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STABILIZATION OF TEMPERATURE REGIMES OF BEARING STRUCTURES OF MEASURING SYSTEMS

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Abstract. This paper describes the problem of the of the automatic thermogradient dimensional stabilization. The solution of the automatic thermogradient dimensional stabilization defines the management, ensuring the permissible level of dynamic and static quality criteria under the implementation of restrictions. We have built function-oriented management simplified mathematical model. On this basis it is possible to solve the problem of the synthesis of the corresponding system of automatic stabilization of the temperature field of the construction using discrete-distributed control.

1. INTRODUCTION

The reliability of the readings under the extreme operating conditions largely depends on the thermal deformation of the structure on which they are mounted.

We consider the canonical example. Let the fuel rods of measuring system are distributed in a certain way on the surface of the rectangular plate, and its activation and deactivation is performed arbitrarily and randomly. The controllable fuel elements are placed on the surface of the plate to compensate the effect of thermal deformations of the structure and the heat dissipation is organized through the controllable liquid cooling system.. Then the problem can be interpreted in the form of respective task of determination of the vector control, in which components are considered as power fuel rods and the temperature of the coolant liquid to ensure uniformity of the temperature field in the volume under the most unfavorable plate perturbation from the fuel measuring devices.

The solution of the automatic thermogradient dimensional stabilization defines the management, ensuring the permissible level of dynamic and static quality criteria under the implementation of restrictions.The solution of the corresponding optimal problem provides the extreme importance of these criteria.

The problem of determining the structure and parameters of the algorithm and the corresponding automatic control system requires the application of the function-oriented management simplified mathematical model (FOM) temperature load-bearing structures. On such models define the structure and approximate values of the system parameters, which are then refined during the simulation more accurate detailed mathematical model [1].

2. SOLUTION

Let's introduce a number of assumptions and simplifications to build the FOM:
• load-bearing structure in the thermal sense will be represented as a solid prism;
• plate material will be assumed to be isotropic;

• the point concentration of the fuel measuring and driving devices is assumed for the approximate determination of the structure and parameters of the automatic control system; this assumption is admissible under the condition of the small scale and in the specified calculations the real scale is taken into account;
• a heat-exchanger tube will be placed on some faces of the prism to cool it;
• contact with the face of the tube is ideal;
• the heat transfer occurs across the whole forming of the outer wall of the tube;
• uneven heating of the heat transfer fluid in the tube section can be ignored.

The corresponding boundary value problem of the heat transfer from the fuel measuring and control elements for the convenience of further analysis should be presented in the form of equivalent inhomogeneous differential equation:

$$\frac{\partial\Theta(x,y,z,\tau)}{\partial\tau}-a\left[\frac{\partial\Theta^2(x,y,z,\tau)}{\partial x^2}+\frac{\partial\Theta^2(x,y,z,\tau)}{\partial y^2}+\frac{\partial\Theta^2(x,y,z,\tau)}{\partial z^2}\right]=\omega(x,y,z,\tau) \quad (1)$$

$$\omega(x,y,z,\tau)=Q_{X_1}(0,y,z,\tau)+Q_{X_2}(R_x,y,z,\tau)+Q_{Y_1}(x,0,z,\tau)+Q_{Y_2}(x,R_y,z,\tau)+ \\ +Q_{Z_1}(x,y,0,\tau)+Q_{Z_2}(x,y,R_z,\tau) \quad (2)$$

and homogeneous boundary conditions:

$$\left.\frac{\partial\Theta(x,y,z,\tau)}{\partial x}\right|_{x=0}=\left.\frac{\partial\Theta(x,y,z,\tau)}{\partial y}\right|_{y=0}=\left.\frac{\partial\Theta(x,y,z,\tau)}{\partial z}\right|_{z=0}=0, \quad (3)$$

where R_x, R_y, R_z - the sizes of the prism;

$Q_{X_1}(0,y,z,\tau)=q_{X_1}(\tau)$; $Q_{X_2}(R_x,y,z,\tau)=q_{X_2}(\tau)$; $Q_{Y_1}(x,0,z,\tau)=q_{Y_1}(\tau)$;
$Q_{Y_2}(x,R_y,z,\tau)=0$; $Q_{Z_1}(x,y,0,\tau)=q_{Z_1}(\tau)+q_A(\tau)V_A(x,y)+q_C(\tau)V_C(x,y)$;
$Q_{Z_2}(x,y,R_z,\tau)=q_{Z_2}(\tau)+q_B(\tau)V_B(x,y)++q_D(\tau)V_D(x,y)$; - the heat flows on the appropriate side of the prism, $q_A(\tau)$, $q_B(\tau)$, $q_C(\tau)$, $q_D(\tau)$- managed and unmanaged intensity of the heat of the fuel elements located on the edges $z=R_z$, $z=0$, - $V_A(x,y)=\delta(x-x_A)\cdot\delta(y-y_A)$, $V_B(x,y)=\delta(x-x_B)\cdot\delta(y-y_B)$, $V_C(x,y)=\delta(x-x_C)\cdot\delta(y-y_C)$, $V_D(x,y)=\delta(x-x_D)\cdot\delta(y-y_D)$ - the area of concentrated heat fluxes; $q_{X_1}(\tau)=\sigma_{\text{ст}}\varepsilon\left(T_{sr}^4(\tau)-T_{g_3}^4(\tau)\right)$, $q_{X_2}(\tau)=\sigma_{\text{ст}}\varepsilon\left(T_{sr}^4(\tau)-T_{g_4}^4(\tau)\right)$, $q_{Y_1}(\tau)=\sigma_{\text{ст}}\varepsilon\left(T_{sr}^4(\tau)-T_{g_5}^4(\tau)\right)$, $q_{Y_2}(\tau)=0$,
$q_{Z_1}(\tau)=\sigma_{\text{ст}}\varepsilon\left(T_{sr}^4(\tau)-T_{g_2}^4(\tau)\right)$, $q_{Z_2}(\tau)=\sigma_{\text{ст}}\varepsilon\left(T_{sr}^4(\tau)-T_{g_1}^4(\tau)\right)$ - the intensity of the external heat flows on the brink; $T_{g_1}(\tau)$, $T_{g_2}(\tau)$, $T_{g_3}(\tau)$, $T_{g_4}(\tau)$, $T_{g_5}(\tau)$, $T_{g_6}(\tau)$ - the average temperature of the plate edges.

