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A SYSTEM OF EQUATIONS FOR OSCILLATION AND STABILITY OF A VISCOELASTIC PLATE TAKING INTO ACCOUNT THE GENERALIZED HEAT CONDUCTIVITY EQUATIONS

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ANNOTATION

At In this paper, the equation of nonlinear oscillations and dynamic stability of viscoelastic plates is obtained, based on the Kirchhoff- Love model, taking into account temperature, as well as the associated mechanical and thermal fields.

Keywords: composite material, mechanics, reinforced concrete, fiberglass, carbon fiber, viscoelastic, structural, intense dynamic, polymer.

Modern composite materials (reinforced concrete, fiberglass, carbon fiber and others) are widely used in many areas of technology. Therefore, the mechanics of composite materials has received intensive development - a direction in mechanics that arose in connection with the need for materials that have a pre-predictable set of properties that best meet specific extreme operating conditions. In a market economy, one of the directions for the accelerated development of the country's economy is the widespread use of polymers, various composites in a variety of products of modern technology and the widespread use of resource-saving technologies and design solutions, which is directly related to a decrease in the material consumption of building structures. The solution of this problem is directly related to the improvement of methods for calculating structures due to a more complete consideration of the properties of materials, i.e. due to the large approximation of the calculated model of a solid body to the real one. One of these properties is the viscoelasticity of the material of construction, i.e. the dependence of the stressed and deformed state of the structure on time under load. Viscoelastic materials include polymers and composites, concretes and rocks, metals at elevated temperatures, traditional piezoceramic materials , etc. properties. Plastics at 0 ^{0} C have weakly expressed viscoelastic properties, i.e. are close to elastic bodies, but already at +50 ^{0} C they exhibit very significant properties of viscoelastic materials [1,2]. Therefore, the study of the problems of deformation and strength of structural elements operating in intense dynamic modes, taking into account temperature and other factors, is relevant. Especially, the problem of connectivity, the subject of which is the study of the interaction of mechanical, thermal, electromagnetic and other fields, acquires great scientific and applied importance in continuum mechanics. This is caused both by the needs of practice and by the internal logic of the development of continuum mechanics.
Accounting for the interaction of these fields is of fundamental theoretical interest, allowing a deeper, more complete and quantitatively accurate description of the motion of viscoelastic

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media, revealing a number of qualitatively new effects and evaluating the limits of applicability of theories in which coherence is reserved [3,4].

All of the above determines the relevance of this work to non-linear problems of vibrations and dynamic stability of viscoelastic thin-walled structures based on the Kirchhoff- Love model with and without temperature, as well as the coupling and non-coupling of mechanical and thermal fields.

Let a viscoelastic plate of thickness h be under the influence of the temperature field $T = T(x,y,z,t)$ and the relationship between stress $\sigma_{x,}\sigma_{y,}\tau_{xy}$, strain $\varepsilon_{x,}\varepsilon_{y,}\gamma_{xy}$ and temperature $T(x,y,z,t)$ look like

$$\sigma_x = \frac{E}{1-\mu^2}(1-R^*)[\varepsilon_x + \mu\varepsilon_y - \alpha_T(1+\mu)T],$$

$$\sigma_y = \frac{E}{1-\mu^2}(1-R^*)[\varepsilon_y + \mu\varepsilon_x - \alpha_T(1+\mu)T], \text{ (one)}$$

$$\tau_{xy} = \frac{E}{2(1+\mu)}(1-R^*)\gamma_{xy}$$

where, E is the elasticity modulus, is the α_T linear expansion coefficient , μ is Poisson 's ratio a , R* is the integral operator with the relaxation kernel and R(t)

$$R^*\varphi = \int_0^t R(t-\tau)\varphi(\tau)d\tau.$$

Using the laws of the theory of viscoelasticity [4] , it is possible to obtain systems of equations of motion of the plate relative to the displacement $U = U(x,y,t),\ \ V = V(x,y,t)$ and $W = W(x,y,t)$

$$(1-R^*)\left[\frac{\partial^2 U}{\partial x^2} + \frac{1-\mu}{2}\frac{\partial^2 U}{\partial y^2} + \frac{1+\mu}{2}\frac{\partial^2 V}{\partial y\partial x} + \frac{\partial W}{\partial x}\frac{\partial^2 W}{\partial x^2} - \frac{\partial W_0}{\partial x}\frac{\partial^2 W_0}{\partial x^2} + \right.$$

$$+\frac{1+\mu}{2}\left(\frac{\partial W}{\partial y}\frac{\partial^2 W}{\partial x\partial y} - \frac{\partial W_0}{\partial y}\frac{\partial^2 W_0}{\partial x\partial y}\right) + \frac{1-\mu}{2}\left(\frac{\partial W}{\partial x}\frac{\partial^2 W}{\partial y^2} - \frac{\partial W_0}{\partial x}\frac{\partial^2 W_0}{\partial y^2}\right) -$$

$$\left. - \frac{(1+\mu)\alpha_T}{2}\frac{\partial}{\partial x}\int_{-h/2}^{h/2} T(x,y,z,t)dz \right] + \frac{1-\mu^2}{Eh}P_x - \frac{\rho(1-\mu^2)}{E}\frac{\partial^2 U}{\partial t^2} = 0,$$

