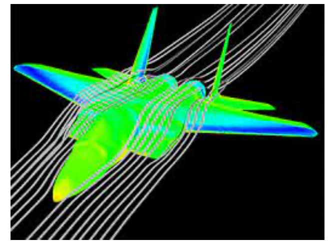
Chapter five: FLUID DYNAMICS



5.1. Introduction

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Highlights

Objective Type Questions Theoretical Questions Unsolved Examples

5.1. INTRODUCTION

When the fluids are at rest, the only fluid property of significance is the specific weight of the fluids. On the other hand, when a fluid is in motion various other fluid properties become significant, as such the nature of flow of a real fluid is complex. *The science which deals with the geometry of motion of fluids without reference to the forces causing the motion is known as* **"hydro kinematics"** (or simply *kinematics*). Thus, kinematics involves merely the description of the motion of fluids in terms of space-time relationship. *The science which deals with the action of the forces in producing or changing motion of fluids is known as* **"hydrokinetics"** (or simply *kinetics*). Thus, the study of fluids in motion involves the consideration of both the kinematics and kinetics. The dynamic equation of fluid motion is obtained by applying Newton's second law of motion to a fluid element considered as a free body. *The fluid is assumed to be incompressible and non-viscous.*

In fluid mechanics the basic equations are: (*i*) *Continuity equation,* (*ii*) *Energy equation,* and (*iii*) *Impulse- momentum equation.* In this chapter energy equation and impulse-momentum equations will be discussed (Continuity equation has already been discussed in Chapter 4).

5.2. DIFFERENT TYPES OF HEADS (OR ENERGIES) OF A LIQUID IN MOTION

There are three types of energies or heads of flowing liquids:

1. Potential head or potential energy:

This is due to configuration or position above some suitable datum line. It is denoted by z.

2. Velocity head or kinetic energy:

This is due to velocity of flowing liquid and is measured as $\frac{V^2}{2g}$ where, V is the velocity of flow and 'g' is the acceleration due to gravity (g = 9.81)

3. Pressure head or pressure energy:

This is due to the pressure of liquid and reckoned as $\frac{p}{w}$ where, p is the pressure, and w is the weight density of the liquid.

Total head/energy:

Total head of a liquid particle in motion is the sum of its potential head, kinetic head and pressure head. Mathematically,

Total head, $H = z + \frac{V^2}{2g} + \frac{p}{w}\ m\ of\ liquid \qquad (5.1a)$

Total energy, , $E = z + \frac{V^2}{2g} + \frac{\frac{p}{w} Nm}{kg} of\ liquid \qquad (5.1b)$

Example 5.1. *In a pipe of 90* mm *diameter water is flowing with a mean velocity of 2 m/s and at a gauge pressure of 350 kN/m*^{2}*. Determine the total head, if the pipe is 8 metres above the datum line. Neglect friction.*

Solution. Diameter of the pipe = 90 mm

Pressure, p = 350 kN/m^2

Velocity of water, V = 2 m/s Datum head, z = 8 m

Specific weight of water, w = 9.81 kN/m^3

Total head of water, H:

$$H = z + \frac{V^2}{2g} + \frac{p}{w}$$

$$= 8 + \frac{2^2}{2X9.81} + \frac{350}{9.81} = 43.88m$$

H = **43.88 m**

5.3. BERNOULLI'S EQUATION

Bernoulli's equation states as follows:

"In an ideal incompressible fluid when the flow is steady and continuous, the sum of pressure energy, kinetic energy and potential (or datum) energy is constant along a stream line."

Mathematically,

$$\frac{p}{w}+\frac{V^2}{2g}+z=constant$$

$\frac{p}{w}=pressure\ energy,$

$\frac{V^2}{2g}=kinetic\ energy, and$

Z= Datum (or elevation) energy.

