NOTATION

T	is the temperature, °K;
ε	is the net emissivity (degree of blackness);
D	is the cylinder diameter;
φ_{ik}	is the mean angular coefficient of radiation (ARC) between i-th and k-th elements of finite area surface;
R	is the coefficient of reflection;
σ	is the Stefan–Boltzmann constant;
ξ	is the dimensionless parameter equal to the ratio of the diameter of coaxial cylinders;
β	is the ratio of the total area of perforations to the geometric area of the cylinder;
β_{max}	is the β value at which radiant energy from the surface is maximum;
β_0, β	is the value below which radiant energy of the perforated cylinder is equal to or greater than the radiant energy of the continuous cylinder;
Q_f	is the resultant radiation flux.

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EFFECT OF THE ELASTIC FACTOR ON THE HYDRODYNAMIC STABILITY OF A STRUCTURALLY VISCOUS MEDIUM

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The effect of relaxation phenomena on the hydrodynamic stability of the plane gradient flow of a structurally viscous medium is investigated using linear theory.

There has recently been interest in various problems of the hydrodynamics of structurally viscous liquids [1, 2] due to the wide use of these media in modern technological processes. These media have a complex physicochemical structure which leads to the appearance of relaxational mechanical properties in addition to Newtonian properties.

The simplest rheological law that simultaneously takes into account the relaxational and Newtonian properties of structurally viscous media can be postulated, e.g., in the form

$$\tau_{ij} + \frac{1}{T_M}\frac{\partial}{\partial t}\tau_{ij} = 2\eta(\Omega)F_{ij},\ \Omega = \sqrt{2F_{ij}F_{ij}}\ . \tag{1}$$

Here T_M is the characteristic relaxation time (the "Maxwellian" time); $\eta(\Omega)$, apparent viscosity, which is different in different intervals of the variation of the intensity of the velocity deformation tensor Ω [3]. If $\Omega \geq \Omega_1$ (Ω_1 is a characteristic of the medium), then $\eta(\Omega) = \eta^* + \tau_0/\Omega$, η^* is the plastic dynamic viscosity, and τ_0 is the limiting shear stress. When $\Omega \leq \Omega_1$, $\eta(\Omega)$ depends monotonically on Ω within the limits $\eta(0) \geq \eta(\Omega) \geq \eta(\Omega_1)$, and $\eta(\Omega_1) \gg \eta^*$.

The motion of an incompressible structurally viscous medium can be described by the following system of equations of motion:

$$\frac{\partial U_i}{\partial t} + U_j\frac{\partial}{\partial x_j}U_i = -\frac{\partial p}{\partial x_i} + \frac{\partial}{\partial x_j}\tau_{ij},\ \frac{\partial U_i}{\partial x_i} = 0, \tag{2}$$

where τ_{ij} is given by Eq. (1).

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If the characteristic intensity of the rate of deformation $\Omega_{char} \gg \Omega_1$, the velocity field for steady-state motion of the liquid (1) in a plane channel acted upon by a longitudinal pressure gradient is identical, apart from terms on the order of $\Omega_1/\Omega_{char} \ll 1$, with the velocity field of a viscous-plastic liquid [4]

$$U(y) = \begin{cases} (1-\xi)^2 & \text{for } |y| \leqslant \xi, \\ (1-\xi)^2 - (|y|-\xi)^2 & \text{for } \xi \leqslant |y| \leqslant 1. \end{cases} \tag{3}$$

Here we have taken as the characteristic quantities the half width of the channel L, the velocity $V = -(\partial p/\partial x) \times (L^2/2\eta^*)$, and the halfwidth of the extremely viscous zone ξ is found from its equilibrium condition

$$\xi = \frac{\varkappa}{2} + O\left(\frac{\varphi_1}{\Omega_{char}}\right). \tag{4}$$

Below we consider the hydrodynamic stability of the flow (3) of the liquid (1) for infinitely small velocity perturbations, the current function $\psi = \psi(x, y, t)$ of which has the form

$$\psi(x, y, t) = \varphi(y) \exp[i\alpha(x - ct)]. \tag{5}$$

The dynamics of perturbations (5) are described by ordinary differential equations for amplitude $\varphi(y)$

$$(U - c)(\varphi'' - \alpha^2\varphi') - U''\varphi = \frac{1}{i\alpha\mathrm{Re}} \frac{\exp(-i\theta)}{\sqrt{1+(\alpha ct_M)^2}} \Big\{(\varphi^{IV} - 2\alpha^2\varphi'' + \alpha^4\varphi) + 2\eta_0'(\varphi''' - \alpha^2\varphi') + \eta_0''(\varphi'' + \alpha^2\varphi) +$$

$$+ \left[U'\left(\frac{\partial\eta}{\partial\omega}\right)_0 (\varphi'' + \alpha^2\varphi)\right]'' + U'\alpha^2\left(\frac{\partial\eta}{\partial\omega}\right)_0 (\varphi'' + \alpha^2\varphi)\Big\} \tag{6}$$

and the boundary conditions [5]

$$\varphi'(-1) = \varphi(-1) = \varphi'''(0) = \varphi'(0) = 0. \tag{7}$$

Here the subscript 0 indicates unperturbed flow, $\eta = \eta(\Omega)/\eta^*$, $t_M = T_M L/V$, $\theta = \arctan(\alpha ct_M)$.

