A Note on Exploratory Measurements of the Rigidity of Flowing Polymeric Solutions

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Experiments were carried out in order to find if high shear rates of flow can change the rigidity of dilute polymeric solutions.

Some investigators have assumed that high shear rates of flow may change the rigidity of polymeric solutions (*1* to *3*) so they could explain the origin of Toms' phenomenon (friction loss reduction in turbulent flow of polymer solutions).

The experimental equipment consisted of hydraulic and electronic systems. The hydraulic system (Figure 1) consisted of an annulus between two bronze coaxial pipes.

The dissolved polymers used in the experiments were EPR X-14940-88 (ethylene propylene rubber) and Oppanol B-200 (polyisobutylene). These polymers were dissolved in kerosene in concentrations of 200, 400, and 800 mg./liter.

At the downstream end of the annulus, a torsional cylindrical quartz crystal was installed (Figure 2). From the hydraulic point of view, this crystal was an integral part of the annulus system.

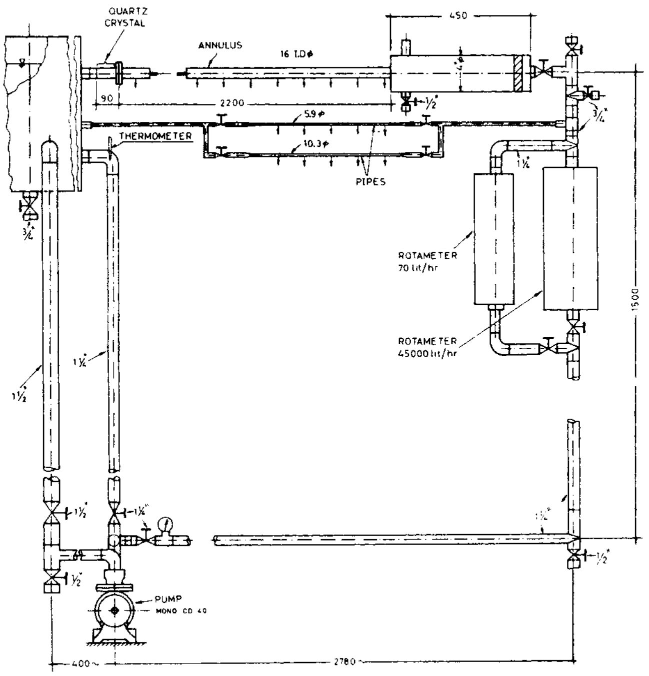

Fig. 1. The hydraulic part of the experimental equipment.

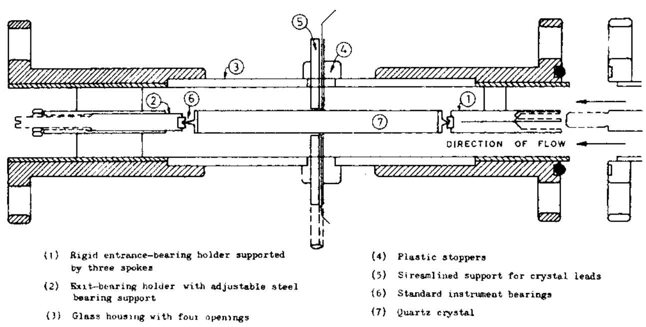

Fig. 2. Special housing of the quartz crystal.

The crystal forms a part of an electronic system which was similar to the one used by Barlow et al. (*4*). By using this system, it was possible to measure the resonance frequency and impendence of the torsional quartz crystal.

In some of the experiments which were conducted the liquid flowed axially, and in other cases it flowed helically. Helical flow was attained by putting pieces of bronze which were arranged in the conduit. Therefore, changes in rigidity to shears of the form $dV_r/d\theta$ and dV_θ/dr could be measured.

Measurements were conducted with kerosene, EPR, and Oppanol solutions in kerosene. Resonance frequency and impendence were measured in quiescent solutions as well as in flowing ones, at high rates of shear, where Deborah number (*5*) was equal to 6. Measurements were also conducted while these liquids were accelerated rapidly to high shear rates.

Changes in the resonance frequency and impendence of the crystal depend on the mechanical impendence of the liquid according to

$$f_R = f_0 - K_2 X_L \tag{1}$$

$$R_R = R_0 + K_1 R_L \tag{2}$$

R_L and X_L are

$$Z_L = R_L + iX_L \tag{3}$$

$$Z_L^2 = \rho G \tag{4}$$

The crystal was calibrated in kerosene, which is a Newtonian liquid. The rigidity of the solutions was found to depend on the concentration and molecular weight of the solute polymer according to Rouse's (*6*) and Zimm's (*7*) theories. However, it was independent of shear rate (no changes in resonance frequency and impendence of the crystal were observed by the high rates of shear). Therefore, it seems that no sudden changes in the structure of the polymer molecules occurred during the flow at high shear rates.

NOTATION

f_0 = crystal resonance frequency in vacuum
f_R = resonance frequency when crystal is surrounded by liquid
G = complex rigidity of liquid
K_1, K_2 = constants depending on type and dimensions of crystal
R_L = real component of mechanical impendence of flowing liquid
R_0 = crystal resonance impendence in vacuum
R_R = impendence when crystal is surrounded by liquid
X_L = imaginary component of mechanical impendence of flowing liquid
Z_L = mechanical impedance of liquid
ρ = liquid density

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