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PROGRAMMING DETERMINATION OF THE STATE OF THE ELECTRIC THERMAL DEVICE FOR THE SYNTHESIS OF MICRO- AND NANOSTRUCTURAL COMPOSITE MATERIALS

Software-hardware complexes, intended for the synthesis of micro- and nanostructural composite materials as far as the control of energy release of electric thermal devices is concerned, refer to the control engineering and temperature regulation, applying electric means. The importance of the provision of rapid and efficient support of the computer-based diagnostics of the state and control of the energy release of the electric thermal devices of the software-hardware complexes in various energy conditions leads to the necessity of the determination of the set of the parameters which would comprehensively characterize instantaneous state of the electric thermal device at random moment of time as well as the set of the information factors, measured by means of the computer for fluctuating calculation of the parameters, determined on their base. The ratio of the instantaneous value of the thermally-dependent resistance of the electric heater to the internal resistance of the supply source is considered to be the determining parameter, regarding the formation of the range of the attainable values of the energy release and, as a result, the range of the attainable temperatures. To characterize the state of electric heater it is suggested to use the set of the instantaneous values of its relative values of thermal power and resistance. The set of the instantaneous values of these two parameters – electric voltages on the thermally- dependent resistance of the electric heater and on its serial connection with thermally-stabilized (reference) resistance is allocated as computer-registrated information factors for further computer-based determination of the electric heater state. The method of computer-based determination of the electric heater state exclusively on the base of the computer-based control of the supply source EMF and registration at the successive moments of time of simultaneously measured voltages on the thermally-dependent resistance of the electric heater and on its serial connection with thermostabilized resistance is suggested.

Key words: *electric thermal device, instantaneous state, software-hardware complex, micro- and nanocomposite.*

Introduction

It is known that the software-hardware complexes for the investigation of the metal composite synthesis technologies [1] and nanostructural composite materials as far as the control of energy release of the electric thermal devices is concerned [2] refer to the sphere of control engineering and temperature regulation, in particular to the means of the programming control of the object temperature according to the preset program. The intensities of the heat release in such computer-controlled electric thermal devices as heating plates for vacuum condensation of the materials, vacuum evaporators of the materials, anemometric measuring devices, heaters of the transporting gas and surface layers of the metalic tape prior the injection of the microparticles in its surface, etc., are technological factors, determining both the possibility itself and production efficiency of the synthesis of the nanostructural composite materials.

For the control of the thermal energy release by means of the electric thermal devices with the temperature feedback, regulation of power voltage pulses parameters (amplitude, duration, form) and their sequeneces (pulse-ratio modulation) is used, in a. c. circuit--- connection angle control, in d. c. circuit – voltage regulation [3]. In certain group of automatic temperature regulators the role of sensitive element of the electric thermal device performs directly heating element itself, the electric resistance of which is measured between the cycles of power supply [4]. The drawbacks of the electronic regulators include besides the necessity of supplying power to heating element during the time of its electric resistance measurement (for certain), also low flexibility relatively the formation of varing in time on-line control and registration of the accounting information mode, that would monitor the energy release.

For energy release monitoring it is expedient to determine the set of rapidly and simply measured parameters, using modern peripherial computing devices, which would characterize the instantaneous state of the diagnosed device. The base of the developed direction of electric thermal devices of the software –hardware complex state determination in the process of their operation is the principle of time combination of three operations – control of heating, determination of the values of the thermally-dependent resistance of the heater and the thermal power, dissipated by it.

Problem set-up

The necessity to provide the operation efficiency of the computer diagnostics of the state and control of energy release of the electric thermal devices of the developed hardware-software research complexes for the investigation and comparison of the productions of metal composite synthesis in various energy conditions leads to problem set-up regarding the determination of the set of parameters, which would characterise the instantaneous state of electric thermal device at a random moment of time as well as the set of the measured information factors for the calculation of the parameters, determined on their base.

