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Abstract

Full Text

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HYDROMECHANICS

Corresponding Member of the Academy of Sciences of the USSR I. I. NOVIKOV

EXPERIMENTAL DETERMINATION OF THE PROPAGATION VELOCITY OF LONG CENTRIFUGAL WAVES FORMED IN A TRANSLATIONAL-ROTATIONAL FLOW OF A LIQUID

In an axisymmetric translational-rotational flow of an incompressible liquid with a stationary gas vortex on the axis of the channel (such a flow arises, for example, when a liquid is introduced tangentially into a cylindrical channel), transverse waves are formed and propagate on the free surface of the liquid, i.e., the surface bounding the vortex; these waves are analogous to gravitational waves on the surface of water, but differ in that they are caused by the action not of gravitational forces, but of centrifugal forces.

The existence of these centrifugal waves was first pointed out by the author as early as 1945. In particular, from a comparison of the equation of a quasi-two-dimensional flow of liquid in a tube

$$\frac{1}{w} \left[w^2 - \frac{w^2}{2r^2} \left(\frac{D^2}{4} - r^2 \right) \right] \frac{dw}{dx} = -\frac{\xi w^2}{D}$$

and the wave equation for the motion of liquid particles on the free surface at r close to $D/2$,

$$\frac{\partial^2 r}{\partial t^2} - \frac{w^2}{2r^2} \left(\frac{D^2}{4} - r^2 \right) \frac{\partial^2 r}{\partial x^2} = 0$$

it was concluded that the critical velocity of the liquid flow through the tube is the propagation velocity of long centrifugal waves, equal to

$$a = \frac{w}{r} \sqrt{\frac{1}{2} \left(\frac{D^2}{4} - r^2 \right)}.$$

Fig. 1. Dependence between w and a . The straight line is theory, the points are experiment

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Here w is the velocity of the translational flow of the liquid along a tube of diameter D , whose axis coincides with the OX axis; w is the velocity of the rotational motion of the liquid on the surface of a gas vortex of radius r ; r is the radius of the free surface of the liquid; ξ is the coefficient of resistance of the tube.

Although the author's theoretical considerations on the existence, in a translational-rotational flow of an incompressible liquid, of long centrifugal waves have found circulation in the literature (see, for example, ⁽¹⁾), nevertheless no direct measurements of the propagation velocity of long centrifugal waves had been made until recently. In this connection, in 1966-1967 the author, together with N. A. Boryakov, carried out experiments to determine the indicated velocity. The idea of these experiments consisted in measuring the velocity of the liquid along the tube axis in translational-rotational liquid flow at the crisis point, where $\partial w / \partial x \rightarrow \infty$.

The latter is characterized by a sharp change in the radius of the gas vortex and is therefore recorded very accurately.

From measurements of the thickness of the liquid layer at the crisis point and of the quantity of liquid flowing through, the radius of the gas vortex and the critical velocity of the liquid flow along the axis, w_{cr} , were determined; and from measurements of the pressure drop of the liquid at the wall of the tube and at the boundary with the gas vortex, taking into account the constancy of the angular momentum in the given cross section—the rotational velocity of the liquid, w_v , at the surface of the gas vortex was determined. Using the found values of r_v and w_v at the crisis point, the propagation velocity of long centrifugal waves was calculated with the aid of the formula given above for a_c .

The results of the experiments are presented in Fig. 1, where the vertical axis gives the experimental values of w_{cr} , and the horizontal axis gives the values of a_c .

It is clear that if, as the theory predicts, $w_{cr} = a_c$, then all experimental points should lie on the bisector of the coordinate angle; this is indeed observed.

Thus, the present experiments experimentally confirm both the very existence, in a translational-rotational flow of liquid, of long centrifugal waves, and the theoretical formula for the propagation velocity of these waves.

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CITED LITERATURE

1. V. A. Borodin, I. F. Dityakin et al., *Atomization of Liquids*, 1967.

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

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