# RESEARCH OF TEMPERATURE PRESSURE ARISING AT FRICTION VISCOUSELASTICITY OF CORES

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*The untied task thermoviscouselasticity (TVE) about distribution thermo-mechanical of waves in viscous elasticity cores is considered(examined). The task about thermo-mechanical influence to viscous elasticity ì to cores is decided in view of dependence of mechanical properties of materials of cores on current temperature simulating wildings of firm bodies by friction.*

It is known, that in metals at the raised temperatures the viscous properties prevail, and therefore viscous elasticity the model describes behavior of firm bodies under influence of high temperatures more precisely. At the moment of time two viscous elasticity of a core of a different diameter with constant loading nestle to each other and one of cores rotates about the axis with constant angular speed

Owing to presence of friction in a joint of two bodies (in section) heating end faces of cores is carried out, i.e. the source of heat of constant capacity works. Duration of course of process it is not enough (only 10-30 sec.), therefore selected thermal energy collects in the field of friction and promotes intensive heating of a material in a zone of a joint, as, it is possible to neglect tap(removal) of heat by convection from a lateral surface of cores.

The mathematical task is reduced to the decision of the following regional task. Equation of movement of particles of cores shall write down as:

$$\frac{\partial \sigma_i(x_i,t)}{\partial x} = \rho_i \frac{\partial^2 V_i(x_i,t)}{\partial t^2}; \quad (i=1,2)$$
$$-l \le x_1 < 0; \quad 0 < x_2 \le l; \qquad t > 0 \tag{1}$$

To the equation of movement the equations heat conductivity of bodies increase:

$$\frac{\partial \theta_i(x_i,t)}{\partial t} = a_i \frac{\partial^2 \theta_i(x_i,t)}{\partial x_1^2}, \tag{2}$$

The initial and boundary conditions will be:

$$V_i(x_i,t) = V_{it}(x_i,t) = 0, \qquad for \;\; t = 0 \tag{3}$$

$$\sigma_i(0,t) = -\sigma_0 H(t)$$
$$\sigma_i(x,t) = 0; \;(i=1,2), \qquad for \quad x = \pm l \tag{4}$$

$$\theta_1(x_1,t) = \theta_2(x_2,t) = 0, \qquad for \quad t = 0, \tag{5}$$

$$\theta_1(x_1,t) = \theta_2(x_2,t), \qquad for \quad x = 0, \tag{6}$$

$$\lambda_1 \frac{\partial \theta_1(x_1,t)}{\partial x_1} - \lambda_2 \frac{\partial \theta_2(x_2,t)}{\partial x_2} = Q_0, \qquad for \qquad x = 0, \tag{7}$$

$$\frac{\partial\theta_i}{\partial x_i}\Big|_{x_i\to\pm l} = 0, \tag{8}$$

Here, $\theta_i(x_i, t) = T_i - T_{0i}$, $a_i, \lambda_i, \rho_i$ - factors thermal diffusivity, heat conductivity and density of materials of cores, accordingly;

$Q_0$ = *const* - specific capacity of the selected thermal energy at friction, which for considered task shall write as:

$$Q_0 = \frac{n_1 f\omega P_k T_0}{n_4 R^4\sqrt{\pi}}\cdot\left(n_2 R_1^2(P_2 + P_k) - n_3 R^2 P_2\right); \tag{9}$$

Where $R_1, R_2 -$ radiuses of cores; $R = 0{,}5(R_1 + R_2)$, $f$ = *const*- factor of friction for rubbing element of pairs; $P_2 = 0{,}7P_0$; $P_k = 0{,}3P_0$; $T_0 = \min\limits_i \{T_{i0}\}$; $n_1, n_2\, n_3\, n_4$ = const., $i$ =1;2- numbers of ph.

Since the moment of rotation, on the area of contact of bodies (in section x=0) superficial source of heat the capacity constantly works $q_0\left(C/(m^2\cdot s)\right)$.