Proof:

Consider an ideal incompressible liquid through a non-uniform pipe as shown in Fig 6.1. Let us consider two sections LL and MM and assume that the pipe is running full and there is continuity of flow between the two sections;

Let, p_1= Pressure at *LL,*

V_1= Velocity of liquid at *LL,*

z_1= Height of *LL* above the datum,

A_1= Area of pipe at *LL*, and

p_2, V_2, z_2, A_2= Corresponding values at *MM.*

Let the liquid between the two sections *LL* and *MM* move to *L' L'* and *M'M'* through very small lengths dl_1 and dl_2 as shown in Fig. 5.1. This movement of liquid between *LL* and *MM* is equivalent to the movement of the liquid between *LL* and *L'L'* and *MM* and *M' M'*, the remaining liquid between *L' L'* and *MM* being unaffected.

Let, *W* = Weight of liquid between *LL* and *L' L'* .

As the flow is continuous,

$\therefore \quad W=wA_1.dl_1=wA_2.dl_2$

Or, , $\quad A_1.dl_1=\frac{W}{w}$

Similarly, $\quad A_2.dl_2=\frac{W}{w}$

$\therefore A_1.dl_1 = A_2 dl_2$

Work done by pressure at *LL,* in moving the liquid to *L′ L′*

= Force × distance = $p_1 . A_1 . dl_1$

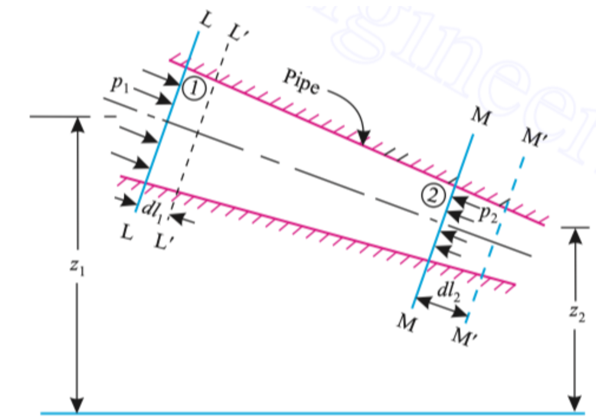


Fig.(5.1). Bernoulli's equation.

Similarly, work done by the pressure at *MM* in moving the liquid to *M′M′* = $- p_2 . A_2 . dl_2$ (– ve sign indicates that direction of p_2 is *opposite* to that of p_1)

∴ Total work done by the pressure

$= p_1 . A_1 dl_1 - p_2 A_2 dl_2$

$= p_1 . A_1 dl_1 - p_2 A_1 dl_1$ $(A_1 dl_1 = A_2 dl_2)$

$= A_1 . dl_1 (p_1 - p_2)$

$= \frac{W}{w}(p_1 - p_2)$ $(\because A_1.dl_1 = \frac{W}{w})$

Loss of potential energy= $W(z_1 - z_2)$

Gain in kinetic energy= $W\left(\frac{V_2^2}{2g} - \frac{V_1^2}{2g}\right) = \frac{W}{2g}(V_2^2 - V_1^2)$

Also, loss of potential energy +work done by pressure=gain in kinetic energy

$\therefore W(z_1 - z_2) + \frac{W}{w}(p_1 - p_2) = \frac{W}{2g}(V_2^2 - V_1^2)$

Or, $\left(z_1 - z_q\right) + \left(\frac{p_1}{w} - \frac{p_2}{w}\right) = (\frac{V_2^2}{2g} - \frac{V_1^2}{2g})$

Or, $\frac{p_1}{w} + \frac{V_1^2}{2g} + z_1 = \quad \frac{p_2}{w} + \frac{V_2^2}{2g} + z_2$

Which proves Bernoulli's equation.

which proves *Bernoulli's equation.*

Assumptions:

It may be mentioned that the following *assumptions* are made in the derivation of Bernoulli's equation:

1. The liquid is ideal and incompressible.
2. The flow is steady and continuous.
3. The flow is along the stream line, *i.e.,* it is one-dimensional.
4. The velocity is uniform over the section and is equal to the mean velocity.
5. The only forces acting on the fluid are the *gravity forces* and the *pressure forces*.

5.4.EULER'S EQUATION FOR MOTION

Consider steady flow of an ideal fluid along the stream tube. Separate out a small element of fluid of cross-sectional area *dA* and length *ds* from stream tube as a free body from the moving fluid. Fig. 5.2 shows such a small element LM of fluid of cross-section area *dA* and length *ds.*

Let, p = Pressure on the element at L,

$p + dp$ = Pressure on the element at M, and

V = Velocity of the fluid element.

