EFFECT OF SMALL ADDITIONS OF SOLUBLE HIGH-MOLECULAR COMPOUNDS ON THE FLUID FLOW REGIME

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In a number of recent articles [1-4] data are given on experiments to reduce the resistance to turbulent flow in pipes and flow past obstacles by introducing into the flow small quantities of high-molecular compounds to form low-concentration solutions. However, the data available do not yet suffice for authorative resolution of the physical causes of this phenomenon. This article presents the results of experiments indicating that the cause of the above sharp reduction in pressure losses in turbulent fluid flows is a change in the character of the pulsating motion produced by the above additions.

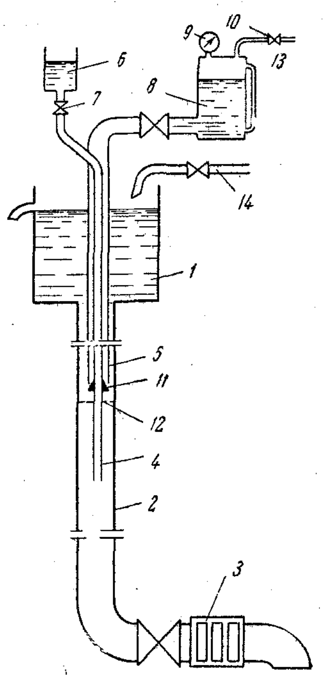

Fig. 1

The experimental apparatus (Fig. 1) consisted of a vertical cylindrical pipe 40 mm in diameter with a glass test section 1.2 m long for observing the character of the flow. At its upper end the pipe was connected to a supply tank 1, the liquid level in which during the experiment was maintained constant by supplying water through tube 14. From the lower end of the pipe the fluid flowed through a control valve to flowmeter 3. The flow velocity averaged over the cross section was determined on the basis of the measured flow rate per second.

In the upper part of the test section, along the axis, were mounted two concentric tubes—an inner tube 4, 3 mm in diameter, for supplying colored indicator fluid, and an outer tube, 5, 8 mm in diameter, for supplying the polymer solution. The indicator fluid was supplied from tank 6 and its volume was regulated by valve 7. The polymer solution was displaced from the special tank 8 by compressed air, which was supplied through tube 13. The compressed air pressure was controlled by manometer 9 and was adjusted by valve 10. To ensure uniform distribution of the polymer admixture, a tapered collar 11 and screen 12 made of 0.3 mm wire, mesh size 0.5 × 0.5 mm, were installed below the point where the polymer was introduced. The stream of colored indicator fluid was introduced into the flow below the screen at a distance of 300 to 400 mm (600-800 mesh units).

In the absence of polymer additions laminar flow changed to turbulent flow at Reynolds numbers $R = ul/\nu$ of approximately 2000-2100. Here u is the average flow velocity, determined by the flowmeter, l is the pipe diameter, and ν the kinematic viscosity.

In laminar flow the colored jet of fluid introduced through the indicator tube was straight and stable during any observation period.

The experimental prodecure was as follows. First, during laminar flow we carefully adjusted the flow rate of the stream of indicator fluid, which consisted of carefully filtered aqueous solutions of ink for automatic recording instruments or of brilliant green, in order to equalize the rates of flow of the stream and the moving fluid [5]. Under these conditions the colored stream had the same thickness throughout the entire test section of the pipe. Then the valve was used to increase the rate of flow of the fluid through the pipe cross section until the desired Reynolds number was obtained and the shape of the stream was photographed at 5 to 10 second intervals. Then the polymer solution was introduced further upstream and when the polymer solution, mixing with the fluid from the supply tank, had entirely filled the test section of the pipe, the shape of the indicator stream was photographed at the same time intervals.

It was observed that when the polymer solution was introduced, the shape of the stream changed sharply. The stream remained continuous over the entire observed length. The number of small protuberances and individual ejections of colored particles into the flow from the pipe axis sharply decreased. Large bends in the stream became smoother.

Typical experimental results are shown in Figs. 2 and 3. Figure 2, at the top of the page, shows the shape of the stream without polymer solution at $R = 3.2 \times 10^3$, and the same figure at the bottom of the page shows the corresponding changes in the stream shape after polymer solution was added to the flow. The volume concentration of solution in the test section of the pipe did not exceed 5×10^{-4}, and the viscosity of the solution was 1.2 centipoises. Figure 3 shows the results of the same experiment, but at R = 5300. At the top of the page are typical stream shapes without polymer solution, and at the bottom the changes produced by adding solution.

It should be noted that visual observations with increasing Reynolds number are rendered difficult by the fact that the irregularities in the indicator stream are carried rapidly downstream by the flow, and hence the picture is less clear.

The polymer additives used in the experiment consisted of aqueous solutions of polyvinyl alcohol and carboxymethylcellulose . The rate at which these solutions were introduced into the flow was lower than the rate of flow of the fluid in the pipe. The outflowing stream of colored polymer was constricted at the tapered collar and then uniformly scattered over the flow cross section.

The results of the above experiments indicate that the addition to the flow of small quantities of high-molecular compounds has a marked effect on the character of turbulent fluid flow, suppressing the pulsating motion, and particularly, the small-scale part of this motion.

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