The decisions of a task (2), (5) - (8) are the expressions:

$$\theta_i(x_i,t) = T_i(x_i,t) - T_{i0} = \frac{2Q_0}{\lambda_i}\sqrt{a_i t}\cdot\frac{k_\varepsilon}{1+k_\varepsilon} ierfc\frac{|x_i|}{2\sqrt{a_i t}} \tag{10}$$

Where $k_\varepsilon = \frac{\lambda_1}{\lambda_2}\sqrt{\frac{a_2}{a_1}} = \sqrt{\frac{\lambda_1 c_1 \rho_1}{\lambda_2 c_2 \rho_2}}$ -- criterion describing thermal activity of the first core on the relation to second,

$ierfcx = \int\limits_a^\infty erfc\,\xi\, d\xi = \frac{e^{-x^2}}{\sqrt{\pi}} - x\, erfc\, x$ - tabulated function.

Materials of cores is accepted thermoviscouselasticity computational (TRC). Agrees [1], when mechanical properties of materials depend from temperature determining parities TRC , using temperature-time analogy, can write as:

$$\sigma_i(x_i,t) = \int\limits_0^t R_i\left(t_i' - \tau_i'\right) d\left(\frac{\partial V_i(x_i,\tau)}{\partial x_i} - \alpha_i\theta_i(x_i,\tau)\right) \tag{11}$$

Where $R_i\left(t_i'\right)$ – function relaxation, $t'$ - given time expressed by the formula

$$t_i' = \int\limits_0^t \frac{d\xi}{\alpha_{T_1}\left[\theta_i(x_i,\xi)\right]} \tag{12}$$

Where

$$\alpha_{T_i} = \exp\left(\frac{C_1(t)(\theta_i - \theta_{si})}{C_2 + \theta_i - \theta_{si}}\right),\ \theta_{si} = T_{ci} \pm 50^\circ C + T_{i0}, \tag{13}$$

$T_{ci}$ – temperature verifications of materials, $\left(a_i(\theta_{si}) \equiv 1\right)$,

$$C_1(t) = C_1\left(1 + \frac{C_0}{n}\sum_{i=1}^{k}\left(1 - \frac{t_0}{t}\right)^{b_{ki}}\right) \tag{14}$$

$t_0, C_1, C_2, C_0, k, b_i = const$

The case corresponds thermoreology- simple materials. According to the stated technique in [2], task (1) - (9) is resulted in the decision of system of the integer-differential equations (for simplicity of record is accepted x = $x_i$ , i.e. when $i = 1,\ x = x_1$ ; $i = 2$ , $x = x_2$ ):

$$\rho_i \frac{\partial^2 V_i}{\partial t^2} = \int_0^t \frac{\partial R_{in}(x, t-\tau)}{\partial x} d\left(\frac{\partial V_{0i}}{\partial x} - \alpha_i \theta_i\right) + \sum_{k=1}^{n}\left[\int_0^t \frac{\partial R_{i,n-k}(x, t-\tau)}{\partial x} d\left(\frac{\partial V_{ki}}{\partial x}\right) + \right.$$
$$\left. + \int_0^t R_{i,n-k}(x, t-\tau) d\left(\frac{\partial^2 V_{ik}}{\partial x^2}\right)\right] + \int_0^t R_{in}(x, t-\tau) d\left(\frac{\partial^2 V_{i0}}{\partial x^2} - \alpha_i \frac{\partial \theta_i}{\partial x}\right), \tag{15}$$

$$\sigma_{in}(x,t) = \int_0^t R_{in}(x, t-\tau) d\left(\frac{\partial V_{i0}}{\partial x} - \alpha_i \theta_i\right) + \sum_{k=1}^{n}\int_0^t R_{i,n-k}(x, t-\tau) d\left(\frac{\partial V_{ik}}{\partial x}\right) \tag{16}$$

The initial and boundary conditions accept a kind:

$$V_{in}(x,t) = V_{\text{int}}(x,t) = 0; \quad for \quad t = 0,\ (i = 1,2;\ n = 0,1,2,.......)$$
$$\sigma_{i0}(x,t) = -\sigma_0 H(t); \ for \ \ x = 0;\ \sigma_{in}(0,t) = 0,\ (n = 1,2,3........) \tag{17}$$

