THE EFFECT OF POLYMER ADDITIVES ON PRESSURE PULSATION IN A BOUNDARY LAYER

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The spectral components of pressure pulsation in the boundary layer of a plate supplied with an aqueous solution of polyoxyethylene are measured. The effects of concentration and supply rate of the solution are studied, together with transformation of the pressure pulsation spectrum along the plate.

Investigations of the Toms effect have shown that the mechanism of hydraulic resistance reduction by polymer additives is quite complex. Experiments performed with tubes and flows around bodies, measuring the resistance coefficient, average velocity profile, and tangent stresses have not given a complete clear understanding of the mechanism by which polymer additives affect the turbulent characteristics of flows. Recently, ever greater attention has been paid to the behavior of the pulsation characteristics of a turbulent boundary layer affected by polymer additives. Nevertheless, the studies [1, 2] did not sufficiently clarify the question of the effects of concentration, molecular weight, and supply rate of the polymer, as well as transformation of the pulsation characteristics along the body flowed over. This present study will offer the results of experimental investigations of the effect of polymer additives on the pressure pulsation spectrum in the boundary layer of a hydraulically smooth plate.

Measurements were made in a hydraulic tube 340 × 340 mm in section, inside of which was mounted a plate 1200 × 310 mm, 12 mm thick. The rate of flow around the plate was 9.0 m/sec. The polymer solutions were introduced near the front edge of the plate through a slit in a surface tangent to the plate. In Fig. 1 a schematic diagram of the working portion of the hydrodynamic tube with plate is shown. Polyoxyethylene of molecular weight $7 \cdot 10^6$ (P-1) and $2.5 \cdot 10^6$ (P-2) was used. Pressure fluctuations were measured by piezoceramic sensors with sensitive element diameter 4.0 mm, located flush with the plate surface. Sensor signals were recorded with a Brule and Kerr two channel instrumentation tape recorder, type 7001, in the frequency range 2-20,000 Hz.

Spectral analysis of the information was performed by a type 1461A Déiv spectral analyzer with bandwith of 7%, and recorded by a type 2305 Brule and Kerr chart recorder. The effect of the polymer

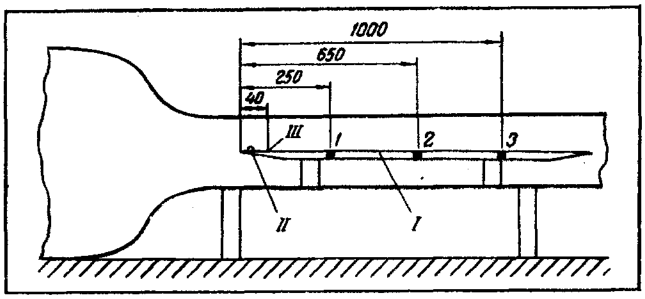

Fig. 1. Working portion of the hydrodynamic tube: I, plate; II, turbulizer; III, slit.

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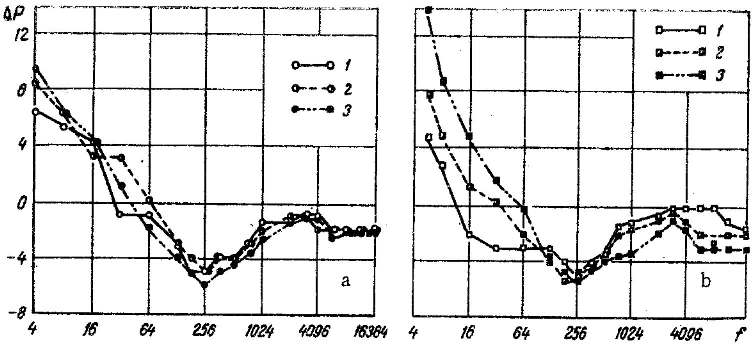

