CONNECTION BETWEEN AVERAGE AND PULSATION
CHARACTERISTICS IN TURBULENT FLOW OF
POLYMER SOLUTIONS IN A ROUND TUBE

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Results are given for measurements of the average and pulsation characteristics of dynamically stable turbulent flows of polymer solutions in a round tube. Experimental dependences are presented which indicate the presence of a close and unique connection between the turbulent pressures and shear stresses at the wall of the tube.

We have attempted to obtain additional information on the mechanism of action of polymer solutions on boundary turbulent flow. Controlled changes in the concentration and degree of degradation of the solutions and a change in the type of dissolved polymer served as the means of investigation. In this connection all the other experimental conditions were kept constant. For example, the experiments were conducted in a closed circulating instrument filled with a homogeneous polymer solution. The measurement section was located at a distance of more than 100 diameters from the start of the working section of the instrument, a round tube of constant diameter. This eliminated the effect of longitudinal gradients in the average flow characteristics and transverse gradients in the polymer concentration. Since the experiments were conducted on a continuously moving solution, statistically stationary dynamically steady flow was achieved, at least in the absence of degradation of the solution.

Finally, the average stream velocity was chosen within limits such that the shear stress did not affect the magnitude of the Toms effect [1], thanks to which the most stable limiting modes were achieved.

The effect of extraneous instrument noises which interfere with measurements of the pulsation characteristics of the flow was also eliminated by the choice of the modes of operation. This choice was made

Fig. 1. Comparison of results obtained with data of experiment of [2] in an air stream. For a: 1) data of Corcos; 2) our experiment; for b: 1) our experiment; 2) data of Corcos.


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Fig. 2. Degeneration of effects of polymer solutions on shear stress $S$ at wall and on spectral power densities $P(f)$ of pressure pulsations. $dB = 10 \log \left[ \frac{|P(f)|}{\text{rel}[1 \mu \text{bar}]^2 \cdot \text{Hz}} \right]$. For a: 1) $C_{\text{init}} = 10^{-6} \text{ g/cm}^3$; 2) $5 \cdot 10^{-5}$; 3) $10^{-5}$; 4) $2.5 \cdot 10^{-5}$; 5) $10^{-4}$; 6) $5 \cdot 10^{-4}$; for b) polyox $C_{\text{init}} = 10^{-4} \text{ g/cm}^3$; $U_{\text{av}} = 7.05 \text{ m/sec}$; 1) $t = 0.5 \text{ min}$; $S = 0.765$; 2) 7.0 and 0.6, respectively; 3) 38.0 and 0.4; 4) water.

on the basis of a special spectral and mutual spectral analysis of the instrument noises. The average and pulsation characteristics of the flow were recorded during the experiment and their relationship was studied. The average characteristics measured included the average flow velocity and the shear stress at the wall. In addition, profiles of the transverse distributions of the average velocity, and consequently any scale of the average flow, were known.* The intensity of the pressure pulsations at the wall of the tube and their power spectra and mutual spectra were chosen as the pulsation characteristics studied. It is known that polymer additions introduced into the stream distort the readings of a thermoanemometer used to measure the velocity pulsations. In this regard a pickup for the pressure pulsations at the wall which is mounted flush with the inner surface of the tube is more acceptable. And this, of course, had its own difficulties: the measured levels of the high-frequency pressure pulsations were distorted by the finite dimensions of the pickups. The magnitude of these distortions can be calculated, however, if the dimensionless mutual spectral functions of the pulsations are known. The spectral characteristics of flows of solutions obtained are very useful as a whole since these characteristics contain much more information than the overall pulsation intensity. In order to exclude the possibility of measuring random individual results, the characteristics of the average [1] and pulsation flows of streams of the solvent, water, were studied before the start of the experiments. Pressure pulsations in tubes have been measured much more rarely than in boundary layers. Of the published results one can mention only the results of the spectral analysis of Corcos [2] in an air stream for its velocities from 30 to 150 m/sec, and the data which have appeared recently in [3], [4]. In the latter case the measurements were conducted in a tube with a rectangular cross section. A comparison with the results of Corcos is presented in Fig. 1. The agreement of the intensity levels and the low-frequency pulsation spectra is fully satisfactory despite the great difference in experimental conditions. The disagreement of the spectral levels at high frequencies is explained by the difference in pickup sizes. The frequency range in the measurements was 0.2–20 kHz. The range of variation in average stream velocities was from 4 to 10 m/sec. All the characteristics enumerated

* From previous measurements of Yu. F. Ivanyuta and L. A. Chekalova.