Applying transformation Laplas to the first equations of system (15) and (16), (at $n$ =0, in view of the entry conditions (3) and (5) is received:

$$\frac{d^2 \overline{V}_{i0}(x,p)}{\partial x^2} - \frac{\rho P}{R_{i0}(p)} \overline{V}_{i0}(x,p) = \overline{\psi}_{0i}(x,p),$$
$$\overline{\sigma}_{i0}(x,p) = \overline{R}_{i0}(p)\left(\frac{d\overline{V}_{i0}}{dx} - \alpha_i \overline{\theta}_i\right); \tag{18}$$

Where, $\overline{\psi}_{0i}(x,p) = \widetilde{\alpha}_i \dfrac{d\overline{\theta}_i}{dx}$ , $\alpha_i, \widetilde{\alpha}_i$ are factors of linear and volumetric thermal expansion of materials of cores. Decision of a regional task find as:

$$\overline{V}_{i0}(x,p) = \sqrt{\overline{\mu}_i(p)} \cdot \left(\alpha_i k_i \psi_{0i}(p) / (c_i p - k_i \overline{\mu}_i(p)) + P_0 \bar{f}(p) / (\rho_i p^2)\right) \cdot$$
$$\cdot \exp\left(-x\sqrt{\overline{\mu}_i(p)}\right) - \sqrt{c_i p k_i}\left(\alpha_i \overline{\psi}_{0i}(p)(c_i p - k_i \overline{\mu}_i(p))\right)^{-1} \cdot \exp\left(-x\sqrt{c_i p / k_i}\right)$$

Where; $\overline{\mu}_i(p) = \rho_i p / \overline{R}_{0i}(p)$, $\quad \bar{f}(p) = L(H(t)) = \dfrac{1}{p}$; $\quad c_i = \lambda_i / a_i$; $\quad k_i = \lambda_i / \rho_i$

Passing from the images to the originals, we receive:

$$V_{i0}(x,t) = a_i k_i \eta_i(i) * (D_2(x,t) - \delta(t)) * \theta_{0i}(x,t) + \sigma_0 \rho_i^{-1} H(t) * t * \partial(D_1(x,t)) / \partial x.$$

From (15) at $n$ =0 we find $\sigma_{i0}$ etc. others $V_{ni}(x,t)$, $(n = 1,2,......)$, are similarly calculated, and in expression (18) $\psi_{0i}(x,t)$ , is replaced $\psi_{in}(x,t)$. Expressions of functions, $\psi_{in}(x,t)$, $D_i(x,t)$, $\eta_1(t)$, are given in [2]. The offered method of the decision of non-stationary dynamic tasks thermoviscouselasticity, allows reception of materials with the given operational properties, by a presence of meanings reology of functions. The automation of accounts of meanings of operational technological parameters of process of welding with friction on the computer, i.e. direct continuous control above increase of temperature and heat-stress in a joint of bodies, will ensure qualitative welding of polymers without warming-up and metals without melting. The presence of mathematical model of physical process and analytical decision of the appropriate mathematical task allows an optimum choice of meanings power weight-lifting of parameters, complete automation of process and creation qualitatively new - portable machines of welding by friction. As against metals the polymeric details can easily be welded at periodic fluctuating load with use longitudinal shift pressure and this feature allows simplifying a design of machines of welding by friction. On the basis of the received results is developed thermo friction the fascinating device for clearing stuck of columns of petroleum chinks. As an example the material polymethylmethacrylate is considered, thermal and which mechanical properties are given in [3]. The various cases reology of functions, analyses variants thermoreology of simple and complex materials are considered. Is established, that the received theoretical results will well be coordinated to available skilled - experimental data for metals given in [3,4], for a case hereditary experimental of Y.N. Rabotnov's nucleuses, which are given on the table 1. Is revealed, that included of complexity of a material specifies meanings of a pressure and temperature approximately on 10 %-22 %.

## Literature

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