In the flow region $|y| \leq \xi$ with the accuracy assumed above, we can take $U(y) = \text{const}$. Hence, in this region assuming that $\mathrm{Re} \gg \eta(0)/\eta^*$, four linearly independent solutions of Eq. (6) can be defined in the form

$$\varphi_{1,2} = \exp(\pm\alpha y) + O\left(\frac{1}{\alpha\,\mathrm{Re}}\right),$$

$$\varphi_{3,4} = \exp\left\{\pm\sqrt{i\alpha\mathrm{Re}^*}\int_0^y \sqrt{\frac{}{(U-c)\left[\eta_0' + U'\left(\frac{d\eta}{d\omega}\right)_0\right]}}\,dy\right\}\left[1 + O\left(\frac{1}{\sqrt{\alpha\,\mathrm{Re}}}\right)\right], \tag{8}$$

$$\mathrm{Re}^* = \mathrm{Re}\exp(i\theta)\sqrt{1+(\alpha ct_M)^2}.$$

In the region $1 \geq |y| \geq \xi$ $\eta = 1 + \varkappa/\omega$ ($\omega = \Omega/\Omega_{char}$), and Eq. (6) can be written [6]

$$(U - c)(\varphi'' - \alpha\varphi) - U''\varphi = \frac{1}{i\alpha\mathrm{Re}^*}\left\{(\varphi^{IV} - 2\alpha^2\varphi'' + \alpha^4\varphi) - 4\varkappa\alpha^2\left(\frac{\varphi'}{U'}\right)\right\}. \tag{9}$$

The solution of Eq. (8) can be written in the form

$$\varphi_1^* = \sum_{k=0}^{\infty} a_k (y - y_c)^{k+1};\quad \varphi_2 = a_1\varphi_1 \ln(y - y_c) + \sum_{k=0}^{\infty} b_k (y - y_c)^k,$$

$$\varphi_{3,4}^* = \int_{\pm\infty}^{z} dz \int_{\pm\infty}^{z} z^{1/2} H_{1/3}^{(1,2)}\left[\frac{2}{3}(iz)^{3/2}\right] dz, \tag{10}$$

where

$$U(y_c) = c,\quad z = (y - y_c)\left[\alpha\,\mathrm{Re}\sqrt{1+(\alpha ct_M)^2}\,U'(y_c)\right]^{1/3} \exp(i\theta/3), \tag{11}$$

where $-7\pi/6 \leq \arg z \leq \pi/6$ [5].

It follows from condition (11) that $-\pi/2 \leq \theta \leq \pi/2$. The corresponding interval of variation of t_M is $[-\infty, \infty]$.

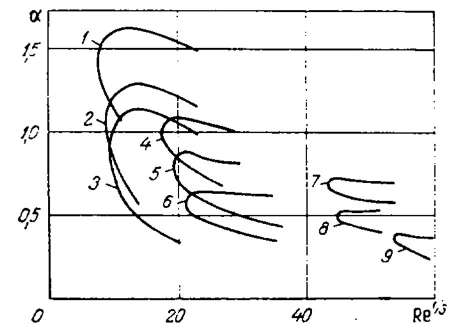

Fig. 1

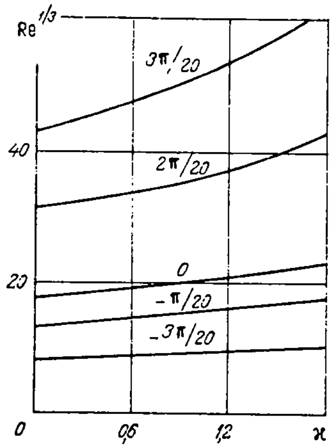

Fig. 2

Fig. 1. Curves of the neutral stability of the flow of a structurally viscous liquid. For $\theta=-3\pi/20$: 1) $\xi=0$; 2) 0.3; 3) 0.6; for $\theta=0$: 4) $\xi=0$; 5) 0.3; 6) 0.6; for $\theta=3\pi/20$: 7) $\xi=0$; 8) 0.3; 9) $\xi=0.6$.

Fig. 2. The critical Reynolds number $(\mathrm{Re}_1^{cr})^{1/3}$ as a function of the plasticity parameter $\varkappa$ for different θ. The numbers on the curves are the values of θ.

