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TANGENTIAL DISCONTINUITIES OF PARAMETERS OF A POLAR FLUID UNDER SHEAR STRAIN

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Possible formation of tangential discontinuities of parameters of a deformable polar fluid is examined by the example of glycerin. It is experimentally established that glycerin under weak shear loads possesses the properties of a non-Newtonian elastoviscoplastic fluid, and formation of tangential discontinuities in viscosity is possible. In the discontinuity region, glycerin has the properties of a low-viscosity fluid, and the structure of the medium is reconstructed after unloading. A rheological equation of the examined fluid is derived, which allows one to analyze the behavior of the medium in different modes of its deformation, including the formation of a local region with reduced viscosity and a tensile stress field.

Key words: *polar fluid, shear strain, structural viscosity, tangential discontinuities.*

It is known that ductile failure of condensed media is characterized by some basic mechanisms, such as the development of cavitation cavities in the field of tensile stresses (bubbles in liquids or voids in solids) and macroscale plastic flow under the action of shear stress [1, 2]. In this connection, in addition to the rheological model of cavitation development in condensed media (valid for both liquid and solid-plastic media) [3], it seems important to construct a generic model of plastic deformation of these media with a transition to the viscous flow mode.

There are many publications dealing with plastic deformation of solids (see, e.g., [2, 4]) and liquid-type media (strong emulsions and suspensions, bitumens, paints, gels, polymer melts, etc.) [5–8]. It is commonly accepted that the so-called Newtonian fluids do not possess shear strength, and their viscosity is independent of flow velocity. Investigations of fluid media under the action of ultra-weak shear loading, however, show that these media also possess a certain shear strength. Thus, the experiments of [9] made it possible to estimate the static shear modulus of water (about 10^{-6} Pa). It was demonstrated in [10, 11] with the use of an optical technique that quiescent polar fluids (water, acetone, ethyl alcohol, glycerin, etc.) have an ordered structure destroyed by weak shear strains. (Water in the liquid state has the maximum shear strength at $T = +8°$C.) Thus, the polar fluids mentioned (at least low-viscosity water with the shear-strength limit $\tau_* \approx 2 \cdot 10^{-2}$ Pa at $T = +8°$C [11] and high-viscosity glycerin with $\tau_* = 1$ Pa at $T = +20°$C [9]) have an ordered structure under shear loads below the threshold values, and the structure is destroyed by loads above the strength threshold, i.e., the rheological parameters become different. Hence, it seems important to study possible formation of tangential discontinuities of medium parameters in fluids, which can trigger fragmentation of the loaded specimen.

1. Experimental Study of Formation of Tangential Discontinuities of Rheological Parameters of a Polar Fluid (Glycerin). 1.1. For the present investigations, glycerin was chosen as a model high-viscosity polar fluid. Viscoelastic properties of glycerin were determined in an experiment aimed at observing the Weisenberg effect [6] (Fig. 1): viscoelastic fluid 1 capability of uprising on a vertical rod 2 rotating in the fluid medium. This ascent is caused by the fact that viscoelastic fluids possess stresses normal to the shear plane, directed toward the axis of revolution, and increasing the pressure in the vicinity of the rod.

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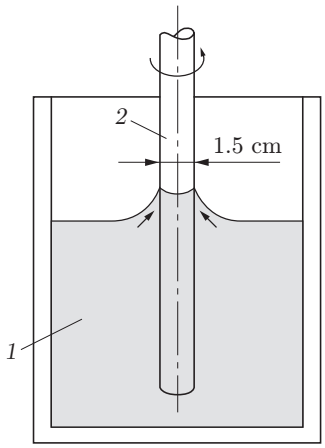

Fig. 1. Weisenberg effect in glycerin.

The experiments revealed that glycerin possesses viscoelastic properties: noticeable uprising of the fluid along the rod surface was observed at a temperature below +21°C and velocity of revolution of the rod equal to 0.5–2.0 rounds per second (the rod diameter was 1.5 cm). (With a further increase in angular velocity of the rod, the uprising distance decreased, which is apparently associated with failure of the ordered structure of glycerin owing to shear-strain-rate growth.)

