REYNOLD'S EXPERIMENT

As we are aware that for determining the type of flow we use to calculate the Reynolds number and on the basis of Reynolds number we use to decide the flow type. So let us see here the basics behind the determination of type of flow based on the Reynolds number.

Value for Reynolds number might be calculated with the help of following formula

$$Re = \rho V D / \mu$$

Where,

V = Flow velocity of the Hydraulic fluid i.e. liquid (m/s)D

= Diameter of pipe (m)

μ = viscosity (poise)

O Reynold had explained this concept with one experiment, which is explained here, in 1883. Reynold had concluded that transition from laminar flow to turbulent flow in a pipe depends not only on the velocity but also it depends on the diameter of the pipe and viscosity of the fluid flowing through the pipe.

Reynolds experiment apparatus

Apparatus for Reynolds experiment are as mentioned here

1. A tank containing water at constant head

3. A glass tube with bell-mouthed entrance at one end and a regulating valve at otherend

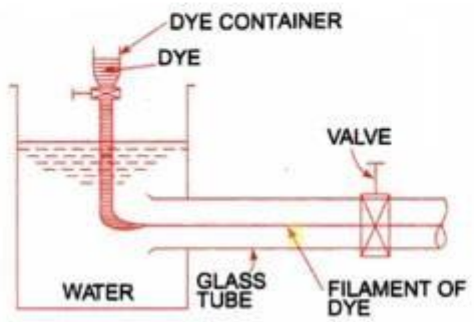


Figure 4.1.1 Apparatus for Reynolds experiment

[Source: "Fluid Mechanics and Hydraulics Machines" by Dr.R.K.Bansal, Page: 442]

Now we will allow water to pass through the glass tube from the water tank. Regulating valve is provided here to vary the velocity of water flowing through the glass tube.

We will introduce a liquid dye, of having same specific weight as of water, in to the glass tube as displayed here in following figure.

Observations made by Reynold

Observation I

When velocity of water flow is low, dye filament will be in the form of straight line in the glass tube. It could be seen in the glass tube that dye filament is in the form of straight line and parallel to the wall of glass tube.

Above condition is the example of laminar fluid flow. Therefore at lower velocity of water flow through the glass tube, the type of water flow will be laminar.

Following figure, displayed here as figure a, indicates the case of water flow through the glass tube at low velocity of water flow.

(a) Laminar flow

Observation II

Now velocity of flow is increased with the help of regulating valve. Dye filament will not be in the form of straight line in the glass tube. It could be seen in the glass tube that dye filament is in the form of wavy one now.

Above condition is the example of transition of fluid flow. Therefore when velocity of water flow through the glass tube is increased, the type of water flow will be transition flow. Transition flow means the flow between laminar flow and turbulent flow.

Following figure, displayed here as figure b, indicates the case of transition flow through the glass tube.

(b) Transition

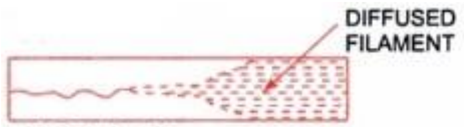
Observation III

Now velocity of flow is increased again with the help of regulating valve. Wavy dye filament will be broken and finally diffused in the water as displayed here in following figure.

It could be seen in the glass tube that particles of dye filament liquid are moving in random and irregular fashion at this higher velocity of water flow. Mixing of particles of water and dye filament is intense and water flow will be random, irregular and disorderly.

Above condition is the example of turbulent fluid flow. Therefore when velocity of water flow will be higher, the type of water flow will be turbulent flow.

Following figure, displayed here as figure c, indicates the case of turbulent flow through the glass tube.



(c) Turbulent flow

In case of laminar fluid flow, loss of pressure head will be proportional to the velocity of fluid flow.

The Reynolds number is a very useful parameter in predicting whether the flow is laminar or turbulent.