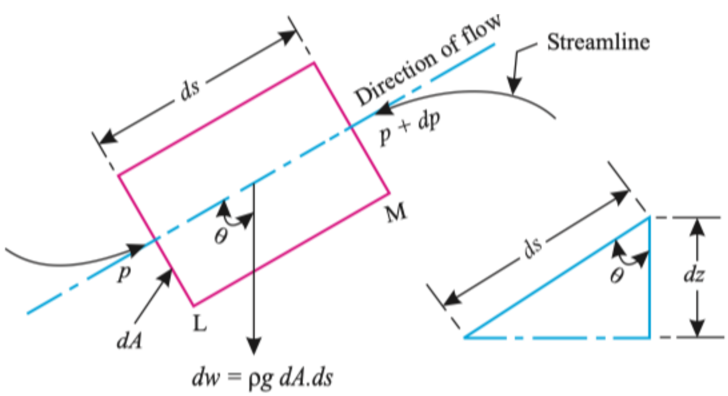


Fig. 5.2. Forces on a fluid element (Euler's equation).

The external forces tending to accelerate the fluid element in the direction of stream line are as follows:

1. Net pressure force in the direction of flow is,

$p.dA - (p + dp)\, dA = - dp\, .\, dA$ (*i*)

2. Component of the weight of the fluid element in the direction of flow is

$= -\rho . g . dA . ds . cos\theta$

$= -\rho . g . dA . ds \left(\frac{dz}{ds}\right)$ $(cos\theta = \frac{dz}{ds})$

$= -\rho . g . dAdz$ (ii)

$-\rho . g . dA . ds . cos\theta$

Mass of the fluid element = ρ.$dA.ds$ (iii)

The acceleration of the fluid element

$a = \frac{dV}{dt} = \frac{dV}{ds} X \frac{ds}{dt} = V . \frac{dV}{ds}$ (iv)

Now, according to Newton's second law of motion, Force = Mass × acceleration

$-dp . dA - \rho . g . dA . dz = p . dA . dsXV . \frac{dV}{ds}$

Dividing both sides by ρ.*dA,* we get:

$\frac{-dp}{\rho} - g . dz = V . dV$

Or, $\frac{dp}{\rho} + V . dV + g . dz = 0$ (5.3)

This is the required **Euler's equation** for motion, and is in the form of *differential equation.* Integrating the above eqn., we get:

$\frac{1}{\rho} \int dp + \int V dV + \int g dz = constant$

$\frac{p}{\rho} + \frac{V^2}{2} + gz = constant$

Dividing by g, we get:

$\frac{p}{\rho g} + \frac{V^2}{2g} + z = constant$

Or, $\frac{p}{w} + \frac{V^2}{2g} + z = constant$

Or, in other words,

$$\frac{p_1}{w} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{w} + \frac{V_2^2}{2g} + z_2$$

which proves *Bernoulli's equation.*

Example 5.2. *Brine of specific gravity 1.15 is draining from the bottom of a large open tank through an 80 mm pipe. The drain pipe ends at a point 10 m below the surface of the brine in the tank. Considering a stream line starting at the surface of the brine in the tank and passing through the centre of the drain line to the point of discharge and assuming the friction is negligible, calculate the velocity of flow along the stream line at the point of discharge from the pipe.*

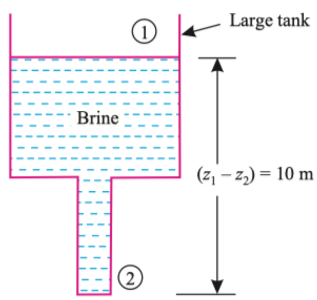


Fig.(5.3)

Solution. Refer to Fig. 5.3.

Section 1– The surface of brine in the tank

Section 2 – The point of discharge.

