# FLOW OF VISCOELASTIC FLUIDS UNDER HIGH SHEARING STRESSES

V. I. Popov

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Some characteristics of viscoelastic fluid flow under high shearing stresses are analyzed here.

Much attention has been given in recent studies to the flow of viscoelastic fluids under high shearing stresses. The reason for this is the importance of the problem concerning the instability of such a flow which occurs when certain critical strain levels in the medium are exceeded (Fig.1).

We will examine here the discharge of a viscoelastic fluid from rectangular channels. The velocity profile of an unstable flow has been measured by the stroboscopic method [1].

A 3.5% aqueous solution of polyacrylamide (PAA) was used as the viscoelastic medium. This solution is an interesting one, since it exhibits a considerable degree of elasticity along with its viscous structural properties (Fig.2).

In these tests the solution was extruded through horizontal L = 250 mm long rectangular channels with a 1:10 or a 1:20 ratio of sides. At the exit of the elastic solution from a channel one could observe an expansion of the continuous (regular) jet and then, when the tangential shearing stress at the channel wall had reached a certain level $\tau_W = \Delta ph/L = 310$ N/m$^2$, this jet became irregular. (In repeated discharge tests this irregularity set in always at almost the same value of $\tau_W$.)

The irregularities at the exit consisted of contracting longitudinal overshoots which periodically broke up the flow pattern, when viewed in a plane, as if into separate jets (Fig.1). These jets, the number of which varied, besides flowing in their principal mode (downward) also rolled across the stream in a wavelike manner and, as $\tau_W$ increased, successively pulsated in the direction of flow. At the same time, the highest Reynolds number was never more than unity.

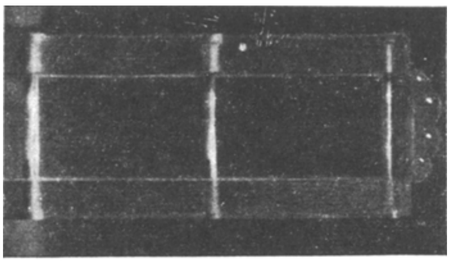

Fig.1

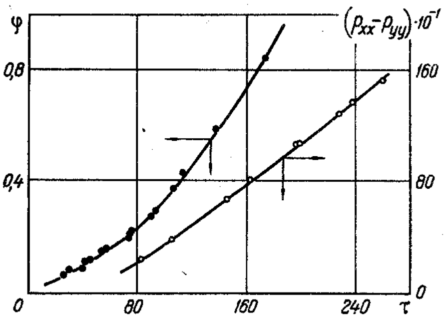


Fig.2

Fig.1. Irregularity of a 3.5% aqueous PAA jet at the exit from a rectangular channel (top view).

Fig.2. Fluidity and the first difference between normal stresses, as functions of the tangential shearing stress, for a 3.5% water solution of PAA. $\varphi$ (m$^2$/N $\cdot$sec), $\tau$ (N/m$^2$).

Institute of Thermophysics, Siberian Branch of the Academy of Sciences of the USSR, Novosibirsk.
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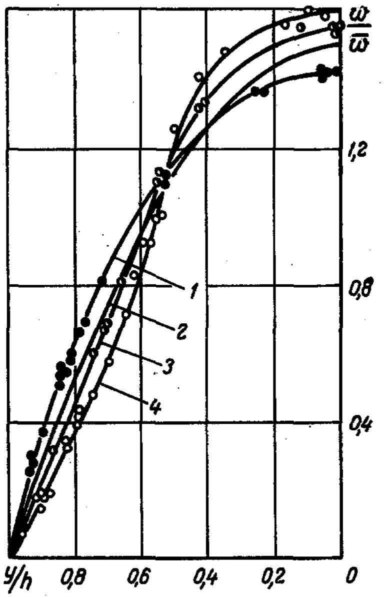


Fig. 3. Velocity profiles of 3.5% aqueous solution of PAM at various shearing stresses. Distance from entrance 150 mm: 1) $\tau_w$ = 210 N/m$^2$; 2) calculational parabolic velocity profile; 3) $\tau_w$ = 375 N/m$^2$; 4) $\tau_w$ = 420 N/m$^2$.

Apparently, we are dealing here with a unique laminar instability of viscoelastic flow in rectangular channels, which in somewhat different form has been observed by other authors during the extrusion of viscoelastic substances through round capillaries [2, 3].

The velocity profile was measured in the upper half-plane of a channel section with a 1:20 ratio of sides, at a shearing stress $\tau_w$ = 210 N/m$^2$; i.e., when the flow at the exit section was still regular and also during laminar instability at $\tau_w$ = 420 N/m$^2$. The results of some of the measurements are shown in Fig. 3. Each profile has been plotted from one set of tracings properly processes, while the mean velocity $\omega$ has been determined with the aid of a planimeter and with reference to any particular flow section.

The measurements show that the velocity profiles of the viscoelastic fluid inside the channel are flatter (as in the case of pseudoplastic fluids) when the jet discharge from a channel is regular, while being more elongated than in a Newtonian fluid (as in the case of dilatant fluids) with an inflection point when the jet discharge is irregular.

It is well known in the hydromechanics of Newtonian fluids [4] that the latter case must correspond to an unstable flow mode due to arbitrarily small perturbations.

On the basis of this analogy, the measurements seem to indicate some specific instability of viscoelastic flow [3].

Thus, at low Reynolds numbers an increasing $\tau_w$ transforms the stable mode of viscoelastic flow into a laminar instability of such a flow due to arbitrarily small perturbations at the channel entrance, for example, and this causes irregularities in the jet at the channel exit.

## NOTATION

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|---|---|
| $\tau_w$ | is the tangential shearing stress at a channel wall; |
| h | is the half-height of a channel; |
| L | is the channel length; |
| $\omega = w/\bar{w}$ | is the flow velocity, dimensionless; |
| $\bar{w}$ | is the mean flow velocity at a given section; |
| $\varphi$ | is the fluidity of viscoelastic fluid; |
| $p_{xx}-p_{yy}$ | is the first difference of normal stresses, N/m$^2$; |
| $\xi = y/h$ | is the distance from channel wall, dimensionless. |

## LITERATURE CITED


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