1.2. Tangential discontinuities of parameters of a condensed medium can be divided into two types. The first-stage tangential discontinuity (TD1) implies formation of a zone extended in the direction of shear strain, where the following condition is satisfied: $\mu_z \ll \mu$. Here μ and μ_z are the values of structural viscosity of the medium (whose definition is given in [6]) outside and inside the zone, respectively; the density of the medium inside and outside the TD1 zone is almost identical. The second-stage tangential discontinuity (TD2) involves formation of a zone extended in the direction of the shear strain, where the conditions $\rho_z/\rho_0 \to 0$ and $\mu_z/\mu \to 0$ are satisfied (ρ_z and ρ_0 are the densities in the TD2 zone and in the undisturbed medium, respectively).

Let us consider conditions necessary for TD1 and TD2 formation. As the structural viscosity of condensed media decreases with increasing shear-strain rate $\dot{\varepsilon}_\tau$ [12, 13], for the TD1 to form, the medium should be subjected to shear strain with a gradient of shear velocity in the direction perpendicular to shear. The value of $\dot{\varepsilon}_\tau$ should have a maximum localized in the TD1 zone such that $\dot{\varepsilon}_{\tau\,\max} \geqslant \dot{\varepsilon}^*_\tau$ ($\dot{\varepsilon}^*_\tau$ is the threshold value of the strain rate at which the decrease in structural viscosity reaches the value μ_0 corresponding to viscosity of the Newtonian flow of the medium). For a wide range of liquid-type media, the dependence of the structural viscosity μ on the strain rate is adequately described by the formula [14] $\mu(s\lambda') = \mu_0 + (\mu_{\max} - \mu_0)\operatorname{arsinh}\sqrt{s\lambda'}/\sqrt{s\lambda'}$, where $s = 2\,\mathrm{tr}\,(D^2)$, D is the strain-rate tensor, $\mathrm{tr}\,(D^2)$ is the trace of the tensor D^2, and λ' is the time constant of the deformation process. In addition, the dependence of μ on the shear stress τ is determined by the expression [12] $\mu = \mu_0 + (\mu_{\max} - \mu_0)\bar{\tau}/\sinh\bar{\tau}$, where $\bar{\tau} = \tau/\tau_*$. (The relation between the shear stress τ and ε_τ is determined from the rheological equation for a particular medium.)

Under shear strain of solid-plastic materials, μ also decreases with increasing $\dot{\varepsilon}_\tau$. Thus, in the case of steel and aluminum [13], the decreasing viscosity of materials reaches almost a minimum value at $\dot{\varepsilon}_\tau > 10^4$ sec^{-1}. This effect can be explained as follows: at $\dot{\varepsilon}_\tau$ exceeding a certain threshold value $\dot{\varepsilon}^*_\tau$, metal crystals pass to the atom-vacancy state [2], and their plastic deformation passes to the Newtonian fluid flow mode. A similar effect is known to be observed in shaped-charge jets.

As the density of the medium by definition should vanish in the zone of the discontinuity for the TD2 to form, i.e., the total volume of the medium should increase, it is obvious that deformation should be three-dimensional: it should involve shear deformation of the medium and extension in the direction perpendicular to shear. Real condensed media always contain microcavities (microvoids in solid-plastic materials and microbubbles in liquids); hence, cavitation is developed in the field of tensile stresses under certain conditions [3]: growth of voids, their coalescence, and TD2 formation. Because of the three-dimensional character, however, this discontinuity cannot be regarded as purely tangential, and it is not considered in the present work.

