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DYNAMIC NONLINEAR PROPERTIES OF VISCOELASTIC

LIQUIDS FROM THE RHEOLOGICAL FLOW CURVE

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A method is developed for prediction and calculation of nonlinear properties of viscoelastic liquids solely by measurement of tangent stresses during flow in a rheometer.

A method was proposed in [1] for calculation of elastic characteristics of non-Newtonian liquids from their rheological flow curve, based on the fact that the viscosity measured in a rotation viscosimeter  $\eta_m$  differs from the true inelastic viscosity  $\eta_t$ , due to the effect of the elastic properties of the liquid. The relationship between  $\eta_m$  and  $\eta_t$  has the form [1]

$$\frac{1}{\eta_m^2} = \frac{1}{\eta_t^2} + \frac{\tau^2}{4G^2\eta_m^2} \quad (1)$$

For a linear viscoelastic liquid ( $\eta_t$  and  $G$  constant) the relationship between  $1/\eta_m^2$  and  $\tau^2$  is linear in character and can serve to define the modulus of elasticity  $G$ , and thus, the liquid relaxation time. In [1] good agreement between calculation results and direct measurements with a Weissenberg rheogoniometer was demonstrated.

If the dependence of  $1/\eta_m^2$  on  $\tau^2$  is nonlinear, this means that the viscosity or the modulus of elasticity (one, the other, or both together) depends on shear velocity. In the "inelastic" flow region, where  $\tau^2 \ll 4G^2$  and  $\eta_m \approx \eta_t$  (for low shear rates) one can establish the form of  $\eta_t(\gamma)$  and calculate the value of  $G(\gamma)$  from Eq. (1) transformed in the following manner:

$$\left(\frac{\eta_t}{\eta_m}\right)^2 = 1 + \frac{\tau^2}{4G^2} \quad (2)$$

To evaluate the applicability of the proposed method, relaxation times were calculated for several polymers from their rheological flow curves as presented in [2]. The results obtained are presented in Table 1.

The quite satisfactory agreement of the results obtained indicates the possibility of using the proposed method for operative evaluation of liquid relaxation characteristics.

A practical realization of this approach can be illustrated by results of calculating

TABLE 1. Comparison of Calculated Relaxation Times for Polymers

Polymer	Sprigs model	Meister model	Bog model	Present method
PEVP	78,96	23,27	29,70	27,55
PENP	2,80	0,94	5,82	4,21
PS	1,85	1,72	1,02	1,41
PP	1,03	0,72	0,94	1,25

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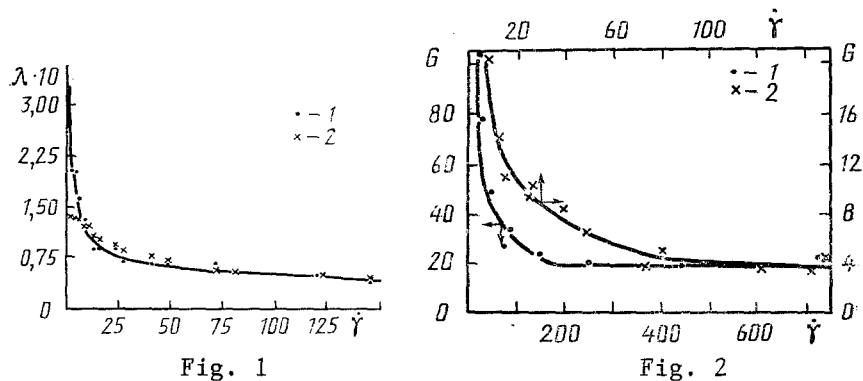


Fig. 1. Relaxation time vs shear rate: 1) 0.25% solution of biopolymer KS in water; 2) 0.4% solution of biopolymer KS in water; 3) 1% solution of OEC in water  $\lambda$  sec;  $\dot{\gamma}$   $\text{sec}^{-1}$ .

Fig. 2. Modulus of elasticity vs shear rate for 0.25 (1) and 0.4% (2) solutions of biopolymer KS in water, G, dPa.

the dependence of relaxation time and modulus of elasticity on deformation rate for various liquids (Figs. 1, 2).

The materials studied were 0.25 and 0.4% aqueous solutions of the biopolymer KS, and a 1% aqueous solution of oxyethylcellulose (OEC).

The calculations established that for the 0.25% KS solution the relaxation time was constant and equal to  $\lambda = 0.1$  sec, while the modulus of elasticity depended on deformation rate; for the 0.4% KS solution the relaxation time and the modulus of elasticity depend on deformation rate. The nonlinearity in the properties of the 1% OEC solution is expressed by dependence of the relaxation time on shear rate, while the constant modulus of elasticity has the value of 3.7 Pa.

Thus, the proposed method allows discrimination of the type of nonlinearity in viscoelastic properties of liquids, i.e., determination of which parameter, relaxation time, or modulus of elasticity, has an effect on deformation flow, without performing dynamic measurements or direct measurements of normal stress.

#### NOTATION

$\eta_m$ ,  $\eta_t$ , measured and true viscosities;  $\dot{\gamma}$ , shear rate;  $\tau$ , tangent stress; G, modulus of elasticity;  $\lambda$ , relaxation time.

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