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Some basics of fluid Dynamics for young mind

Dr. Harish Kumar, Associate professor
Department of Mathematics, SNKP Govt College, Neem Ka Thana,
District - Sikar, Rajasthan Pin – 332713

Abstract: The behaviour of fluids under the influence of various forces was the focus of fluid mechanics. The information for the analysis and design of a system in which fluid is a working medium is provided by fluid mechanics. Such systems are employed in a variety of fields, including vehicles, hydraulic equipment, and hemodynamic. Therefore, certain key terminology are defined in this essay to help readers understand the idea of fluid dynamics.

Introduction: First we define the fluid, then types of fluid and fluid properties are given.

Fluid: It is defined as a substance which must continue to change shape as long as there is a shear stress however small present.

Fluid as a continuum: All fluids are made up of molecules which are separated from each other by spaces. At the microscopic level, the properties of fluids cannot be defined in these spaces due to non-existence of mass. To overcome these difficulties, a fluid is regarded as a continuum i.e. a hypothetical continuous substance. The study model on continuum hypothesis breaks down whenever the mean free path of the molecules approaches the smallest characteristic dimension of the problem under consideration.

Fluid Properties: Manifestations which are primarily characteristic of a particular fluid and not the manner of the flow are called fluid properties. Viscosity and surface tension are examples of fluid properties, whereas pressure and density of gases are primarily flow-dependent and hence are not considered fluid properties.

Types of Fluids:

(i) Ideal Fluid: An ideal fluid is one that is incompressible and has no viscosity i.e.

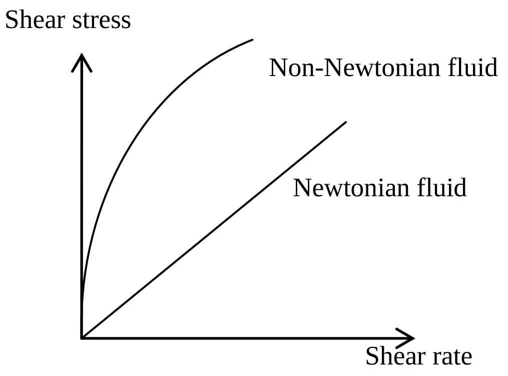
$$\text{Ideal Fluid Flow}: \begin{cases} \text{Inviscid Fluid} & \nu = 0 \\ \text{Incompressible Flow} & \dfrac{d\rho}{dt} = 0 \quad \text{or } \nabla.\bar{v} = 0 \end{cases}$$

It is termed as inviscid fluid. No real fluid is inviscid. In flat-plate, the flow at a sufficiently large distance from the plate, fluid will behave as a non-viscous flow system. The reason for this behaviour is that the velocity gradient normal to the flow direction is very small and hence the viscous-shear forces are small.

Viscous Fluid : Fluid in which friction (viscosity) has significant effect on the solution. The inclusion of the frictional forces in the fluid layers was lying on following observation. When a sphere moves with uniform velocity in an ideal fluid at rest at infinity or fluid past through a sphere at rest, there was no drag observed on the sphere. This result was not simply a consequence of the symmetrical shape of the sphere, but a body of the arbitrary shape at rest in a uniform stream or moving uniformly through a fluid at rest experiences no force. The inability of an ideal fluid to produce a force in such circumstances is known as D'Alembert's Paradox. But in real situations this is not possible. Therefore, ideal fluid theory does not explain adequately drag on the rigid body in the fluid. In this connection to explain the drag, the concept of viscous fluid theory was introduced by Prandtl (1904).

If fluid is located between two parallel plates, the ratio of the shear force F to the contact area between the liquid and the plate give rise to the *shear stress*.

ratio of the relative velocity of the top and bottom plate with the distance between the plate is called *shear rate*.



The viscosity of the fluid is defined as the ratio of the shear stress and shear rate. Thus the slope of the relation between shear-stress and shear-rate gives the viscosity (η). If the plot between shear-stress and shear-rate is a straight line, the fluid is Newtonian, otherwise, it is non-Newtonian.

Incompressible Fluid: If density of the fluid under static condition undergo very little change despite the existence of large pressures. These fluids are invariably in the liquid state for such behaviour. For incompressible fluid it is assumed that during computation of such type of fluid, density is constant.

Compressible Fluid: A fluid is called compressible, if the pressure variation in the flow field are large enough to effect substantial change in the density of fluid.

Newtonian Fluid :- A fluid which obey Newtonian's law of viscosity i.e. A fluid for which shear force per unit area is proportional to the negative of the local velocity gradient.

$$\tau_{yx} = -\mu \frac{dv_x}{dy}$$

where

$\tau_{yx} \rightarrow$ shear stress exerted in the x-direction

$\mu \rightarrow$ viscosity

$v_x \rightarrow$ velocity of the fluid along x-axis.

(vi) Non-Newtonian Fluid: Fluids, those doesn't obey Newton's law of viscosity are known as non-Newtonian fluid.

The power law is one way to describe the behaviour of Non-Newtonian fluids

$$\tau = k\left(\frac{dv}{dy}\right)^n$$

for $n < 1$, fluid is called 'pseudoplastic' and for $n > 1$, the fluid is called 'dilatant'.

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