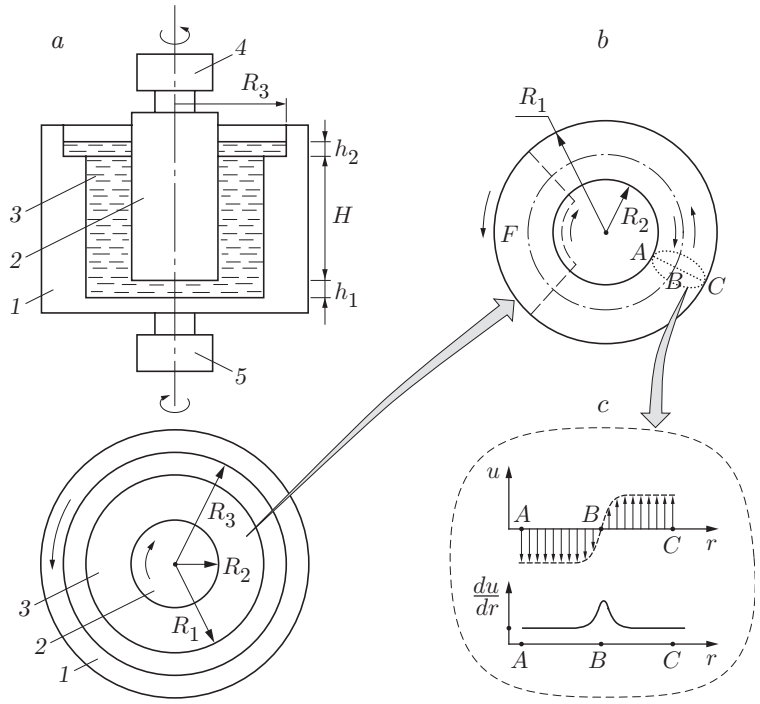

Fig. 2

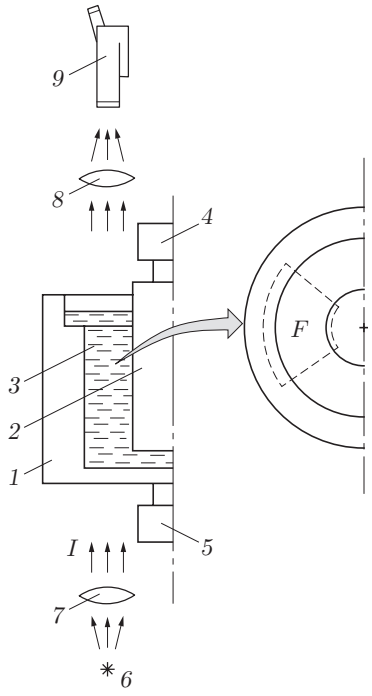

Fig. 3

Fig. 2. Schematic of the experiment on studying tangential discontinuities in glycerin parameters.

Fig. 3. Visualization of the tangential discontinuity in dielectric permeability of the fluid.

1.3. Formation of the first-stage tangential discontinuities was considered on an experimental setup shown schematically in Figs. 2a and 3. The setup operates on the following principle. The space between two counter-rotating coaxial cylinders 1 and 2 is filled by a fluid medium 3. Electromechanical units 4 and 5 set the cylinders into motion in the opposite directions with linear velocities that could be adjusted from 0.002 to 25 cm/sec. Counter-rotation of the cylinders results in formation of coaxial counter-current flows in the examined medium with a transitional layer in between, in which certain velocities of the flows can ensure the existence of shear modes of deformation, providing failure of the ordered structure of the medium. The main geometric parameters of the setup (see Fig. 2a) are $R_1 = 7.4$ cm, $R_2 = 4$ cm, $R_3 = 9$ cm, $h_1 = 1.5$ cm, $h_2 = 1$ cm, and $H = 2$ cm. The glycerin temperature was +19°C. To register the process, the system of coaxial cylinders was placed into a parallel light beam I formed by the optical system (light source 6 and condenser 7); after condenser 8, the light beam was incident onto the video camera 9 registering the examined process (Fig. 3). The "field of vision" of the optical system covered the sector F (Figs. 2b and 3).

