ON THE HYDRODYNAMIC ACTION OF TRACES OF POLYMER ADDITIVES*

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Hydromechanics as a science has really never, since Newton till the middle of this century, extended beyond research on the flow of viscous fluids. Progress made in this area cannot possibly be exaggerated: fundamental equations have been formulated, the boundary-layer theory has been worked out, and many important problems in fast developing science and technology have been solved. Some difficulties still remain unresolved, however, owing to the great diversity of hydrodynamic phenomena and the mathematical intricacies involved in their description. The equations of a viscous fluid are essentially nonlinear and even their qualitative analysis alone is not easy. Meanwhile, these equations contain what is needed for establishing the conditions of flow instability, i.e., of random turbulent motion. Within the range where turbulence can be analyzed by exact methods there has not been accomplished much. The turbulence of a viscous fluid remains, as before, an unsolved problem in mechanics: a "blank spot."

Research in the field of hydromechanics has, in our century, been challenged repeatedly by scientific developments. It has become necessary to add even more complexity to the still not thoroughly analyzed viscous-fluid model. This model cannot always be used for describing the flow of real fluids. Another model has been introduced and used successfully for describing the flow of structurized media, a model with initial shear stress, while the earlier Maxwell model of a fluid with stress relaxation has provided the necessary impetus for developing the theory of media with memory and applying it to the flow of molten polymers or concentrated polymer solutions. Hydromechanics of plasma and magnetic fluids, flow with attendant chemical reactions, these are among the many complexities added to the viscous-fluid model.

The scope of classical hydromechanics must now be extended also to the flow fluids with traces of polymer additives. One can certainly obtain results here, and in some cases one already has obtained significant results of both scientific and practical value. So far, however, no consensus has been reached yet concerning the manner in which the classical viscous-fluid model should be modified so as to cover this specific case.

It is well known that traces of certain polymers can significantly affect a turbulent flow; the turbulent friction drag may be reduced if as little as a few parts per million of polymer are added to the solvent. Such a drag reduction is extraordinarily effective and easily reproducible. This effect can be utilized for reducing the drag associated with the motion of bodies in fluids, for reducing the drag in water, crude oil, fuel, or other liquids pumped through systems, also for extending the range of jets.

Turbulent heat and mass transfer is also substantially affected by traces of polymer additives, and this too is very important in engineering applications.

Traces of polymers serve as a delicate instrument in the study of changes in the turbulence pattern. Turbulence in a boundary layer has been studied for years and the results indicate that narrow regions in the boundary layer at the wall play the decisive role in the behavior of the entire turbulent stream. Traces of dissolved polymer affect these regions foremost, and only changes occurring here do, in turn, effect changes in the overall turbulence pattern.

*The opening address by Academician A. Yu. Ishlinskii, member of the USSR Academy of Sciences, to the All-Union seminar on the hydrodynamic action of polymer additives (a chronicle of this seminar appears on p. 1559).

Translated from Inzhenerno-Fizicheskii Zhurnal, Vol. 25, No. 6, pp. 965-966, December, 1973.

The anomalous (in terms of classical hydrodynamics) properties of dilute polymer solutions become evident not only in turbulent boundary layers but also during transient laminar flow, in flow patterns with curved streamlines, etc. Instruments used in classical hydrodynamic experiments, namely Pitot tubes and thermoanemometers, also behave anomalously here.

There is reason to believe that not all hydrodynamic effects related to dilute polymer solutions have been discovered yet. A new effect, different in nature, has in fact been discovered recently by the staff of our Institute and will be reported at this seminar. This effect is that of piercing steel barriers by water jets containing traces of polymer additive, under pressures which would be too low for achieving the same result with pure water.

The diversity of hydrodynamic effects is due to the structural chracteristics of polymer solutions. This explains why more attention is paid to research concerning the structure of solutions, especially on the supermolecular level.

Research in the hydromechanics of dilute polymer solutions is complex. We have no reliable basic knowledge on hand yet pertaining to the hydromechanics or, more precisely, to the turbulence of a viscous fluid and pertaining to the physics of polymer solutions. Any results obtained in these two areas will be the more valuable, therefore, the better they can be used also for solving classical problems.

The vast accumulated material, the rapid appearance of new data and new ideas, all this calls for modern and effective means of exhanging information about the hydromechanical action of traces of polymer additives. That, essentially, was the purpose of organizing the All-Union seminar in which Soviet experts in this field will participate together for the first time.