Control of the state of electric thermal devices by changing the electric motive force of the supply source

Proceeding from the reproduction in the electric circuit of the electric thermal device the value of the electric motive force which is established and regulated by the signal of modern analog-to-digital converter (ADC), we will use it as the determining for all technological characteristics of this device in its stable(steady) states. We assume that the change of EMF value leads, after transient processes, to a new balance state of the thermal device with new complex of the values of its characteristics and to the reproduction of this complex of the characteristics when returning to the corresponding value of EMF. We assume the stability of the electric resistance while changing the values of the EMF of that part of the supply circuit of the electric thermal device that is not heated considerably.

In case of provision of stable EMF, operating in the closed circuit of serially connected R_T (electric resistance of the electric thermal device) and r (internal resistance of the supply source), their complete released power P (Fig. 1, line 2) , is inversely proportional to the sum of these resistances and the efficiency factor η that characterises the part of the complete power conversion P in thermal power P_T, released at the resistance R_T of the electric thermal device, non-linearly (Fig. 1, line 1) depends on the relation of the resistances $\frac{R_T}{r}$. This leads to the formation of maximum (this meets the requirement $R_T = r$) relatively the value of power P_T (Fig. 1, line 3) from the relation $\frac{R_T}{r}$.

Fig. 2 shows the calculation dependences of heating lines 7 – 15 and scattered by the similar by form band electric heaters of various electric resistance of the line 1 – 6 of powers P (rated for maximum), from the relation $\frac{R_T}{r}$. Lines 1 – 6 correspond to the following set of values of the relation $\frac{R_0}{r}$: 1 – 0,034, 2 – 0,075, 3 – 0,15, 4 – 0,3, 5 – 0,5, 6 – 0,75, where R_0 – is the value of the resistance of the electric heater at the initial temperature (prior the first connection of the current). Numbers 7 – 15 designate the dependences from the relation $\frac{R_T}{r}$ of the values of the heating powers P (rated for maximum), that correspond to the decrease of the electromotive force E of the supply source with the step of 1 V, starting from the maximum E = 11 V (line 7).

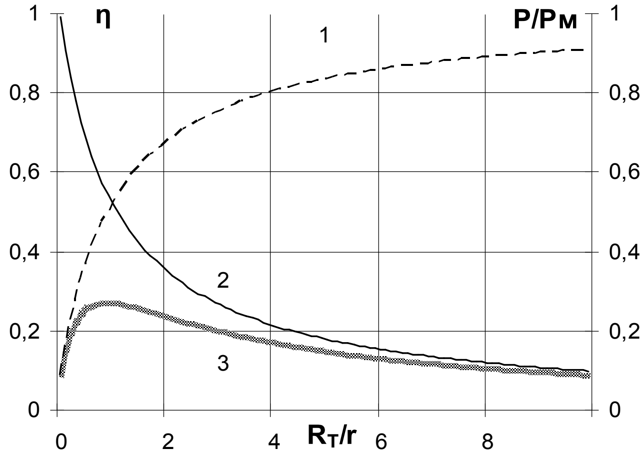

Fig. 1. Efficiency factor (1) and the character of the full (2) and useful (3) powers change (in relative coordinates calculated for certain values of e. m. f. and r) in the circuit of the electric heater, depending on the parameter $\frac{R_T}{r}$.

Graphs, shown in Fig. 2, illustrate the computational dependences of the thermal power, released mainly by radiation in stabilized states by the band electric heaters, made of the same material, which have almost similar geometrical dimensions and differ only by the thickness. Under the given conditions variations of the heaters thickness determine the variations of the initial (prior to heating) values of their resistances R_0 and corresponding starting values of $\frac{R_0}{r}$ parameter.

Instantaneous state of the electric heater at a random moment of time is characterized by the point on the field of the graph in Fig. 2 in the coordinates of the relative thermal power and relation of its resistance R_T to the internal resistance r of the supply source.

Taking into account the fact that in vacuum the thermal power is dissipated from the electric heater mainly by radiation from the surface (it is determined by Stefan-Baltzmann law with the account of the selectivity of the absorption capacity of the material) and heat removal across the contacts (determined by Fourier heat conductivity law), the dependence of the heat power, dissipated by same heater in the unchanged environment in the stabilized states is the temperature function. Type of this function and numerical values of the error, the mathematical model describes the stationary heat dissipation in the electric heater with, in general dependens both on constructive features of the active element of the electric heater (thickness, area of the surface, form) and the materials, surrounding it in the reaction chamber (availability, configuration and thermal physical properties of thermoinsulation, location, temperature and configuration of other thermal elements, etc.).