Applying Bernoulli's equation between point 1 and 2, we get:

$$\frac{p_1}{w} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{w} + \frac{V_2^2}{2g} + z_2$$

Here, $p_1 = p_2 = p_{atm}(atmospheric\ pressure)$

$V_1 = 0$ $\quad and \quad$ $(z_1 - z_2) = 10m$

$\therefore \quad V_2^2 = 2g(z_1 - z_2) = 2gX10 = 2X9.81X10 = 196$

Or, $\quad V_2 = 14m/s$

Example 5.3. *An open circuit wind tunnel draws in air from the atmosphere through a well contoured nozzle. In the test section, where the flow is straight and nearly uniform, a static pressure tap is drilled into the tunnel wall. A manometer connected to the tap shows that the static pressure within the tunnel is 45 mm of water below atmosphere.*

Assume that air is incompressible and at 25°C, pressure is 100 kPa (absolute). Calculate the velocity t $_0$= 25°C

in the wind tunnel section (Refer to Fig. 5.4). Density of p $_0$= 100 kPa V1 *water is 999 kg/m*^{3}*and characteristic gas constant for* V $_0$= 0*air is 287 J/kg K.*

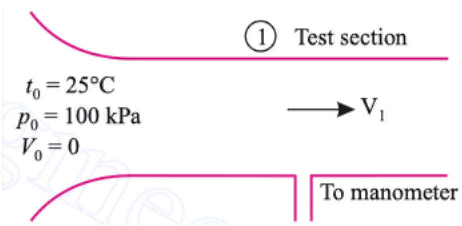


Fig.(5.4)

Solution. *Given*: T_0= 25 + 273 = 298 K;

p_0= 100 kPa (abs.); V_0= 0; **Velocity in the wind tunnel section V_1:**

As per the problem, air is assumed as incompressible (*i.e.*, $\rho_0 = \rho_1 = \rho$). Velocity at test section can be found by using the equation:

$$\frac{p_o}{w} + \frac{V_o^2}{2g} + z_o = \frac{p_1}{w} + \frac{V_1^2}{2g} + z_1$$

Where, $z_o = z_1;\ V_o, p_o = 100kpa(abs)$

$p_1 = 45mm\ of\ water\ below\ atmospher$

$= 999X9.81\frac{45}{1000}pa$

$= 999X9.81X\frac{45}{1000}X10^{-3}kpa = 0.44kpa\ \ below\ atmospher$

$p_1(absolute) = p_{atm}(in\ kpa) - 0.44kpa$

$= 100 - 0.44 = 99.56kpa$

Also, $pV = mRT = \rho RT \qquad (where\ \rho = \frac{m}{V})$

Or, $\rho = \frac{p}{RT} = \frac{100X10^3}{287X298} = 1.169kg/m^3$

$\therefore \quad w = \rho g = 1.169X9.81 = 11.468N/m^3$

Substituting these values in (i) we get:

$$\frac{100X10^3}{11.468} = \frac{99.56X10^3}{11.468} + \frac{V_1^2}{2X9.81}$$

$$8719.9 = 8681.5 + \frac{V_1^2}{2X9.81}$$

$$V_1 = \sqrt{(8719.9 - 8681.5)X2X9.81} = 27.45\ m/s$$

Example 5.4. *Water flows in a circular pipe. At one section the diameter is 0.3 m, the static pressure is 260 kPa gauge, the velocity is 3 m/s and the elevation is 10 m above ground level. The elevation at a section downstream is 0 m, and the pipe diameter is 0.15 m. Find out the gauge pressure at the downstream section.*

Frictional effects may be neglected. Assume density of water to be 999 kg/m³.

Solution. Refer to Fig. 5.5.. D_1= 0.3 m; D_2= 0.15 m; z_1= 0; z_2= 10 m; p_1= 260 kPa, V_1= 3 m/s; ρ = 999 kg/m^3.