$$(1-R^*)\left[\frac{1+\mu}{2}\frac{\partial^2 U}{\partial x\partial y}+\frac{\partial^2 V}{\partial y^2}+\frac{1-\mu}{2}\frac{\partial^2 V}{\partial x^2}+\frac{\partial W}{\partial y}\frac{\partial^2 W}{\partial y^2}-\frac{\partial W_0}{\partial y}\frac{\partial^2 W_0}{\partial y^2}+\right.$$
$$+\frac{1+\mu}{2}\left(\frac{\partial W}{\partial x}\frac{\partial^2 W}{\partial x\partial y}-\frac{\partial W_0}{\partial y}\frac{\partial^2 W_0}{\partial x\partial y}\right)+\frac{1-\mu}{2}\left(\frac{\partial W}{\partial y}\frac{\partial^2 W}{\partial x^2}-\frac{\partial W_0}{\partial y}\frac{\partial^2 W_0}{\partial x^2}\right)-$$
$$\left.-\frac{(1+\mu)\alpha_T}{2}\frac{\partial}{\partial y}\int_{-h/2}^{h/2}T(x,y,z,t)dz\right]+\frac{1-\mu^2}{Eh}P_y-\frac{\rho(1-\mu^2)}{E}\frac{\partial^2 V}{\partial t^2}=0,$$

$$\frac{h^2}{12}\nabla^4(1-R^*)\left[(W-W_0)+\frac{(1+\mu)\alpha_T}{2}\frac{\partial}{\partial y}\int_{-h/2}^{h/2}zT(x,y,z,t)dz\right]+$$
$$+\frac{\partial}{\partial x}\left\{\frac{\partial W}{\partial x}(1-R^*)\left[\frac{\partial U}{\partial y}+\mu\frac{\partial V}{\partial y}+\frac{1}{2}\left[\left(\frac{\partial W}{\partial x}\right)^2-\left(\frac{\partial W_0}{\partial x}\right)^2\right]+\right.\right.$$
$$\left.+\frac{1}{2}\left[\left(\frac{\partial W}{\partial y}\right)^2-\left(\frac{\partial W_0}{\partial y}\right)^2\right]-\frac{(1+\mu)\alpha_T}{2}\int_{-h/2}^{h/2}T(x,y,z,t)dz\right]+$$
$$\left.+\frac{1-\mu}{2}\frac{\partial W}{\partial y}(1-R^*)\left(\frac{\partial U}{\partial y}+\frac{\partial V}{\partial x}+\frac{\partial W}{\partial x}\frac{\partial W}{\partial y}-\frac{\partial W_0}{\partial x}\frac{\partial W_0}{\partial y}\right)\right\}-$$
$$-\frac{\partial}{\partial y}\left\{\frac{\partial W}{\partial y}(1-R^*)\left[\mu\frac{\partial U}{\partial x}+\frac{\partial V}{\partial y}+\frac{\mu}{2}\left[\left(\frac{\partial W}{\partial x}\right)^2-\left(\frac{\partial W_0}{\partial x}\right)^2\right]+\right.\right.$$
$$\left.+\frac{1}{2}\left[\left(\frac{\partial W}{\partial y}\right)^2-\left(\frac{\partial W_0}{\partial y}\right)^2\right]-\frac{(1+\mu)\alpha_T}{2}\int_{-h/2}^{h/2}T(x,y,z,t)dz\right]+$$
$$\left.+\frac{1-\mu}{2}\frac{\partial W}{\partial x}(1-R^*)\left(\frac{\partial U}{\partial y}+\frac{\partial V}{\partial x}+\frac{\partial W}{\partial x}\frac{\partial W}{\partial y}-\frac{\partial W_0}{\partial x}\frac{\partial W_0}{\partial y}\right)\right\}-$$
$$-\frac{1-\mu^2}{Eh}q+\frac{\rho(1-\mu^2)}{E}\frac{\partial^2 W}{\partial t^2}=0 \qquad (2)$$

This system is considered with the generalized heat conduction equation [5,6] of the form

$$\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}+\frac{\partial^2 T}{\partial z^2}=\frac{1}{a_T}\frac{\partial T}{\partial t}+\frac{1}{c_q^2}\frac{\partial^2 T}{\partial t^2}+\frac{E\alpha_T T_0}{(1-2\nu)\lambda_T}(1-R^*)e \qquad (3)$$

where T $_0$ - initial absolute temperature , $a_T=\frac{\lambda_T}{c_T}$- temperature conductivity coefficient, e - volumetric expansion, $c_q=\sqrt{\frac{a_T}{\tau_r}}$ - heat propagation rate, τ_r - heat flow relaxation time (for metals $\tau_r \approx 10^{-11}$ *сек*).

Equation (3) differs from the classical heat equation. Firstly, this equation is interconnected with system (2) through volumetric expansion, and secondly , the $\frac{\partial^2 T}{\partial t^2}$ thermal inertia of the heat flow is taken into account. Accounting for the thermal inertia of the heat flow was first proposed by A.V. Lykov as a hypothesis about the finite speeds of heat propagation [5]. The given systems of equations (2) - (3) corresponding initial and boundary conditions is the mathematical model of the task.

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