1. Re < 2000 viscous / laminar flow
2. Re 2000 to 4000 Transient flow
3. Re > 4000 Turbulent flow

Laminar flow through circular pipe

In this case the boundary layer develops all over the circumference. The initial development of the boundary layer is similar to that over the flat plate. At some distance from the entrance, the boundary layers merge and further changes in velocity distribution becomes impossible. The velocity profile beyond this point remains unchanged. The distance upto this point is known as entry length. It is about 0.04 Re × D. The flow beyond is said to be fully developed. The velocity profiles in the entry region and fully developed region are shown in Fig. 3.3.1a. The laminar or turbulent nature of the flow was first investigated by Osborn Reynolds in honour of whom the dimensionless ratio of inertia to viscous forces is named. The flow was observed to be laminar till a Reynolds number value of about 2300. The Reynolds number is calculated on the basis of diameter (ud/v).

In pipe flow it is not a function of length. As long as the diameter is constant, the Reynolds number depends on the velocity for a given flow. Hence the value of velocity determines the nature of flow in pipes for a given fluid. The value of the flow Reynolds number is decided by the diameter and the velocity and hence it is decided at the entry itself. The development of boundary layer in the turbulent range is shown in Fig. 2.3.1b. In this case, there is a very short length in which the flow is laminar. This length, x, can be calculated using the relation ux/v = 2000. After this length the flow in the boundary layer turns turbulent. A very thin laminar sublayer near the wall in which the velocity gradient is linear is present all through. After some length the boundary layers merge and the flow becomes fully developed. The entry length in turbulent flow is about 10 to 60 times the diameter.

LAMINAR FLOW THROUGH CIRCULAR PIPE

Boundary layer is the region near a solid where the fluid motion is affected by the solid boundary. In the bulk of the fluid the flow is usually governed by the theory of ideal fluids. By contrast, viscosity is important in the boundary layer. The division of the problem of flow past an solid object into these two parts, as suggested by Prandtl in 1904 has proved to be of fundamental importance in fluid mechanics.

This concept of hydraulic gradient line and total energy line is very useful in the study of flow This concept of hydraulic gradient line and total energy line is very useful in the study of flow of fluids through pipes. f fluids through pipes

HYDRAULIC GRADIENT AND TOTAL ENERGY LINE

1.Hydraulic Gradient Line

It is defined as the line which gives the sum of pressure head (p/w) and datum head (z) of a flowing fluid in a pipe with respect to some reference line or it is the line which is obtained by joining the top of all vertical ordinates, showing the pressure head (p/w) of a flowing fluid in a pipe from the centre of the pipe. It is briefly written as H.G.L (Hydraulic Gradient Line).

2.Total Energy Line

It is defined as the line which gives the sum of pressure head, datum head and kinetic head of a flowing fluid in a pipe with respect to some reference line. It is also defined as the line which is obtained by joining the tops of all vertical ordinates showing the sum of pressure head and kinetic head from the centre of the pipe. It is briefly written as T.E.L (Total Energy Line).

1 FLOW OF VISCOUS FLUID THROUGH CIRCULAR PIPE

For the flow of viscous fluid through circular pipe, the velocity distribution across a section, the ratio of maximum velocity to average velocity, the shear stress distribution and drop of pressure fora given length is to be determined. The flow through circular pipe will be viscous or laminar, if the Reynold's number is less than 2000.

Due to viscosity of the flowing fluid in a laminar flow,some losses of head take place.The equation which gives us the value of loss of head due to viscosity in a laminar flow is known as Hagen-Poiseuille's law.

$$p1-p2=32\mu UL/D^2$$

$$=128\mu QL/\pi D4$$

This equation is called as Hargen-Poiseuille equation for laminar flow in the circular pipes.

DARCY'S EQUATION FOR LOSS OF HEAD DUE TO FRICTION IN PIPE

A pipe is a closed conduit through which the fluid flows under pressure.When the fluid flows through the piping system,some of the potential energy is lost due to friction.

$$h_f=4fLv^2/2gD$$