From continuity equation, $A_1V_1 = A_2V_2$,

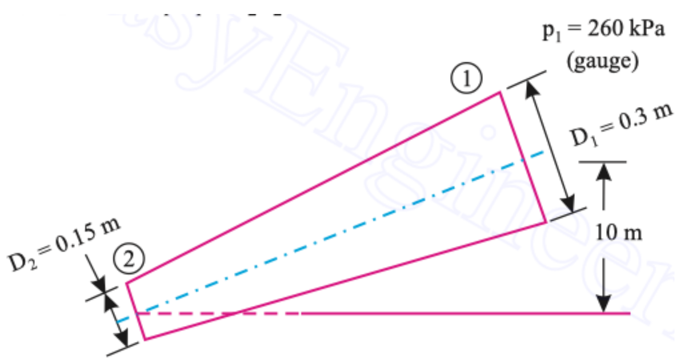


Fig.(5.5)

$$V_2 = \frac{A_1}{A_2} X V_1 = \left(\frac{\frac{\pi}{4} X D_1^2}{\frac{\pi}{4} X D_2^2}\right) X V_1$$

$$(\frac{D_1}{D_2})^2 X V_1 = (\frac{0.3}{0.15})^2 X 3 = 12 m/s$$

Weight density of water, $w = \rho g = 999 \times 9.81 = 9800.19$ N/m^3

From Bernoulli's equation between sections 1 and 2 (neglecting friction effects as given), we have:

$$\frac{p_1}{w} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{w} + \frac{V_2^2}{2g} + z_2$$

$$\frac{260 X 1000}{9800.19} + \frac{V_2^2}{2 X 9.81} + z_2$$

$$= \frac{p_2}{9800.19} + \frac{12^2}{2 X 9.81} + 0$$

$$26.53 + 0.459 + 10 = \frac{p_2}{9800.19} + 7.34$$

$$p_2 = \frac{290566 N}{m^2} = 290.56 kPa$$

5.5. BERNOULLI'S EQUATION FOR REAL FLUID

Bernoulli's equation earlier derived was based on the assumption that fluid is non-viscous and therefore frictionless. Practically, all fluids are real (and not ideal) and therefore are viscous as such there are always some losses in fluid flows. These losses have, therefore, to be taken into consideration in the application of Bernoulli's equation which gets modified (between sections 1 and 2) for *real fluids* as follows:

$$\frac{p_1}{w} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{w} + \frac{V_2^2}{2g} + z_2 + h_L \qquad (5.4)$$

Where, $h_L = loss\ of\ energy\ between\ section\ 1 and 2.$

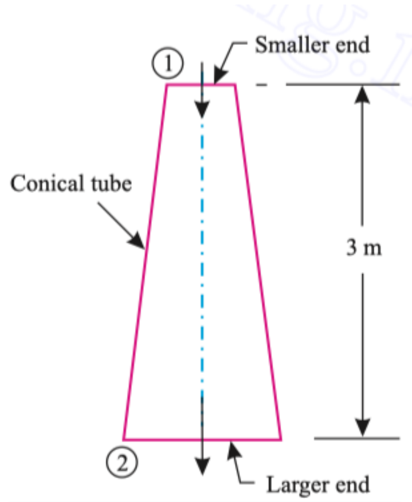


Fig.(5.6)

Example 5.6. *The following data relate to a conical tube of length 3.0 m fixed vertically with its smaller end upwards and carrying fluid in the downward direction.*

The velocity of flow at the smaller end = 10 m/s.

The velocity of flow at the larger end = 4 m/s.

$$the\ loss\ of\ head\ in\ the\ tube = \frac{0.4(V_1 - V_2)^2}{2g}$$

where, V_1 and V_2 are velocities at the smaller and larger ends respectively.

Pressure head at the smaller end = 4 m of liquid. Determine the pressure head at the larger end.

Solution.

Length of tube, l = 3.0 m

Velocity, V_1 = 10 m/s.