The transfer function of the corresponding control object with distributed parameters:

$$W(x,\xi_x,y,\xi_y,z,\xi_z,p)=G(x,\xi_x,y,\xi_y,z,\xi_z,p)=\frac{1}{c\cdot\rho\cdot R_1}\left[\frac{1}{p}+4\sum_{n=1}^{\infty}\frac{k_{x,\xi_x}}{p+\mu_n^2}\right]+\frac{1}{c\cdot\rho\cdot R_2}\left[\frac{1}{p}+4\sum_{m=1}^{\infty}\frac{k_{y,\xi_y}}{p+\psi_m^2}\right]+ \\ +\frac{1}{c\cdot\rho\cdot R_3}\left[\frac{1}{p}+4\sum_{k=1}^{\infty}\frac{k_{z,\xi_z}}{p+\gamma_k^2}\right] \quad (4)$$

This transfer function should be presented in the form of a parallel connection of an integrator and an infinite number of aperiodic links with time constants

$$T_{x_n} = \frac{R_1^2}{a \cdot \pi^2 \cdot n^2},\quad T_{y_m} = \frac{R_3^2}{a \cdot \pi^2 \cdot m^2},\quad T_{z_\chi} = \frac{R_3^2}{a \cdot \pi^2 \cdot \chi^2} \tag{5}$$

and transmission coefficients

$$T_{x_n} = \frac{R_1^2}{a \cdot \pi^2 \cdot n^2},\quad T_{y_m} = \frac{R_3^2}{a \cdot \pi^2 \cdot m^2},\quad T_{z_\chi} = \frac{R_3^2}{a \cdot \pi^2 \cdot \chi^2} \tag{6}$$

which depend on space coordinates *x*, *y*, *z*, ξ_x, ξ_y, ξ_z

The transfer functions of the liquid heat exchanger under assumptions take the form:

$$W_\theta(S) = \frac{\frac{1}{\chi}\sqrt{p}\, sh\sqrt{p}}{ch\sqrt{p} + \frac{1}{\chi}\sqrt{p}\, sh\sqrt{p}} \approx \frac{T_b S}{T_q S + 1} \tag{7}$$

– heat transfer from the edge to the flow of the liquid heat transfer

$$W_{mp} = \frac{\sum_{i=1}^{\infty} b_i p^i}{1 + \sum_{i=1}^{\infty} a_i p^i} \approx \frac{T_b S}{1 + T_q S} \tag{8}$$

– heat transfer along the flow of the liquid heat transfer.

$$W_\lambda(p) = \frac{k_\lambda}{T_{o\delta} p + 1}\; W_\mu(p) = \frac{k_\mu}{T_{o\delta} p + 1} \tag{9}$$

– the transfer functions of the mix heat exchanger on the temperature and expenditure the input actions.

3. Conclusion

On this basis it is possible to solve the problem of the synthesis of the corresponding system of automatic stabilization of the temperature field of the construction using discrete-distributed control. Figure 1 shows the structure of discrete distributed system construction of the temperature stabilization at one point. The synthesis technique is based on the finite-dimensional Laplace transform of the corresponding Green's function.

The construction parameters are specified in the control algorithm simulation finite element model in the package ANSYS, thus relieving the majority of assumptions.

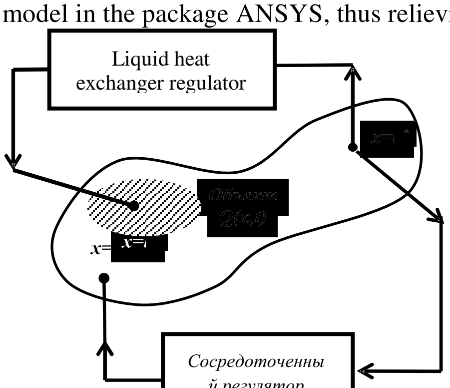

Figure 1. Structure of discrete-distributed system of the temperature stabilization at one point.

References

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