Cylinders 1 and 2 (Figs. 2a and 3) rotating in the opposite directions form two coaxial counter-current flows in the medium 3 (Fig. 2b); a typical diagram of velocities in the vicinity of the interface is shown in Fig. 2c. In this diagram, $u(r)$ is the velocity distribution in the fluid along the r coordinate and B is the point located in the transitional layer between the counter-current flows. To determine the velocity diagram, polymer spheres 0.04–0.06 cm in diameter were introduced into the medium in some experiments; the densities of the spheres and the medium were identical. The "frozen" spheres moved together with the glycerin flows, and the distribution of flow velocity in the r direction was determined on the basis of the velocity of these spheres. Figure 2c shows the qualitative dependence of the flow-velocity gradient $Gr = du/dr$, and hence, the shear strain rate $\dot{\varepsilon}_\tau$, on the radius r. Obviously, at the point B corresponding to the transitional layer between the opposing flows, the dependence $Gr(r)$ has a "sharp" maximum $Gr(r = AB) = \max\{Gr(r)\}$; therefore, the transitional layer has the greatest probability of failure of the ordered structure of the medium and, under certain conditions, violation of continuity of the medium as well.

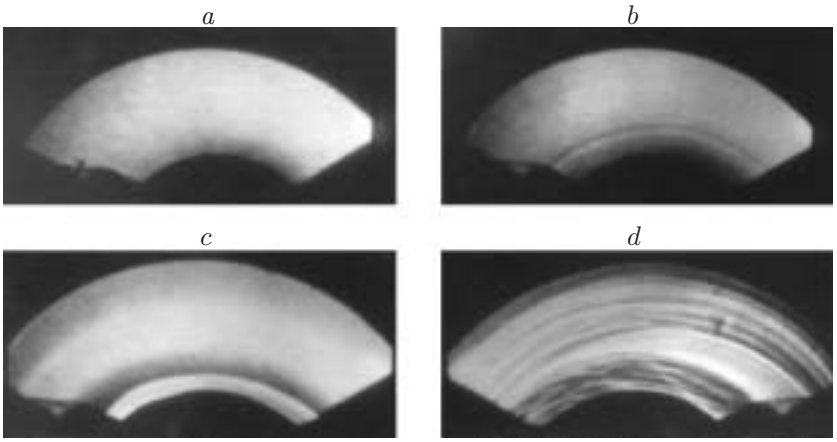

Fig. 4. Video frames of formation of tangential discontinuities in shear viscosity in glycerin.

1.4. The experiments performed revealed the following information. Glycerin is an optically isotropic liquid medium in the initial state (Fig. 4a), which loses optical homogeneity, i.e., homogeneity of dielectric permeability, in the case of formation of opposing coaxial flows in the transitional layer already at low values of $\dot{\varepsilon}_\tau$ (Fig. 4b). This means that a thin cylindrical layer with a broken structure is formed in the medium [10]; the viscosity and, hence, the relaxation time of shear stresses in this layer have lower values than those in the ambient medium. Such a layer has some features of the TD1, but the time needed for the glycerin-structure breakdown in the transitional layer t_b strongly depends on the level of $\dot{\varepsilon}_{\tau *} = \dot{\varepsilon}_\tau (r = AB)$. Thus, $t_b = 5$ min for $\dot{\varepsilon}_{\tau *} = 0.008$ sec^{-1}, $t_b = 63$ sec for $\dot{\varepsilon}_{\tau *} = 0.052$ sec^{-1}, $t_b = 48$ sec for $\dot{\varepsilon}_{\tau *} = 0.095$ sec^{-1}, and $t_b = 10$ sec for $\dot{\varepsilon}_{\tau *} = 0.2$ sec^{-1}. When the cylinders are stopped, rotation of the coaxial opposing flows is terminated, and the glycerin structure in the transitional layer is reconstructed. In all cases, the time of visible "healing" of the glycerin structure is about 15 min (at a temperature of +19°C). It should be noted that the width of the transitional layer with the broken structure remains almost constant during rotation of the cylinders in the examined range of $\dot{\varepsilon}_{\tau *}$, i.e., a stable zone of the tangential discontinuity of the ordered structure of glycerin is formed. As $\dot{\varepsilon}_{\tau *}$ increases to 2–3 sec^{-1}, the discontinuity zone (layer with the broken structure) is substantially expanded (Fig. 4c); judging by the flow character, glycerin viscosity in this layer is rather low: the video filming reveals a rapid transition from the laminar to the turbulent flow and vice versa (when the cylinder-rotation velocity decreases). Thus, we can assume that the regime of the Newtonian (viscous) flow is established in the zone of the tangential discontinuity with $\dot{\varepsilon}_{\tau *}$ increasing to 2 sec^{-1} because of the breakdown of the ordered structure and a decrease in structural viscosity of glycerin. When the cylinders are stopped, the structure of the medium is reconstructed; the reconstruction has a cellular character at the initial stage (Fig. 4d), but the entire broken ring zone TD1 acquires a uniform structure with time.

