Turbulent and Laminar Regime of Liquid Movement

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ABSTRACT

This article describes the turbulent and laminar modes of hydrodynamic fluid motion, the effects on solids and liquids, and the effects of minimal tangential forces.

Keywords: Hydrodynamics, laminar, turbulent, tangential forces, matter, fluid properties, compressibility.

Hydrodynamics is the most important branch of physics that studies the laws of fluid motion under external conditions. An important issue to consider in hydrodynamics is the determination of laminar and turbulent flow of fluid.

What is a liquid?

To better understand the issue of laminar and turbulent fluid flow, it is first necessary to consider what this substance is. Fluid is called one of the 3 aggregate states of matter in physics, it is able to maintain its volume under given conditions, but under the influence of minimal tangential forces it changes its shape and begins to flow. Unlike a solid, a liquid has no resistance to external influences, they tend to return to their original shape. The difference between a liquid and a gas is that it is able to maintain its volume at a constant external pressure and temperature.

Parameters describing the properties of liquids

The problem of laminar and turbulent flow is determined, on the one hand, by the properties of the system under consideration of fluid motion and, on the other hand, by the properties of the liquid substance. Here are the main properties of liquids:

Density. Any liquid is homogeneous, so this physical quantity, which represents the amount of mass per unit volume of liquid substance, is used to describe it.

Stickiness. This value describes the friction that occurs between different layers of a fluid during its flow. Since the potential energy of molecules in liquids is approximately equal to their kinetic energy, it results in the presence of a certain viscosity in any real liquid substance. This property of liquids is the reason for the loss of energy during their flow.

Compression ability. As the external pressure increases, any liquid substance decreases in volume, but for liquids this pressure must be large enough to slightly reduce the volume they occupy, so that in many practical cases this state of aggregation is not compressed.

Surface tension. This value is determined by the work that must be expended to form the unit surface of the liquid. The presence of surface tension is related to the presence of intermolecular interaction forces in liquids, which determines their capillary properties.

Laminar flow

By studying the problem of turbulent and laminar flow, we consider the latter first. If there is a pressure difference at the ends of this pipe for the liquid in the pipe, then it will start to flow. If the flow of a substance is calm and each of its layers moves along a smooth trajectory that does not cross the lines of motion of the other layers, then we are talking about a laminar flow regime. During it, each liquid molecule moves along a certain trajectory along the pipe.

The characteristics of laminar flow are:

There is no mixing between the individual layers of liquid. The layers closest to the axis of the pipe move at a higher speed than those around it. This fact is due to the presence of frictional forces between the liquid molecules and the inner surface of the pipe.

As an example of laminar flow, there are parallel streams of water flowing out of the shower. If a few drops of dye are added to the laminar flow, it can be seen how they are drawn into the flow, which continues the smooth flow without interfering with the main part of the liquid.

Turbulent flow

This mode is radically different from laminar. Turbulent flow is a chaotic flow in which each molecule moves along an arbitrary trajectory, which can only be predicted at the first moment of time. This mode is characterized by small amounts of twists and circular motions in the fluid flow. Nevertheless, despite the randomness of the trajectories of the individual molecules, the total flow moves in a certain direction and this velocity can be characterized by some average value. An example of a turbulent flow is the flow of water in a mountain river. If the dye falls into such a stream, it can be seen that a stream appears in the first minute, it begins to experience distortions and fine rotations, and then mixes with the whole volume of the liquid and disappears.

What determines fluid flow?

Laminar or turbulent flow regimes depend on the ratio of two quantities: the viscosity of the liquid substance, which determines the friction between the fluid layers, and the inertial forces that characterize the flow rate. The lower the viscosity of the material and its flow rate, the higher the probability of laminar flow. Conversely, if the viscosity of the fluid is low and its velocity is high, then the flow will be turbulent.

Below is a video that clearly explains the characteristics of the modes of flow of the substance under consideration. How to determine the flow mode?

For practice, this question is very important because the answer to it depends on the properties of motion of bodies in a liquid environment and the magnitude of energy losses.

The transition between laminar and turbulent fluid flow can be estimated using Reynolds numbers. They are immeasurable quantities and are named in honor of Osborne Reynolds, an Irish engineer and physicist who proposed their use in practice in the late 19th century to determine the mode of motion of a liquid substance.

The Reynolds number (laminar and turbulent flow of fluid in a pipe) can be calculated using the following formula: $Re = r * D * v / m$, where r and m are the densities and viscosities of the substance, v. the average velocity of its flow, D - diameter pipes. In the formula, the numerator reflects the inertial forces or currents and determines the frictional forces or stickiness of the friction. From this we can conclude that if the Reynolds number for the system under consideration is large, the fluid will flow in a turbulent mode and conversely, small Reynolds numbers indicate the presence of laminar flow.

Specific meanings of Reynolds numbers and their use

As mentioned above, the Reynolds number can be used to determine laminar and turbulent flow. The problem is that this depends on the characteristics of the system, for example, if there are irregularities on the inner surface of the pipe, the turbulent flow of water in it starts at a lower flow rate than smooth.1

Numerous experimental statistics have shown that, regardless of the system and nature of the fluid, if the Reynolds number is less than 2000, then laminar motion occurs, but if it is greater than 4000, the flow is turbulent . Intermediate values of the numbers (2000 to 4000) indicate the presence of a transition mode. These Reynolds numbers are used to determine the motion of various technical objects and apparatus in a liquid medium, to study the flow of water through pipes of different shapes, and also play an important role in the study of certain biological processes, such as motion. microorganisms in human blood vessels. Turbulent flow is characterized by rapid and random oscillations of velocity, pressure, and concentration around their mean values. These oscillations are, as a rule, of interest only in the statistical description of the systems. Therefore, as a first step in the study of turbulent flow, equations for the average quantities that characterize the flow are usually considered. In this case, differential equations containing higher order moments are obtained for some average values. Thus, this method does not allow any direct calculation of the average. The problem of turbulent flow has a direct similarity in the kinetic theory of gases, where the details of the random motion of molecules are insignificant and only some moderately measured quantities are of interest.2

In most cases it is possible to find a simple solution of the motion equation (94-4) describing the laminar flow, but the observed flow is turbulent in this case. This situation led to the study of the stability of laminar flow. The problem of flow stability is structured as follows: if the flow is disturbed by an infinitely small value, will the distortion increase in space and time, or will it disappear and the flow become laminar? This question is usually solved by making the problem linear close to the basic, laminar solution.

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