Pressure head, $\frac{p_1}{w} = 4m$ of liquid

Velocity, V_2 = 4 m/s.

$$loss\ of\ head, h_L = \frac{0.4(V_1 - V_2)^2}{2g} = \frac{0.4(10-4)^2}{2X9.81} = 0.73m$$

Pressure head at the larger end, $\frac{P_2}{W}$

Applying Bernoulli’s equation at sections (1) and (2), we get:

$$\frac{p_1}{w}+\frac{V_1^2}{2g}+z_1=\frac{p_2}{w}+\frac{V_2^2}{2g}+z_2+h_L$$

Let the datum line passes through section (2). Then,

z_2=0, z_1= 3.0m

$$4+\frac{10^2}{2G}+3.0=\frac{P_2}{2}+\frac{4^2}{2g}+0+0.73$$

Or, $(4+5.09+3.0)=\frac{p_2}{w}+0.815+0.73$

Or, $12.09=\frac{p_2}{w}+1.54$

$\therefore p_2=10.55m\ of\ liquid$

5.6. PRACTICAL APPLICATIONS OF BERNOULLI’S EQUATION

Although Bernoulli’s equation is applicable in all problems of incompressible flow where there is involvement of energy considerations but here we shall discuss its applications in the following *measuring devices*:

1. Venturi meter
2. Orifice meter
3. Rotameter and elbow meter
4. Pitot tube.

5.6.1. Venturi meter

A venturi meter is one of the most important practical applications of Bernoulli’s theorem. *It is an instrument used to measure the rate of discharge in a pipeline and is often fixed permanently at different sections of the pipeline to know the discharges there.*

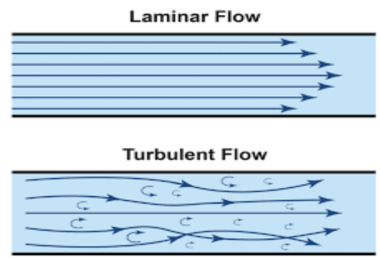
A venturi meter has been named after the 18th century Italian engineer *Venturi.*

Types of venturi meters:

Venturi meters may be *classified* as follows:

1. Horizontal venturi meters.
2. Vertical venturi meters.
3. Inclined venturi meters.

Chapter Six: LAMINAR FLOW AND TURBULENT FLOW IN PIPES



6.1. : LAMINAR FLOW

So far, in the preceding chapters, primarily the flow of an ideal fluid has been discussed. In the case of Newtonian fluid, the flows can be classified as (*i*) laminar (or viscous), and (*ii*) turbulent, depending on characteristic

Reynolds number, $\frac{\rho V l}{\mu}$ where l is the characteristic length.

Examples of laminar/viscous flow:

(*i*) Flow past tiny bodies.

(*ii*) Underground flow.

(*iii*) Movement of blood in the arteries of a human body.

(*iv*) Flow of oil in measuring instruments.

(*v*) Rise of water in plants through their roots etc.

Characteristics of laminar flow:

(*i*) 'No slip' at the boundary.

(*ii*) Due to viscosity, there is a shear between fluid layers, which is given by $\tau = \mu.\frac{du}{dy}$ for flow in X-direction.

(*iii*) The flow is rotational.

(*iv*) Due to viscous shear, there is continuous *dissipation of energy* and for maintaining the flow of energy must be supplied externally

(*v*) Loss of energy is proportional to *first power of velocity* and *first power of viscosity*.

(*vi*) No mixing between different fluid layers (except by molecular motion, which is very small).

(*vii*) The flow remains laminar as long as $\frac{\rho l V}{\mu}$ is *less* than critical value of Reynolds number.

6.2.REYNOLDS EXPERIMENT

Osborne Reynolds in 1883, with the help of a simple experiment (see Fig. 6.1), demonstrated the existence of the following two types of flows:

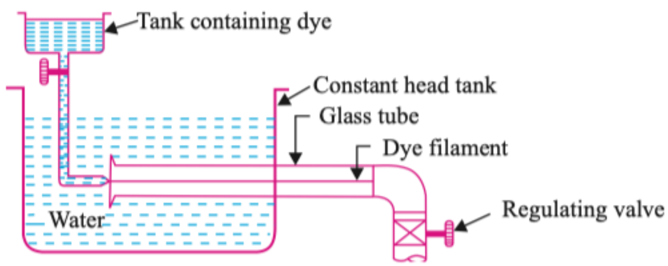


Fig.(6.1)

1. Laminar flow (Reynolds number, $Re < 2000$)
2. Turbulent flow (Reynolds number, $Re > 4000$)

(Re between 2000 and 4000 indicates *transition from laminar to turbulent flow*)

Reynolds experiment:

***Apparatus*:**

Refer to Fig. 6.1. Reynolds experiment apparatus consisted essentially of the following:

1. A constant head tank filled with water,
2. A small tank containing dye (sp. weight of dye same as that of water),
3. A horizontal glass tube provided with a bell mouthed entrance, and
4. A regulating valve.

