = (t_p - t_{p-1})$), is the distance between grid nodes at a given time interval (p = 1,2,3,... - node numbers), which can be expressed by the formula:

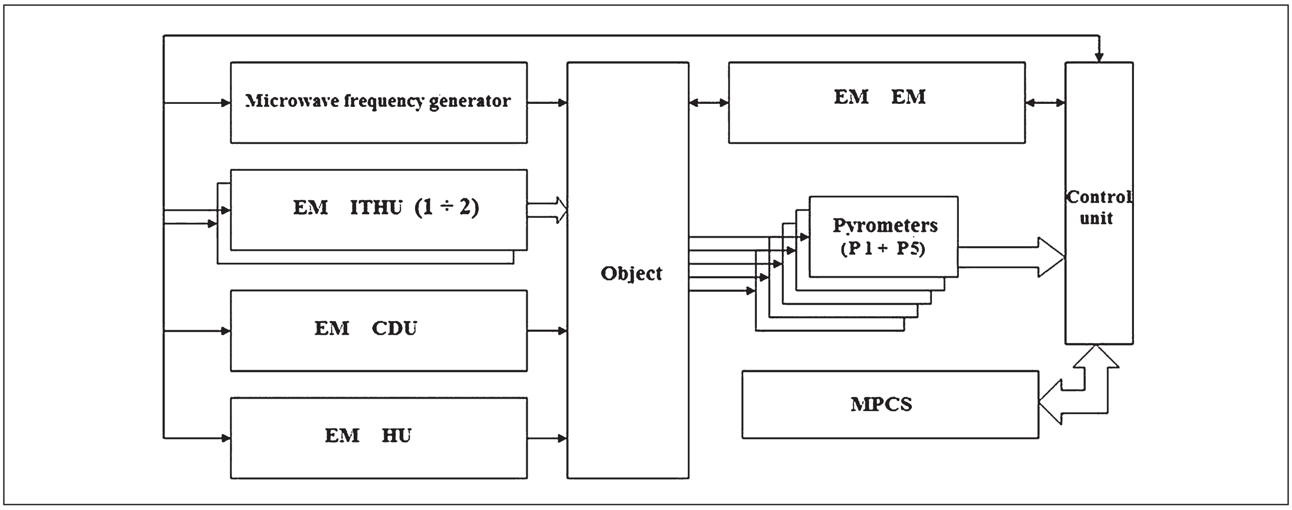


Figure 1 The contours block diagram of the automated control parameters of the technological process

$$f(z,r,t_{p-1}+Dt1)=$$
$$f(z,r,t_{p-1})+Dt1\frac{\partial f}{dt}+O(Dt1^2)\equiv$$
$$\equiv(E+Dt1\cdot A)f(z,r,t_{p-1})+O(Dt1^2)$$

wherein E is a unity operator.

Present the equation (3) right part as follows:

$$Af = A_1f + A_2f.$$

Then it will be rewritten as follows:

$$\frac{\partial T}{\partial \tau} = A_1 f + A_2 f \tag{4}$$

This equation allows splitting into the following two equations:

$$\left.\begin{array}{l}\dfrac{\partial \nu}{\partial \tau} = A_1\nu, \quad t_{p-1}\le t\le t_p, \\ \nu(z,r,t_{p-1}) = f(z,r,t_{p-1}),\end{array}\right\}, \tag{5}$$

$$\left.\begin{array}{l}\dfrac{\partial w}{\partial t} = A_2 w, \quad t_{p-1}\le t\le t_p, \\ w(z,r,t_{p-1}) = \nu(z,r,t_p).\end{array}\right\}. \tag{6}$$

Note that

$$w(z,r,t_p)\equiv f(z,r,t_{p-1})+O(Dt1^2)\,. \tag{7}$$

Equality (7) provides a basis for each time interval, when $t_{p-1} \le t \le t_p$, instead of equation (2), sequentially solve (5) and (6).