Fig. 2. Difference in level of spectral components of pressure pulsation ΔP (dB) versus frequency f (Hz) and: a) supply rate of polymer at constant concentration (1, Q = 140 cm^3/sec; 2, 240; 3, 340; polyox 1, $c = 5 \cdot 10^{-4}$, sensor 2); b) solution concentration at constant supply rate (1, $c = 62 \cdot 10^{-5}$; 2, $250 \cdot 10^{-5}$; 3, $1000 \cdot 10^{-5}$; polyox 1, Q = 340 cm^3/sec, sensor 2).

additives on pressure pulsation in the boundary layer was presented in the form of the difference in component spectral levels for introduction of the polymer and for pure water. A negative value of this difference corresponds to a reduction in spectral components; positive value, to increase.

It is evident from Figs. 2, 3, that the introduction of polyoxyethylene into the boundary layer changes the pressure pulsation spectrum over the entire frequency range studied. A peculiarity of polymer introduction through a slit is that in the low frequency range there occurs an increase in spectral components of pressure pulsation. At the same time a reduction in the component level at medium and high audio frequencies is observed. It should be noted that supply of water through the slit at the same rate as the polymer was supplied had no noticable effect on the pulsation pressure level over the entire frequency range studied.

The amount of the pressure pulsation reduction, as the experiments showed, was dependent on the supply rate, concentration, and molecular weight of the polymer introduced. In the supply rate range studied, the amount of pulsation reduction varied little. This is supported by the graphs of Fig. 2a. For example, increase in the supply rate by a factor of 2.5 at a concentration of $5 \cdot 10^{-4}$ increased the effectiveness of the polymer additive action by about 13%. It was observed that variation of the concentration of the polymer introduced exerts a greater influence on the pressure pulsation. Figure 2b shows the difference in pressure pulsation spectral component level as a function of polymer concentration (data from sensor 2). As is evident from the figure, increase in concentration from $6.2 \cdot 10^{-5}$ to 10^{-3} leads to an increase in spectral component level in the range 4-250 Hz, and a reduction in the range 250-20,000 Hz.

The transformation of the pressure pulsation spectrum along the plate was also studied. The results of these studies, performed with solutions of polyoxyethylene P-2 with molecular weight $M = 2.5 \cdot 10^6$, are presented in Fig. 3. During the measurements concentration, polymer supply rate, and flowby velocity were maintained constant. It was observed that with removal from the point of introduction the spectral

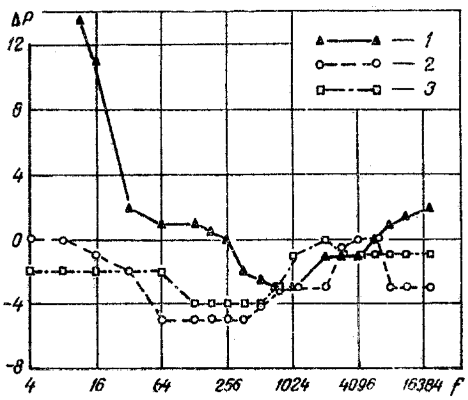

Fig. 3. Transformation spectrum of pressure pulsation ΔP (dB) versus f (Hz) along plate for constant supply rate Q (cm^3/sec) and concentration: 1) sensor 1; 2) 2; 3) 3; polyox 2; Q = 225 cm^3/sec, c = 5.

component level undergoes a transformation, namely, the polymer effectiveness increases in the low frequency range, while it falls at medium and high frequencies. It follows from Fig. 3 that the optimum polymer effect occurs in the area of the second sensor. Comparing the curves shown in Figs. 2a and 3, for polymers of differing molecular weight, at similar supply rates and concentrations, it can be seen that the effectiveness of the polymers differs only in the low frequency range; the low weight polymer decreases the pressure pulsation more effectively while the high weight polymer produces an increase.

LITERATURE CITED

1. I. F. Kadykov and L. M. Lyamshev, Akust. Zh., 16, 1 (1970).
2. E. M. Greshilov and A. V. Evtushenko, Tr. Akust. Inst., 17 (1971).