Procedure followed:

The water was made to flow from the tank through the glass tube into the atmosphere and the velocity of flow was varied by adjusting valve. The liquid dye was introduced into the flow at the bell mouth through a small tube as shown in Fig. 6.1.

Observations made:

1. When the *velocity* of flow was *low*, the dye remained in the form of a *straight* and *stable filament* passing through the glass tube so steadily that it scarcely seemed to be in motion.

This was a case of **laminar flow** as shown in Fig. 6.2 (*a*).

Dye filament 2. With the increase of velocity a critical state was reached at which the dye filament showed irregularities and began to waver (see Fig. 6.2 *b*). This shows that the flow is no longer a laminar one. This was (a) Wavy filament

transitional state.

3. With further increase in velocity of flow the fluctuations in the filament of dye became more intense and ultimately the dye diffused over the entire cross-section of the tube, due to the intermingling of the particles of the flowing fluid. This was the case of a **turbulent flow** as shown in Fig.6.2 (*c*).

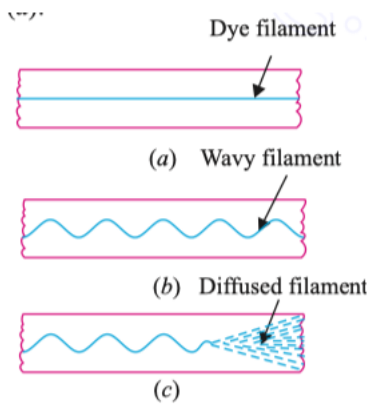


Fig. 6.2. Appearance of dye filament in

On the basis of his experiment Reynolds discovered that:

(*i*) In case of **laminar flow:** The loss of pressure head ∝ velocity.

(*ii*) In case of **turbulent flow:** The loss of head is approximately $\propto V^2$

[More exactly the loss of head $\propto V^n$ where n varies from 1.75 to 2.0]

Fig. 6.3 shows the apparatus used by Reynolds for estimating the loss of head in a pipe by measuring the pressure difference over a known length of the pipe.

(*i*) The velocity of water in the pipe was determined by measuring the volume of water (Q) collected in the tank over a known period of time ($V = \frac{Q}{A}$, where A is the area of cross-section of the pipe.)

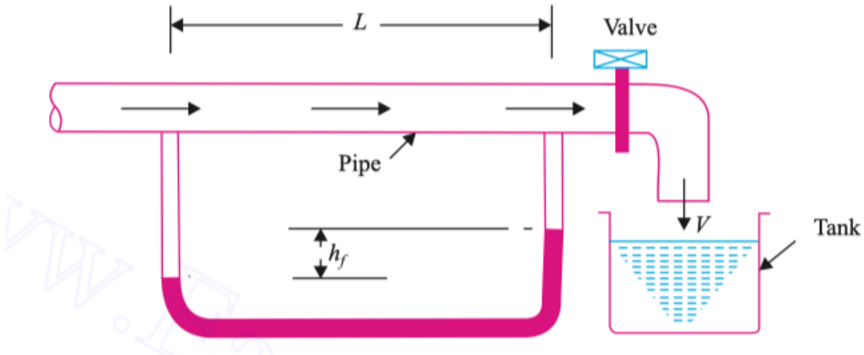


Fig. 6.3. Loss of head in a pipe.

(*ii*) The velocity of flow (V) was changed and corresponding values of h_f (loss of head) were obtained.

(*iii*) A graph was plotted between V (velocity of flow) and h_f (loss of head). Such a graph is shown in Fig. 6.4.