Thus, according to the experimental results obtained, the viscous polar fluid (glycerin) at rest possesses shear elasticity, but the orderliness of the medium structure is violated with increasing $\dot{\varepsilon}_\tau$; hence, the structural viscosity decreases to a level of the Newtonian shear viscosity; for this reason, glycerin behaves as a low-viscosity fluid (flow turbulization). This process has a reversible character: the ordered structure of glycerin is recovered as $\dot{\varepsilon}_\tau \to 0$. Localization of the region of existence of high values of $\dot{\varepsilon}_\tau$ leads to formation of a tangential discontinuity in viscosity of the medium.

2. Rheological Model of Macroscale Shear Deformation of a Polar Fluid. 2.1. It follows from the above-described experimental results that a polar fluid (glycerin) in the region of weak shear loads behaves as an elastoviscous medium with possible formation of zones with a discontinuous viscosity coefficient. Let us consider the possibility of constructing a macrorheological model of shear deformation of the examined medium. As glycerin and water possess shear strength [9–11], they can pass from the elastic to the viscous state only through the stage of plastic deformation. Indeed, if these media had no shear strength, their mechanical model would have the form shown in Fig. 5a, where the element μ_0 corresponding to viscous flow is always open, and the medium flow begins at an arbitrary level of shear stress. Possessing shear strength means that, for stresses below the threshold value, the fluid element μ_0 in the mechanical model is blocked by the St. Venant element η_* (Fig. 5b), and the

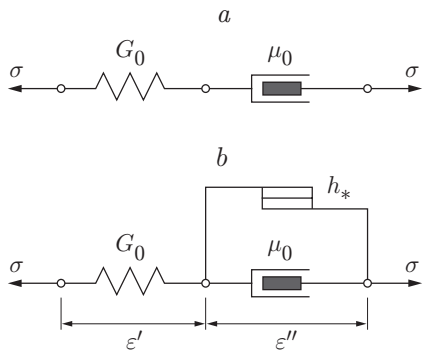

Fig. 5. Mechanical analog of an elastoviscoplastic medium.

medium is deformed in the shear elasticity mode (element G_0). When the shear stress exceeds the threshold value, the St. Venant element is opened, and a shear flow starts developing in the medium. With allowance for this circumstance, we choose a rheological analog of the examined medium to be an elastoviscoplastic medium (EVPM) corresponding to the mechanical model in Fig. 5b, where G_0 is the shear elasticity modulus of the fluid, η_* is the effective EVPM viscosity at the time when the stress reaches the yield point of the medium, and μ_0 is the shear viscosity of the fluid in the viscous (Newtonian) flow mode. The strain of the mechanical model ε can be presented as the sum of the strains of the mechanical units G_0, $\eta_* \mid \mu_0$: $\varepsilon = \varepsilon' + \varepsilon''$. Substituting the expressions relating the stresses σ applied to the model and the strains of the units

$$\varepsilon' = \frac{\sigma}{2G_0}, \qquad \varepsilon'' = \frac{\sigma}{2(\mu_0 + \eta_*)d/dt}$$