The condition for the general solution of Eq. (6) to be nontrivial in the region of variation of the independent variable y[−1, 0], defined by boundary conditions (7) and by the conditions for the general solutions φ and φ^* to be matched at the point $y=-\xi$

$$\frac{d^k\varphi}{dy^k}(-\xi)=\frac{d^k\varphi^*}{dy^k}(-\xi) \tag{12}$$

apart from terms on the order of $O[(\alpha\mathrm{Re})^{-1/3}]$, leads to the secular equation

$$\{\varphi_2(-1)[\varphi_1'(-\xi)+\alpha\varphi_1(-\xi)\,\mathrm{th}\,\alpha\xi]-\varphi_1(-1)[\varphi_2'(-\xi)+\alpha\varphi_2(-\xi)\,\mathrm{th}\,\alpha\xi]\}/\{\varphi_2'(-1)[\varphi_1'(-\xi)+\alpha\varphi_1(-\xi)\,\mathrm{th}\,\alpha\xi]-\varphi_1'(-1)\times[\psi_2'(-\xi)+\alpha\varphi_2(-\xi)\,\mathrm{th}\,\alpha\xi]\}=\varphi_3(-1)/\varphi_3'(-1). \tag{13}$$

In calculations using Eq. (13), the integration path when finding the solution φ_3 is chosen along the real axis 0z from $+\infty$ to 0 and further along the ray $\arg z=\pi+\theta/3$.

Figure 1 shows curves of the neutral stability $\mathrm{Re}=\mathrm{Re}(\alpha_1)$, $\mathrm{Re}=\rho U_1 L_1/\eta^*$, $L_1=L(1-\xi)$, $U_1=V(1-\xi)^2$, $\alpha_1=\alpha(1-\xi)^{-1}$ for different values of ξ and θ calculated from Eq. (13). The dependence of the critical Reynolds number $\mathrm{Re}_{cr}=(\rho U_1 L_1/\eta^*)_{cr}$ on the defining dimensionless parameters of the problem θ, $\varkappa$ is shown in Fig. 2.

The above calculations show that the features of the mechanical behavior of structurally viscous media have a considerable effect on the hydrodynamic stability of their flow. The plastic properties always stabilize the motion. The part played by the relaxational properties of the medium is determined, as was shown by the phase shift between the stresses and the rate of deformation. The time lag of the stresses ($T_M>0$) leads to destabilization of the motion – a reduction in the critical Reynolds numbers. Otherwise the motion is stabilized.

NOTATION

τ_{ij}	is the stress tensor deviator;
U_i	are the components of the velocity vector;
x_i	are the coordinates;
t	is the time;
P	is the pressure;
$\varkappa=\tau_0 L/\eta^* V$	is the plasticity parameter;
τ_0	is the limiting shear stress;
α and αc	are the dimensionless wave number and the perturbation frequency;

$Re = \rho VL/\eta^*$	is the Reynolds number;
ρ	is the density;
F_{ij}	is the deformation rate tensor.

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VARIATION OF THE RHEOLOGICAL PROPERTIES OF MULTIPHASE MIXTURES DURING THEIR PRESSURE TREATMENT

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Nonequilibrium effects in the barotreatment of non-Newtonian multiphase systems are discussed.

It has been established by a large number of investigations that when non-Newtonian systems are pressure-loaded under static conditions, one observes a slow pressure drop to some stabilized value [1].

These kinetic effects are observed under both static and dynamic conditions [2].

The "pressure-drop" effect was the basis for an examination of the possibility of regulating the rheological properties of non-Newtonian systems through their pressure treatment — barotreatment.

The effect of pressure on the properties of some non-Newtonian systems is discussed below. Proceeding from fluid-transport problems, as the models of non-Newtonian systems we chose: 1) glycerin + quartz dust (10%); 2) glycerin + quartz dust (10%) + CO_2 gas (with gas–liquid ratios $\Gamma = 5$, 10, and 25 cm^3/cm^3); 3) glycerin + quartz sand with fraction of ϕ 0.25-0.75 mm.

The tests were conducted on a specially constructed installation whose main component is the pressure chamber — an RUT cylinder (Fig. 1).

The first series of experiments was performed with a non-Newtonian system, a mixture of glycerin + quartz dust (10%), which was carefully evacuated at T = 40°C before the start of a test.

The presence of a piston in the RUT cylinder, as is known, is associated with some "shear" forces on the order of 1-1.5 atm (tech.) expended in the motion of the piston itself. In order to eliminate this effect, the experiments were conducted inside a container.

The tests were conducted in the following way: excess pressure was produced in the container 2 (Fig. 1) by depressing the piston with the press, and when the assigned pressure P_0 was reached the container was disconnected from the RUT cylinder by the valve 9, with the loading of the system taking place in a relatively short time. The time variation of the pressure was recorded with a standard manometer 6 with a scale division of 0.2 atm (tech.).

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