It follows from the dependences, shown in Fig. 2 and Fig. 3 that the relation of the output value of thermally-dependent resistance of the electric heater to the internal resistance of the supply source is a key parameters, which determines (for each pair current source – construction of electric thermal device) both the range of possible values of energy release, and, as a result, the range of the attainable temperatures. By matching of the values of the initial resistance (R_o) of the electric heater and the internal resistance (r) of the supply source, the control of the energy release range and its optimization is possible.

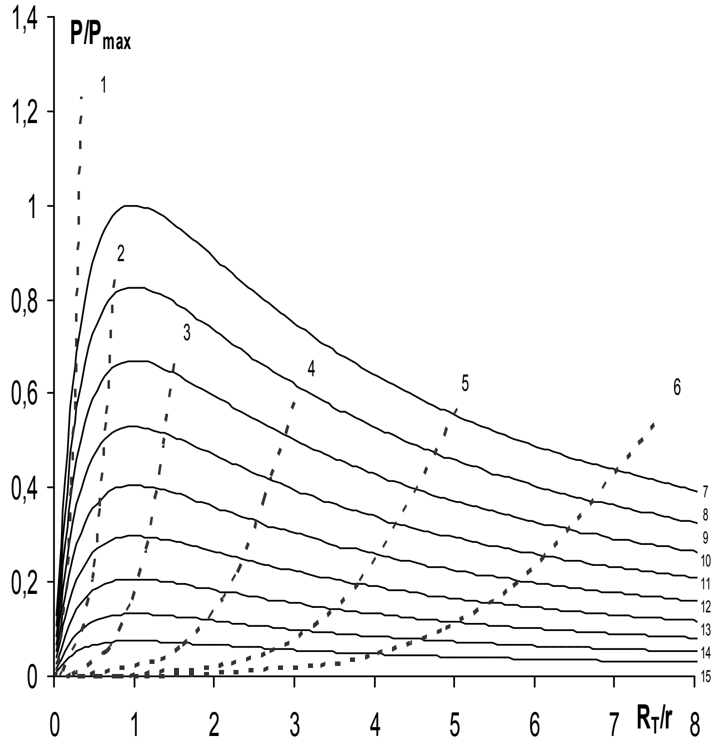

Fig. 2. Dependences of the heating lines 7 – 15 and dissipated by the siminar in form band electric heaters of different electric resistance of lines 1 – 6 of P powers (rated for maximum), on the relation $\frac{R_T}{r}$

Practical use of the parameter $\frac{R_T}{r}$ is complicated due to the necessity of determining by the independent previous measurements of the numerical values of the initial resistance of the electric heater and the internal resistance of the supply source for the calculation of the relation $\frac{R_0}{r}$, and also monitoring in the process of the operation of the electric thermal device the numerical values of the instable temperature of the electric heater, which (taking into account the temperature dependence of the resistance of its active element material) is necessary for the determination of the relation of the instable values of the electric heater resistance to the internal resistance of the supply source.