into the last equation, we obtain

$$(\mu_0 + \eta_*)\dot{\sigma} + G_0\sigma = 2G_0(\mu_0 + \eta_*)\varepsilon$$

or, in the three-dimensional case, passing to the stress tensor T and strain-rate tensor D,

$$(\mu_0 + \eta_*)T^{\oplus} + G_0 T = 2G_0(\mu_0 + \eta_*)D. \tag{1}$$

Here $T^{\oplus}$ is one of the convective derivatives of the stress tensor with respect to time, which transforms to a substantial derivative in the one-dimensional case. Multiplying Eq. (1) by T and taking into account that the relations $\eta_* \gg \mu_0$ and $T \cdot T^{\oplus} = 0$ are valid on exceeding the yield point θ, we obtain

$$\eta_* = 2\theta^2/(2D \cdot T) \tag{2}$$

($2\theta^2 = T \cdot T$ when the yield point is reached). Finally, substituting Eq. (2) into Eq. (1) and performing some transformations, we obtain the rheological equation of state for the EVPM

$$T + \frac{1}{G_0}\Big(\mu_0 + \frac{\theta^2}{D \cdot T}\Big)T^{\oplus} = 2\Big(\mu_0 + \frac{\theta^2}{D \cdot T}\Big)D \tag{3}$$

or

$$T + \lambda_{0*}T^{\oplus} = 2\mu_z D,$$

where $\mu = \mu_0 + \theta^2/(D \cdot T)$ is the structural viscosity of the medium, decreasing to μ_0 with increasing shear stress and strain rate, and $\lambda_{0*} = \mu/G_0$.

2.2. For convenience of analysis, we multiply Eq. (3) by $D \cdot T\theta^{-2}$ and rewrite it in the form

$$\frac{T}{\mu_0}\,\frac{\mu_0 D \cdot T}{\theta^2} + \frac{1}{G_0}\Big(\frac{\mu_0 D \cdot T}{\theta^2} + 1\Big)T^{\oplus} = 2\Big(\frac{\mu_0 D \cdot T}{\theta^2} + 1\Big)D. \tag{4}$$

If a very weak stress is applied to the medium, and deformation of the medium proceeds very slowly, so that $D \cdot T\mu_0\theta^{-2} \ll 1$ and $T/\mu_0 \ll T^{\oplus}/G_0$, then Eq. (4) reduces to the form $T^{\oplus} = 2G_0 D$. It follows from here that pure shear deformation of the medium under very slow and weak loading obeys Hooke's law $\tau = 2G_0\varepsilon_\tau$. This conclusion is in agreement with the experimentally observed behavior of water and glycerin [9]. If the shear-stress intensity

increases to a level at which the condition $\mu_0 D \cdot T\theta^{-2} \geqslant 1$ is satisfied, the rheological characteristic of the medium is described by Eq. (3); because of breakdown of the ordered structure of the medium, this equation reduces to the classical Maxwell equation for $\theta^2(\mu_0 D \cdot T)^{-1} \ll 1$ and, hence, as $\mu \to \mu_0$:

$$T + \lambda_0 T^{\oplus} = 2\mu_0 D, \qquad \lambda_0 = \mu_0/G_0. \tag{5}$$

The behavior of the solution of this equation, as is known from [14], depends on the choice of the convective derivative of the stress tensor with respect to time, whose generic form is $T^{\oplus} = T^{\odot} + a(T \cdot D + D \cdot T)$, where $T^{\odot} = dT/dt + T \cdot W + (T \cdot W)^{\mathrm{t}}$ is the Jaumann rotational derivative, $a \neq 0$ is a constant, $D = 0.5(\nabla \boldsymbol{V} + \nabla \boldsymbol{V}^{\mathrm{t}})$, and $W = 0.5(\nabla \boldsymbol{V} - \nabla \boldsymbol{V}^{\mathrm{t}})$. Substituting the value of $T^{\oplus}$ into Eq. (5), we obtain

$$T + \lambda_0 T^{\odot} + \lambda_0 a(T \cdot D + D \cdot T) = 2\mu_0 D. \tag{6}$$

