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CHE 331

**CLASSIFICATION OF FLUID FLOW**

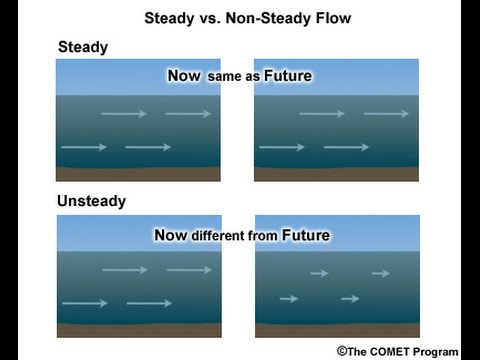
When a fluid flows past a point or through a path different parameters associated with the flow of the fluid, certain parameters vary and others may remain constant.

The two basic parameters of any fluid flow are velocity of the fluid particle or element and the pressure of the fluid at the point under consideration. The flow of fluids can be classified in different patterns based on the variation of the flow parameters with time and distance. The benefit of characterizing the fluid flow as certain patterns helps in analyzing it under the appropriate solution paradigm.

STEADY AND UNSTEADY FLOW

The classification of the fluid flow based on the variation of the fluid flow parameters with time characterizes the flow in two categories, steady and unsteady flow. If the flow parameters, such as velocity, pressure, density and discharge do not vary with time or are independent of time then the flow is steady. If the flow parameters vary with time then the flow is categorized as unsteady.

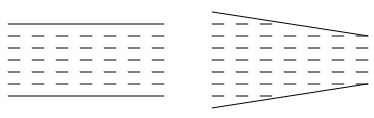
In real conditions it is very rare to have such flows with parameters exactly constant with time. The parameters usually vary with time but variation is within a small range such as the average of particular parameter is constant for certain duration of time.



UNIFORM AND NON UNIFORM FLOW

The other classification criterion for the fluid flow is based on the variation of the flow parameters with distance or space. It characterizes the flow as uniform or non-uniform. The fluid flow is a uniform flow if the flow parameters remain constant with distance along the flow path. And the fluid flow is non-uniform if the flow parameters vary and are different at different points on the flow path.

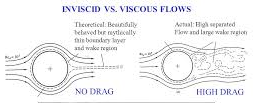
For a uniform flow, by its definition, the area of the cross section of the flow should remain constant. So a fitting example of the uniform flow is the flow of a liquid thorough a pipeline of constant diameter. And contrary to this the flow through a pipeline of variable diameter would be necessarily non-uniform.



Uniform and non-uniform flow

VISCOUS AND INVISCID FLOW

When two fluid layers move relative to each other, a friction force develops between them and the slower layer tries to slow down the faster layer. This internal resistance to flow is called the viscosity, which is a measure of internal stickiness of the fluid. Viscosity is caused by cohesive forces between the molecules in liquids, and by molecular collisions in gases. There is no fluid with zero viscosity, and thus all fluid flows involve viscous effects to some degree. Flows in which the effects of viscosity are significant are called viscous flows. However, in many flows of practical interest, there are regions (typically regions not close to solid surfaces) where viscous forces are negligibly small compared to inertial or pressure forces. Neglecting the viscous terms in such inviscid flow regions greatly simplifies the analysis without much loss in accuracy.



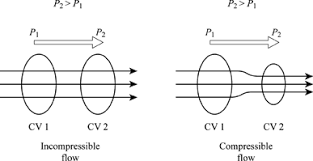
Inviscid and viscous flows

COMPRESSIBLE AND INCOMPRESSIBLE FLOW

A fluid flow is classified as being compressible or incompressible, depending on the density variation of the fluid during flow. The densities of liquids are essentially constant, and thus the flow of liquids is typically incompressible. Therefore, liquids are usually classified as incompressible substances. A pressure of 210 atm, for example, causes the density of liquid water at 1 atm to change by just 1 percent. Gases, on the other hand, are highly compressible. A

pressure change of just 0.01 atm, for example, causes a change of 1 percent in the density of atmospheric air. However, gas flows can be treated as incompressible if the density changes are under about 5 percent, which is usually the case when the flow velocity is less than 30 percent of the speed of sound in that gas (i.e., the Mach number of flow is less than 0.3). The speed of sound in air at room temperature is 346 m/s. Therefore, the compressibility effects of air can be neglected at speeds under about 100 m/s. Note that the flow of a gas is not necessarily a compressible flow.

Small density changes of liquids corresponding to large pressure changes can still have important consequences. The irritating “water hammer” in water pipes, for example, is caused by the vibrations of the pipe generated by the reflection of pressure waves following the sudden closing of the valves.



Incompressible and Compressible flow

ROTATIONAL AND IRROTATIONAL FLOW

To classify any flow as Rotational or Irrotational the angular motion of the fluid elements is analyzed. If the angle between the two intersecting lines of the boundary of the fluid element changes while moving in the flow, then the flow is a Rotational Flow. But if the fluid element rotates as a whole and there is no change in angles between the boundary lines then the flow cannot be Rotational Flow, so it is Irrotational Flow.

This means that there should be some deformation in the fluid element in a Rotational Flow. Such deformation of the fluid element or the shear strain is necessarily caused by tangential forces or shear stresses. Shear stresses are caused by viscosity, thus the flow of viscous fluids is rotational. But this does not mean that the flow of non-viscous or ideal fluid is always irrotational. The flow of ideal fluids can be rotational by external work or heat interaction.

