MECHANICS

I. G. BULINA and V. G. SAVIN

1962

SovietRxiv

Abstract

Full Text

MECHANICS

I. G. BULINA and V. G. SAVIN

FORMATION OF A FORWARD STAGNATION ZONE IN THE FLOW AROUND BLUNT BODIES BY A VISCO-PLASTIC FLUID

(Presented by Academician L. I. Sedov, 10 February 1962)

Problems concerning the flow of visco-plastic fluids around bodies have recently attracted a certain amount of attention from researchers. In the book by A. Kh. Mirzadzhanzade ([1]) a detailed analysis is given of the present state of theoretical and experimental investigations in this field.

In the Hydrophysical Laboratory of Moscow University the authors carried out an experimental investigation of the flow of a visco-plastic fluid around blunt bodies. As a result of the investigation, the existence, under certain conditions, of a forward stagnation zone was discovered—an circumstance that fundamentally distinguishes the flow around bodies by visco-plastic fluids from the flow around them by ordinary fluids. The existence of a forward stagnation zone in the flow around bodies by visco-plastic fluids is dictated by certain natural theoretical considerations. As is known ([2], [3]), in the hydrodynamics of an ideal fluid, schemes of jet flow around blunt bodies with the formation of a forward stagnation zone have been considered; however, schemes of this kind are not realized in the flow around bodies by ordinary fluids.

In our experiments, the flow was produced by drawing the bodies through an open Plexiglas trough filled with a visco-plastic fluid, of dimensions $15 \times 12 \times 240$ cm. To ensure uniform drawing of the body and to mount the motion-picture and photographic apparatus, a special carriage was used, moving along rails installed above the trough. On the carriage were mounted a scale probe with the body under investigation, a motion-picture or still camera, and two illuminating lamps. The carriage was drawn by a cable wound onto an interchangeable pulley, which was driven by a direct-current electric motor through a reducer having two shafts. The installation made it possible to obtain drawing speeds within the range from 0.01 to 150 cm/sec, while providing satisfactory uniformity of motion.

The fluid was a hydrosuspension of gray clay with specific gravity 1.40 g/cm^3, possessing well-pronounced properties of a visco-plastic medium (yield shear stress 430 dyn/cm^2, structural viscosity 190 poise); the characteristics of the fluid were determined by the standard method on an RV-8 viscometer at a rotor rotation speed equal to the speed of motion of the body in the experiments presented in photographs Figs. 1–4. The bodies investigated had various shapes: a rectangular bar, a rectangular bar with an oblique cut, a semicircular bar with a symmetrically cut-off segment, a rectangular bar with a wedge-shaped front part, and others. The depth to which the trough was filled with fluid was 7.8 cm, the depth of immersion of the body 7.0 cm, and the width of the midship section of the body was 3.5 cm.

The bodies under investigation were drawn through the stationary fluid at various speeds from one part of the trough to another, in which the free surface of the fluid was covered with a thin layer of chalk powder and was strongly distinguished by its white color from the dark remaining part of the free surface.

During the motion of the body it was clearly observed that the region of liquid covered with chalk powder is cut through by a previously formed stagnant zone in front of the body, the liquid in which is motionless relative to the body. When the body moves forward, the stagnant zone is deformed very weakly. Figs. 1–3 show typical photographs of the front stagnant regions obtained in flow: in Fig. 1—for a body with a symmetrically truncated semicircular head part; in Fig. 2 —for a rectangular bar with an oblique cut.

Fig. 1
Fig. 1

Fig. 2
Fig. 2

The velocity of motion in these experiments was 0.35 cm/sec. For the latter case, which is of special interest, the flow pattern in plan view is presented in the photograph in Fig. 3. It is curious that in this case the stagnant zone, as it were, supplements the body being flowed around to an almost symmetric one.

Fig. 3
Fig. 3

Fig. 4
Fig. 4

Fig. 4 presents a photograph, taken from another series of experiments, in plan view, of the formation of the front stagnant region for a body of rectangular shape; moreover, instead of a continuous chalk coating on the surface of the liquid, in this series of experiments parallel straight lines were drawn with chalk, perpendicular to the direction of motion, which makes it possible to represent the flow pattern more clearly. In this case the velocity of motion of the body was 0.75 cm/sec, the specific weight of the suspension 1.5 g/cm^3, the structural viscosity 310 poise, and the yield shear stress 480 dyn/cm^2.

The experiments showed that both the size and the shape of the front stagnant zone depend on the velocity of motion: with increasing velocity in the investigated range, the stagnant zone decreases somewhat. It is essential, however, that even when the velocity was increased by more than an order of magnitude, the change in the front stagnant zone proved insignificant. It is noteworthy that, in a certain range of velocities, the stagnant zone on a body with a wedge-shaped head part began periodically to grow and to be washed away, which to a certain extent resembles the periodic motions in the wake behind poorly streamlined bodies in an ordinary liquid.

The presence of a front stagnant zone must be taken into account when considering theoretical schemes for the flow of viscoplastic fluids around blunt bodies.

The authors express their gratitude to G. I. Barenblatt, at whose suggestion the present work was carried out, for valuable advice.

Moscow State University
named after M. V. Lomonosov

Received
9 II 1962

REFERENCES

1. A. Kh. Mirzadzhanzade, *Problems of the Hydrodynamics of Viscoplastic and Viscous Fluids in Oil Production*, Baku, 1959.

2. S. A. Chaplygin, *Collected Works*, 2, Moscow–Leningrad, 1948, p. 5.

3. L. I. Sedov, *Plane Problems of Hydrodynamics and Aerodynamics*, Moscow–Leningrad, 1950.

Note: Figure translations are in progress. See original paper for figures.