Subject Name: **Fluid Mechanics**

Subject Code: **CE-3002**

Semester: **3rd**

UNIT 3

LAMINAR FLOW

Laminar Flow and Turbulent Flow: Introduction to laminar & turbulent flow, Reynolds experiment & Reynolds number. Velocity distribution, Laminar and turbulent boundary layers and laminar sub layer, boundary layer concept, aging of pipes. Losses due to sudden expansion and contraction, losses in pipe fittings and valves, concepts of equivalent length, hydraulic and energy gradient lines, siphon, pipes in series, pipes in parallel, branching of pipes. Concept of Water Hammer transmission of power.

LAMINAR FLOW

. Real fluids

The flow of real fluids exhibits viscous effect that is they tend to "stick" to solid surfaces and have stresses within their body.

You might remember from earlier in the course Newton's law of viscosity:

$$\tau \propto \frac{du}{dy}$$

This tells us that the shear stress, in a fluid is proportional to the velocity gradient - the rate of change of velocity across the fluid path. For a "Newtonian" fluid we can write:

$$\tau = \mu \frac{du}{dy}$$

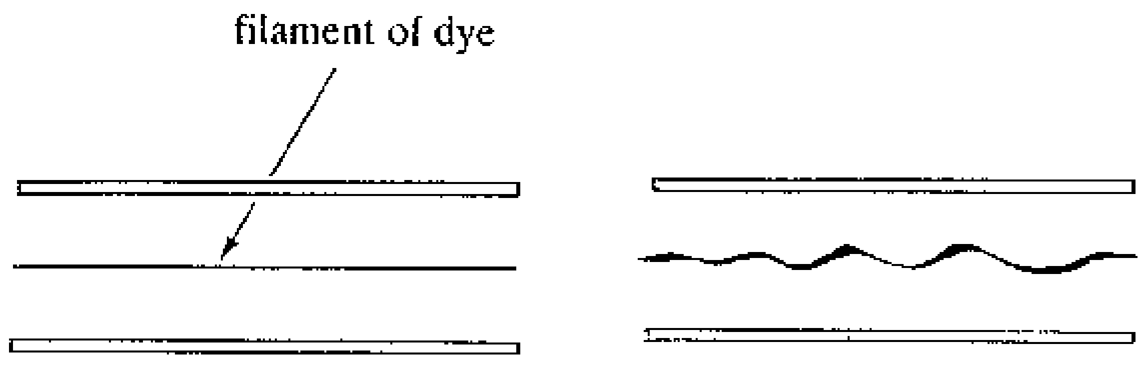
Where the constant of proportionality, μ is known as the coefficient of viscosity (or simply viscosity). We saw that for some fluids - sometimes known as exotic fluids - the value of μ changes with stress or velocity gradient. We shall only deal with Newtonian fluids.

In his lecture we shall look at how the forces due to momentum changes on the fluid and viscous forces compare and what changes take place.

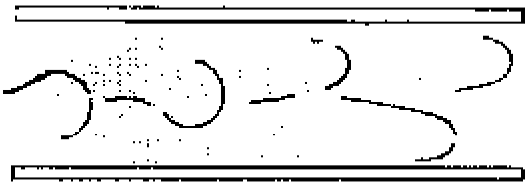
2. Laminar and turbulent flow

If we were to take a pipe of free flowing water and inject a dye into the middle of the stream, what would we expect to happen?

This



Laminar (viscous)   Transitional



Turbulent

Actually both would happen - but for different flow rates. The top occurs when the fluid is flowing fast and the lower when it is flowing slowly.

The top situation is known as turbulent flow and the lower as laminar flow.

In laminar flow the motion of the particles of fluid is very orderly with all particles moving in straight lines parallel to the pipe walls.

But what is fast or slow? And at what speed does the flow pattern change? And why might we want to know this?

The phenomenon was first investigated in the 1880s by Osbourne Reynolds in an experiment which has become a classic in fluid mechanics.