It may be seen from the graph that:

(*a*) At *low velocities* the curve is a straight line, indicating that the h_f (loss of head) is *directly proportional to velocity*—the flow is **laminar**

(*b*) At *higher velocities* the curve is parabolic; in (Low velocities) this range $h_f \alpha V^n$, where the value of n lies between 1.75 to 2.0 — the flow is **turbulent.**

(*c*) In the intermediate region, there is a transition V zone. This is shown by *dotted line*. Fig. 6.4

Reynolds number :

Reynolds from his experiments found that the nature of flow in a *closed conduit* depends upon the following factors:

(*i*) Diameter of the pipe (D),

(*ii*) Density of the liquid (ρ),

(*iii*) Viscosity of the liquid (μ), and

(*iv*) Velocity of flow (V).

By combining the above variables Reynolds determined a non-dimensional quantity equal to $\frac{\rho V D}{\mu}$ which is known as ***Reynolds number*** (Re).

i.e. Reynolds number $R_e = \frac{\rho V D}{\mu}$

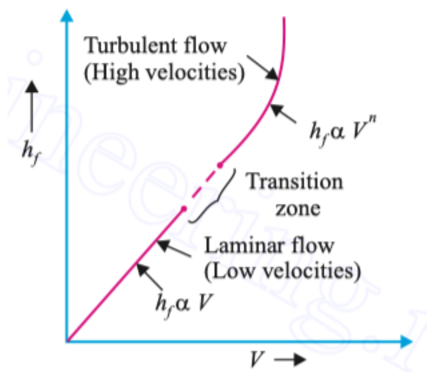


Fig.(6.4)

6.3. TURBULENT FLOW IN PIPES

In a pipe, a laminar flow occurs when Reynolds number (*Re*) is less than 2000 and a turbulent flow occurs when *Re* > 4000. In a turbulent flow, the fluid motion is irregular and chaotic and there is complete mixing of fluid due to collision of fluid masses with one another. The fluid masses are interchanged between adjacent layers. As the fluid masses in adjacent layers have different velocities, interchange of fluid masses between the adjacent layers is accompanied by a transfer of momentum which causes additional shear stresses of high magnitude between adjacent layers. *The shear in turbulent flow is mainly due to momentum transfer*. The contribution of fluid viscosity to total shear is small and is usually neglected. In case of laminar flow, because of definite functional relationship 'between shear stress due to viscosity and velocity' it has been possible to derive a mathematical relationship for evaluation of energy dissipation or frictional head but such a simple relationship does not exist for turbulent flow. However to solve some of the practical problems, efforts have been made to evolve semi-empirical theories of turbulence.

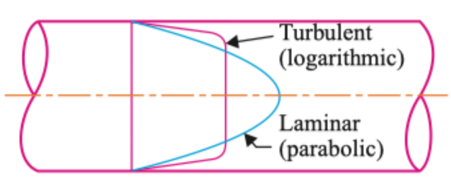


Fig.(6.5): Shows the velocity distribution curves for laminar and turbulent flows in a pipe.

Following points are worth noting about turbulent flow:

(*i*) The velocity distribution in turbulent flow is more uniform than in laminar flow.

(*ii*) In turbulent flow the velocity gradients near the
boundary shall be quite large resulting in more shear.

(*iii*) In turbulent flow the flatness of velocity distribution curve in the core region away from the Fig.6.5. Shows the velocity distribution wall is because of the *mixing of fluid layers and* curves for laminar and turbulent flows in a pipe.

(*iv*) The velocity distribution which is paraboloid in laminar flow, tends to follow power law and logarithmic law in turbulent flow.

(*v*) Random orientation of fluid particles in a turbulent flow gives rise to additional stresses, called the ***Reynolds stresses.***

(*vi*) Formation of eddies, mixing and curving of path lines in a turbulent flow results in much greater frictional losses for the same rate of discharge, viscosity and pipe size. The turbulent motion can be *classified* as follows:

1. ***Wall turbulence.*** It occurs in immediate vicinity of solid surfaces and in the boundary layer flows where the fluid has a negligible mean acceleration.
2. ***Free turbulence.*** It occurs in jets, wakes, mixing layers etc.
3. ***Convective turbulence.*** It takes place where there is conversion of P.E into K.E. by the process of mixing (*e.g.* the turbulent flow in the annular space between the concentric rotating cylinder, conventional flow between parallel horizontal plates etc.).