IDENTIFICATION OF THE PARAMETERS OF THE MATERIALS OF THE CARRIER STRUCTURES OF RADIO-ELECTRONIC SYSTEMS USING A COMPUTER-AIDED MEASURING BENCH

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A method of identifying the physical and mechanical parameters of the materials of the carrying structures of radio-electronic systems is described. A computer-aided measuring bench for solving the identification problem is proposed.

When designing the structure of modern radio-electronic systems, it is extremely important to take mechanical disturbances into account when designing the apparatus. Such disturbances cause from one-third to half of all the failures of radio-electronic apparatus [1]. To solve the problem of protecting the apparatus from mechanical disturbances successfully, the designer must have available the required information on the methods and procedures for protecting radio-electronic apparatus, and must also be able to analyze the effect of mechanical disturbances on the apparatus.

The carrier structures of radio-electronic apparatus — the units and printed components — can be regarded as plane structures or sets of these with the electrical and radio components mounted on them [2]. Forced oscillations of the plane structures are described by the following equation [3]

$$\ddot{\theta} + 2\omega_1 \dot{\theta} + \omega_1^2 \theta = \frac{1}{D_1} \left[ \frac{\partial^2 \theta}{\partial x^2} + \frac{\partial^2 \theta}{\partial y^2} \right] + \frac{1}{D_2} \left[ \frac{\partial^2 \theta}{\partial x^2} + \frac{\partial^2 \theta}{\partial y^2} \right] + m \frac{\partial^2 \theta}{\partial t^2} = q_i (x, y, t),$$

where $D_1 = E_1 S_1/[12(1 - \mu_1 \mu_2)], D_2 = E_2 S_2/[12(1 - \mu_1 \mu_2)]$ are the cylindrical stiffnesses of the plane structures along the x and y axes, $D_3 = D_1 \mu_2 + 2D_k = D_2 \mu_1 + 2D_k$ is the principal stiffness, $D_k = GS_3/12$ is the torsional stiffness, $S$ is the thickness of the plane structure, $\tilde{G} = E_{45}/[2(1 + \mu_{45})]$ is the shear modulus of the material of the plane structure, $E_1, E_2, E_{45}$ are the moduli of elasticity of the material of the plane structures along the x and y axes and at an angle of 45° to the axes respectively (we assume that the direction of the x and y axes coincides with the direction of the sides of the plane structures), $\mu_1, \mu_2, \mu_{45}$ are Poisson's ratios of the material of the plane structures along the x and y axes and at an angle of 45° to the axes, respectively, $\bar{Z}_i$ is the complex bending of the plane structures at a point with coordinates x and y at the instant of time t, $m_i$ is the mass of the plane structure per unit area at the point $i$, $q_i (x, y, t)$ is the external force exciting the oscillations per unit area at the point $i$ at the instant of time t.

A method of changing from the analytical model (1) to a topological model, which is an electromechanical analogy, was described in [4]. This change is made using the method of finite differences. If we divide the plane structure into a rectangular mesh with n nodal points, then for each node of the topological model we can write the following equation in unified notation:

$$\sum_{i=1}^{n} \bar{h}_{i,x} (\varphi_i - \varphi_0) + \bar{h}_{i,y} \varphi_i = \bar{h}_{i,x} (\varphi_i - \varphi_0).$$

where $\varphi_0 = \bar{Z}_0, \varphi_i = \bar{Z}_i, \varphi_i = \bar{Z}_i$ are potential variables of the nodal points of the topological model of the plane structure, $\bar{Z}_r, \bar{Z}_i$ are the complex amplitudes of the displacement of the r-th and i-th nodal points, $\bar{Z}_0$ is the complex amplitude of the dis-

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placement of the reference, connected to the i-th nodal point, \( h_{ir} = \frac{1}{jw k_{ir}} + a_{ir}, \ h_{0} = j\omega \beta_{i0}, \ k'_{0} = \frac{k_{0}}{jw} + a_{0} \) are generalized parameters of the branches of the model of the plane structure, where

\[
k_{1} = k_{1} = \frac{-a^3 b}{4(D_{1} a^2 + D_{2} b^2)}, \ k_{2} = k_{2} = \frac{-a b^3}{4(D_{2} a^2 + D_{1} b^2)}, \ k_{3} = \frac{a b}{2D_{3}}, \ r = 5, 6, 7, 8 \ k_{9} = k_{11} = \frac{b}{D_{1} a}, \ k_{10} = k_{12} = \frac{a^3}{D_{1} b}, \ a_{r} = \frac{1}{\omega k_{r}}, \ r = 1, 12; \ a_{0} = \frac{1}{\omega k_{0}}, \ \beta_{i0} = abm_{r}.
\]

\( a \) and \( b \) are the dimensions of the plane structure along the \( x \) and \( y \) axes, respectively, \( \gamma \) and \( \gamma' \) are the mechanical loss coefficients in the materials of the plane structure and the support, respectively, \( \omega \) is the angular frequency of the oscillations, and \( k_{r} \) is the tension-compression stiffness of the support.

As follows from (2), its coefficients depend on the mechanical loss coefficient \( \gamma \), Young’s moduli \( E_{1}, E_{2}, \) and \( E_{45} \) and on Poisson’s ratios \( \mu_{1}, \mu_{2}, \mu_{45} \), which are the physical-mechanical parameters of the material of the plane structure. How are these obtained?

Data are available in the literature [5] on these parameters for individual structural materials such as glass-textolite, getinax, aluminum alloys, etc. However, these parameters are not constant quantities over the whole frequency band. The mechanical loss coefficient \( \gamma \) depends on the mechanical stress which occurs in the structure and also on the oscillation frequency. Far from resonance the mechanical loss coefficient \( \gamma \) is very small and amounts to about 0.001 for glass-textolite [6]. At resonance frequencies \( \gamma \) increases sharply and for glass-textolite reaches values of the order of 0.01-0.05 [6]. In addition, as experimental investigations show [6], \( \gamma \) falls as the resonance frequency increases.

The model of a plane structure described by analytical expression (2) is nonlinear since the mechanical loss coefficient \( \gamma \) depends on the bending stress \( \sigma_{x} \) [5], which is primarily due to the bending amplitude of the plane structure

\[
\alpha = \sigma_{x} * k_{x} \gamma_{x}
\]

where \( \gamma_{0} \) is the mechanical loss coefficient at the initial point of the linear part of the graph of the mechanical loss coefficient against the mechanical stress, and \( k_{x} \) is the coefficient of the dependence of the mechanical loss coefficient on the stress.

For a numerical analysis using model (2) we need to obtain how the parameters \( \gamma_{0}, k_{x}, E_{1}, E_{2}, E_{45}, \mu_{1}, \mu_{2}, \mu_{45} \) depend on the amplitude of the mechanical action and frequency. Hence, we need to solve the problem of identifying these parameters of the nonlinear mechanical model of the plane structure.

In a wide sense, identification means establishing a correspondence between the object, represented by a certain set of experimental data on its properties, and the model of the object [7]. In our case we need to compare the experimental data