FLOW OF DILUTE POLYMER SOLUTIONS ALONG TUBING AND AROUND AN ENCLOSED DISC

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Measured results are presented for the hydrodynamic drag arising in the flow of water containing small amounts of polyoxyethylene or guar gum.

The hydrodynamic drag of aqueous solutions of the polyoxyethylene Polyox WSR-301 and of the guar gum J2-FP was investigated. The experiments were performed with two devices. One of them was built for the measurement of the hydrodynamic drag created in the flow around a smooth disc which rotated in a case, and the other, for the measurement of drag in a thin, smooth tube.

To rotate the case, a constant-current motor was used with an electromagnetic amplifier in a feedback circuit which made it possible to maintain a fixed rate of rotation even when there was a varying load moment on the rotor shaft. The rotations of the motor were measured by a photoelectric sensor connected to a digital frequency meter. The drive made it possible to maintain a given rate of rotation over the range 40 to 2600 rpm with 1% accuracy. The error in the measurement of rotations was no more than 0.5%. The moment of the hydrodynamic drag force was calculated from a measured force on a known arm. The magnitude of the force was measured by a capacity sensor with auxiliary equipment from the DISA company and recorded with a self-recording potentiometer. The construction of the sensor made it possible to

Fig. 1. Dependence of torque drag coefficient for a disc in a case on Reynolds number for (a) polyoxyethylene solutions of varying concentrations [1) c = 2.5·10⁻⁶; 2) 0.5·10⁻⁶; 3) 10⁻⁶; 4) 3·10⁻⁶; 5) 10⁻⁵; 6) water] and (b) guar gum solutions of varying concentrations [1) c = 5·10⁻⁷; 2) 10⁻⁴; 3) 2·10⁻⁴; 4) 5·10⁻⁴; 5) water].

Dependence of drag coefficient on Reynolds number for flow of polyoxyethylene solutions along tubing with 
d = 3 mm, unshaped entrance, and an initial section 60d long. 1) water; 2) c = 10^{-6}; 3) 2.5 \cdot 10^{-6}; 4) 5 \cdot 10^{-6}; 5) 10^{-5}; 6) 3 \cdot 10^{-5}; I) \lambda = 64/Re; II) \lambda = 0.3164/Re^{0.25}.

The flow in tubing was created by means of an expulsion device. Air pressure supplied from compressors could reach 18 atm. The internal diameter of the tubing was d = 3 mm. The portion in which the pressure drop was measured had a length of 30d. The tubing length from the measuring portion to the end of the tubing was 20d. Depending on the experiment, the tubing either had sharp edges at the entrance or was shaped for \sim 1.5d from the entrance. In both cases the initial section of the tubing was in the plane of the internal wall of the pressure tank. A regulating valve was located at the end of the tubing. The average velocity could reach \bar{u} = 30 m/sec. Flow was measured by the volume method with automatic measurement of flow time into a tared container. The accuracy of the time measurement was 0.01 sec. The pressure drop in the measuring section was recorded by means of two liquid differential manometers with a scale length of 200 cm. Mercury and carbon tetrachloride were used as working fluids in the manometers. Either manometer could be connected to the measuring section during an experiment. This provided a measurement of pressure loss from 2 cm to 25 m of water. Measurement error was no more than 1%.

Polyoxyethylene solutions were prepared by mixing the dry powder with water or by dilution of a concentrated solution no more than two hours before an experiment. The guar gum solutions were held for

![Fig. 2. Dependence of drag coefficient on Reynolds number for flow of polyoxyethylene solutions along tubing with d = 3 mm, unshaped entrance, and an initial section 60d long. 1) water; 2) c = 10^{-6}; 3) 2.5 \cdot 10^{-6}; 4) 5 \cdot 10^{-6}; 5) 10^{-5}; 6) 3 \cdot 10^{-5}; I) \lambda = 64/Re; II) \lambda = 0.3164/Re^{0.25}.](image1)

![Fig. 3. Dependence of drag coefficient on Reynolds number for a polyoxyethylene solution at a concentration c = 10^{-5} in tubing with d = 3 mm and various entrance conditions: 1) unshaped entrance, initial portion 60d; 2, 3, 4) shaped entrance, initial portions 185d, 275d, and 335d respectively. Solid symbols refer to polymer solution, open symbols to water.](image2)