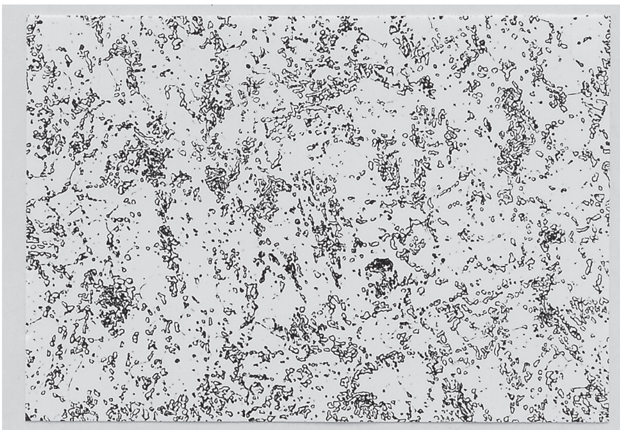
For practical solutions of equations (5) and (6) we formally approximate them with any difference schemes. Then there is already some difference scheme splitting that allows in two stages to compute the function value $f(z, r, t_p)$ by already known value $f(z, r, t_{p-1})$.

EXPERIMENTAL RESEARCH

Several experiments were carried out to test the functions of the proposed installation, with a 20 mm diameter wire from the boron steel grade 20G2P was subjected to the HT. The HT mode was carried out by heating the billets within the intercritical temperature zone. For the given material the following critical points values are set: Ac_1 = 725 °C; Ac_3 = 795 °C. The heating was made to the following value: Ac_1 + (10 – 30 °C). The next processing stage was isothermal holding for 45 seconds. Then followed the steel cooling at a speed of 20 – 30 °C per second to a temperature of 620 °C followed by an isothermal heat holding for 45 seconds. Finally, at the last treatment stage, the sample was heated at a speed of 15 – 25 °C per second to subcritical temperatures.

Consider one of them. During the experiment the obtained curves of the temperature transfer of the sample along the length and area of its cross-section. Simulation of such temperature fields is carried out taking into account the change in the thermophysical properties of the material during its heating.

a)



b)

Figure 2 Microstructure of boron steel grade 20G2P:
a - initial ferrite-beinite (martensitic) structure, x 500;
b - structure after annealing - granite perlite (point 2), x500

During the experiment, the structure formation in the sample material was analyzed. In Figure 2,a and the initial ferrite-bainite (martensitic) metal structure is depicted. The final form of the material structure after spheroidization is given in Figure 2, b. The structure is perlite granular with a standard estimate of 2 points, its hardness is 148 - 169 HB.

Consequently, the spheroidization of the billet in the conditions of the corresponding HT modes provides the granular perlite material structure. Moreover, high-speed spheroidization causes a more even distribution of globules of cementite in a ferrite matrix (Figure 2, b). Samples from steel of almost identical hardness after the HT have a fine-grained structure that ensures a higher level of metal ductility. Due to the rapid heating of the sample and incomplete steel austenitization, certain changes occur in the carbide phase morphology from the lamellar to the fine-grained globular.

CONCLUSION

The scientific novelty of the conducted researches is that on the basis of multiprocessor computing complex there was created an automated control system of the HT temperature regimes of the steel product in real time for the purpose of recrystallization and spheroidizing annealing of calibrated steel. The proposed approach allows controlling the technological parameters of the metal HT, in particular the temperature at the section center of the billet, which provides the material with necessary properties, both in the entire cross-section area and along the sample length.

The practical value of the results obtained is that it was managed to improve the technological process of the metal HT by appropriate mathematical simulations and a set of programs. The application of mathematical simulations processed by a multiprocessor computing system allows controlling the metal temperature field while heating, holding and cooling, and thus it provides a rapid adaptation of the metal products production to the consumer requirements.

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Note: The responsible for English language is V.V. Busygin, Dnipro, Ukraine