2.3. We analyze the elastoviscous characteristics of the examined fluid by the example of a standard linear Couette flow. In the Cartesian coordinate system x^i, this flow has the form $v^1 = \dot{\varepsilon}_\tau x^2$, $v^2 = v^3 = 0$, where v^1, v^2, and v^3 are the components of the velocity vector $\boldsymbol{V}$. Then, we obtain

$$T = \begin{vmatrix} \sigma^{11} & \tau^{12} & \tau^{13} \\ \tau^{21} & \sigma^{22} & \tau^{23} \\ \tau^{31} & \tau^{32} & \sigma^{33} \end{vmatrix}, \qquad D = \begin{vmatrix} 0 & \dot{\varepsilon}/2 & 0 \\ \dot{\varepsilon}/2 & 0 & 0 \\ 0 & 0 & 0 \end{vmatrix}, \qquad W = \begin{vmatrix} 0 & \dot{\varepsilon}/2 & 0 \\ -\dot{\varepsilon}/2 & 0 & 0 \\ 0 & 0 & 0 \end{vmatrix}.$$

Taking into account that $T^{\odot} = T \cdot W + (T \cdot W)^{\mathrm{t}}$ for a simple steady shear flow and writing Eq. (6) in the matrix form with its subsequent expansion in terms of the i and j components, we obtain a system of algebraic equations that yields

$$\tau^{12} = \frac{\mu_0 \dot{\varepsilon}_\tau}{1 + \dot{\varepsilon}_\tau^2 \lambda_0^2 (1 - a^2)} = \frac{\mu_0 \dot{\varepsilon}_\tau}{1 + (1 - a^2)\,\mathrm{De}^2}$$

and, correspondingly,

$$\mu_* = \frac{\tau^{12}}{\dot{\varepsilon}_\tau} = \frac{\mu_0}{1 + (1 - a^2)\,\mathrm{De}^2}; \tag{7}$$

$$k_1(\dot{\varepsilon}_\tau) = \sigma^{11} - \sigma^{22} = \frac{2\mu_0 \dot{\varepsilon}_\tau^2 \lambda_0}{1 + \dot{\varepsilon}_\tau^2 \lambda_0^2 (1 - a^2)} = \frac{2\mu_0 \dot{\varepsilon}_\tau\,\mathrm{De}}{1 + (1 - a^2)\,\mathrm{De}^2}; \tag{8}$$

$$k_2(\dot{\varepsilon}_\tau) = \sigma^{22} - \sigma^{33} = -\frac{\mu_0 \lambda_0 \dot{\varepsilon}_\tau^2 (1 + a)}{1 + \lambda_0^2 \dot{\varepsilon}_\tau^2 (1 - a^2)} = -\frac{(1 + a)\mu_0 \dot{\varepsilon}_\tau\,\mathrm{De}}{1 + (1 - a^2)\,\mathrm{De}^2}. \tag{9}$$