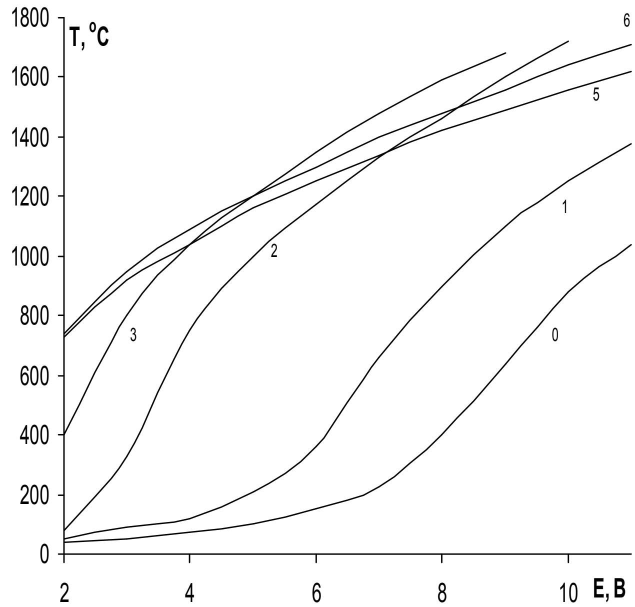

Fig. 3. Steady-state temperature of the electric heater depending on the value of EMF for a number of values of $\frac{R_0}{r}$ parameter (0 – 0,025, 1 – 0,034, 2 – 0,075, 3 – 0,15, 5 – 0,5, 6 – 0,75)

In the conection with the above-mentioned the task to simplify the process of determination of the instantaneous values of the electric heater resistance relation to the internal resistance of the supply source as a result of elimination of the necessity to use in the calculations the results of the independent previous measurements by other devices of the numerical values of the initial resistance R_0 of the electric heater, internal resistance r of the supply source and unstable numerical values of the electric heater temperature.

State of the electric thermal device and its program determination

For the on-line determination of the electric thermal device state , that can be characterized by the set of the relative power and the relation of the electric heater resistance to the internal resistance of the supply source (Fig. 2), the method of its program determination was developed [5], the method comprises computer- based control of the electromotive force of the supply source and is based on the simultaneous measurements of voltages U_T on the electric heater and U_n and on its serial connection with thermostabilized electric resistance. Program determination of the electric heater state can be performed according to the developed method in the following succession. After the conection of the supply source and stabilization of the electric heater temperature in the mode with the efficiency factor that does not exceed 0.5 , by means of switching the electro-motive-force is increased, measured values U_{T_0} and U_{n_0} are registrated immediately after switching, values U_{T1} and U_{n1} are selected in the mode with the efficiency factor that is not less than 0.5, which meet the requirements:

$$\frac{U_{T_0}\left(U_{n_0}-U_{T_0}\right)}{U_{T1}\left(U_{n1}-U_{T1}\right)}=1, \tag{1}$$

parameter is calculated:

$$\alpha = \sqrt{\frac{(U_{n1} - U_{T1}) \cdot (U_{n_0} - U_{T_0})}{U_{T_0} \cdot U_{T1}}} \qquad (2)$$

and determine the state of the electric heater for any i^{th} moment of time by the set of the relative resistance $\frac{R_i}{r}$ and relative thermal power $\frac{P_i}{P_{T_1}}$ which are calculated by the formulas:

$$\frac{R_i}{r} = \frac{\alpha \cdot U_{Ti}}{U_{ni} - U_{Ti}} \text{ and } \frac{P_i}{P_{T_1}} = \frac{U_{T_i}(U_{n_i} - U_{T_i})}{U_{T_1}(U_{n_1} - U_{T_1})}, \qquad (3)$$

where R_i – is the unknown resistance of the electric heater, that corresponds to the instanteneous values of the measured voltages U_{Ti} , U_{ni} and r – is the unknown internal resistance of the supply source.

With the usage of the relations (3) on the points of stationary thermal dissipation from the electric heater, fixed at different values of electromotive force of the supply source, the dependence of the thermal power, dissipated by the studied heater on the parameter $\frac{R}{r}$ is established and conclusions regarding the possibility and ways of its optimization are formulated .

Conclusions

The relation of the values of thermally-dependent resistance of the electrothermal device heater and internal resistance of the supply source is assumed to be a determinant factor regarding the formation of the range of the attainable values of energy release in the active element of the heater and, as a result, the range of the attainable temperatures of the heaters of the software-hardware complexes for the synthesis of micro- and nanostructural composite materials.

Program determination of the unstable state of the electric thermal device electric heater can be realized exclusively on the base of the computer control of EMF of the supply source and registration at the successive moments of time of the simultaneously measured voltages U_T and U_n on the thermally -dependent resistanmce of the electric heater and on its serial connection with thermostabilized (reference) resistance.

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Editorial office received the paper 22.05.2018.
The paper was reviewed 28.05.2018.

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