Here, $\mathrm{De} = \lambda_0 \dot{\varepsilon}_\tau = \lambda_0/t_*$ is the Debora number, which is a criterion of similarity of deformation of elastoviscous media and $t_* = \dot{\varepsilon}_\tau^{-1}$ is the characteristic time of these processes. Since the effective viscosity $\mu_* = \tau^{12}\dot{\varepsilon}_\tau^{-1}$ should always remain positive, the parameter a in accordance with Eq. (7) is bounded by the condition $-1 \leqslant a \leqslant 1$. As the case of the lower convective derivative $a = 1$ does not correspond to real processes [14], the most suitable values of the parameter a corresponding to elastoviscous fluids lie within the range from 0 to -1. Hence, in the case of already broken structural viscosity (i.e., after reaching the regime with $\mu_0 D \cdot T \gg \theta^2$), when the medium behavior is described by the Maxwell model, we have $k_1 \approx 0$ and $k_2 \approx 0$ for low Debora numbers, in accordance with Eqs. (7)–(9). In this case, the medium behaves as a Newtonian fluid without elastic features. After that, the difference in normal stresses k_1 and k_2 starts increasing with increasing De, which indicates that glycerin again acquires elastic properties, i.e., $k_1 \simeq 2\mu_0[\lambda_0(1 - a^2)]^{-1}$ and $k_2 \simeq -\mu_0[\lambda_0(1 - a)]^{-1}$ for $(1 - a^2)\,\mathrm{De} \gg 1$. Thus, if the condition for formation of a zone in the form of a narrow band with a "sharp" maximum of the shear strain rate in this band is ensured, as in the experiment described above, Eq. (3) for this zone acquires the form of Eq. (6) if the condition $D \cdot T \gg \theta^2$ is satisfied. Solving this equation for the case of simple shear (7)–(9) shows that the difference $k_2 - k_1$ increases with increasing $\dot{\varepsilon}_\tau$, i.e., tensile stresses can be formed in this zone. Note, since $\mathrm{De} = \lambda_0 \dot{\varepsilon}$, water (whose shear-stress relaxation time is $\lambda_0 < 10^{-6}$ sec) can manifest elastic properties after breakdown of structural viscosity only if the shear strain rate is very high, which is next to impossible to reach in practice.

Finally, let us compare the experimental data with the estimate obtained by the rheological equation (3). According to the experiment, a layer with a drastic decrease in structural viscosity of glycerin μ_z is formed at $\dot{\varepsilon}_\tau = 2\ \mathrm{sec}^{-1}$. Through a special orifice in the bottom of glass 1 (see Fig. 2a), glycerin with the broken structure

was fed to a capillary viscosimeter, which revealed that $\mu_z = 0.72$ Pa·sec in this layer, and a further increase in $\dot{\varepsilon}_\tau$ leads to a decrease in structural viscosity, which tends to the value $\mu_0 = 0.48$ Pa·sec. After that, the experimental setup was adjusted to the operation mode of a standard rotational viscosimeter with a drive to the inner cylinder 2; at $T = +28.3°$C, when the glycerin viscosity reached $\mu = 72$ Pa·sec, the viscosimeter displayed the shear stress $\tau = 2.365$ Pa. Substituting the experimental data $\dot{\varepsilon}_\tau = 2$ sec^{-1} and $\mu_0 = 0.48$ Pa·sec into Eq. (3), which reduces to the form $\tau - 2\theta^2/\tau = 2\mu_0\dot{\varepsilon}_\tau$ in the case of a pure shear flow with a constant strain history ($\theta = 1$ Pa for glycerin [9]), we obtained the sought shear stress $\tau = 2.669$ Pa. The experimental value of τ is 11.3 % lower than the predicted value because the viscosity was measured in the experiments in a medium with a nonequilibrium structure (slowly reconstructing during the measurement); another reason is the error in determining θ in [9].

Conclusions. The experiments showed that a tangential discontinuity in viscosity can be formed in glycerin. When the shear load is removed, the discontinuity zone is "healed" with time: the initial structure is reconstructed, and this process has a cellular character.

An elastoviscoplastic body can be considered as a macrorheological model of glycerin and water under weak shear strains. The equation of state of the model body (3) in different modifications describes different modes of medium deformation, including formation of zones with low shear viscosity in the medium.

Thus, the EVPM model is valid not only for solid-plastic materials and liquid-plastic media (bitumens, paints, pastes, gels, polymer melts, etc.) but also for polar fluids (water and glycerin), which possess shear elasticity in the range of ultraweak shear loads. In most real processes, however, the loads are above 1 Pa, i.e., they are much higher than the yield point of these media and destroy the ordered structure so that the structural viscosity decreases to the level of Newtonian viscosity. Therefore, polar fluids are commonly called Newtonian fluids. Nevertheless, shear strength of these media should be taken into account in studying sedimentation of suspensions, slow diffusion processes, biophysical processes in a bioplast, and in other cases where Newtonian fluids are subjected to very weak shear loads.

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