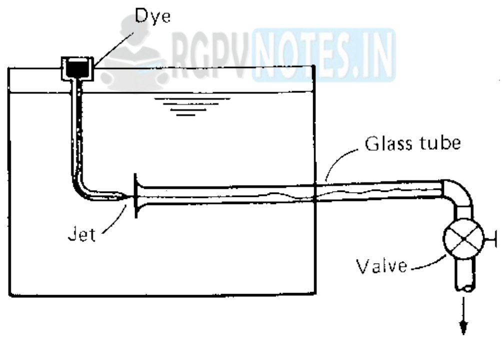


Fig.: Reynolds Experiment

He used a tank arranged as above with a pipe taking water from the centre into which he injected a dye through a needle. After many experiments he saw that this expression

$$\frac{\rho u d}{\mu}$$

Where ρ = density, u = mean velocity, d = diameter and μ = viscosity

Would help predict the change in flow type. If the value is less than about 2000 then flow is laminar, if greater than 4000 then turbulent and in between these then in the transition zone.

This value is known as the Reynolds number, Re:

$$\mathrm{Re} = \frac{\rho u d}{\mu}$$

Laminar flow: Re < 2000

Transitional flow: 2000 < Re < 4000

Turbulent flow: Re > 4000

What are the units of this Reynolds number? We can fill in the equation with SI units:

$$\rho = kg/m^3, \quad u = m/s, \quad d = m$$
$$\mu = Ns/m^2 = kg/ms$$

$$\mathrm{Re} = \frac{\rho u d}{\mu} = \frac{kg}{m^3}\frac{m}{s}\frac{m}{1}\frac{m}{kg} = 1$$

I.e. it has no units. A quantity that has no units is known as a non-dimensional (or dimensionless) quantity. Thus the Reynolds number, Re, is a non-dimensional number.

We can go through an example to discover at what velocity the flow in a pipe stops being laminar.

If the pipe and the fluid have the following properties:

Water density ? = 1000 kg/m^3

Pipe diameter d = 0.5m

(Dynamic) viscosity,? = 0.55x10^{-3} Ns/m^2

We want to know the maximum velocity when the Re is 2000.

$$\mathrm{Re} = \frac{\rho u d}{\mu} = 2000$$
$$u = \frac{2000\mu}{\rho d} = \frac{2000 \times 0.55 \times 10^{-3}}{1000 \times 0.5}$$
$$u = 0.0022\, m/s$$

If this were a pipe in a house central heating system, where the pipe diameter is typically 0.015m, the limiting velocity for laminar flow would be, 0.0733 m/s.

Both of these are very slow. In practice it very rarely occurs in a piped water system - the velocities of flow are much greater. Laminar flow does occur in situations with fluids of greater viscosity - e.g. in bearing with oil as the lubricant.

At small values of Re above 2000 the flow exhibits small instabilities. At values of about 4000 we can say that the flow is truly turbulent. Over the past 100 years since this experiment, numerous more experiments have shown this phenomenon of limits of Re for many different Newtonian fluids - including gasses.

What does this abstract number mean?

We can say that the number has a physical meaning, by doing so it helps to understand some of the reasons for the changes from laminar to turbulent flow.

$$\mathrm{Re} = \frac{\rho u d}{\mu} = \frac{\text{inertial forces}}{\text{viscous forces}}$$

It can be interpreted that when the inertial forces dominate over the viscous forces (when the fluid is flowing faster and Re is larger) then the flow is turbulent. When the viscous forces are dominant (slow flow, low Re) they are sufficient enough to keep all the fluid particles in line, then the flow is laminar.

In summary:

Laminar flow

- Re < 2000
- 'low' velocity
- Dye does not mix with water
- Fluid particles move in straight lines
- Simple mathematical analysis possible
- Rare in practice in water systems.

Transitional flow

- 2000 > Re < 4000
- 'medium' velocity
- Dye stream wavers in water - mixes slightly.

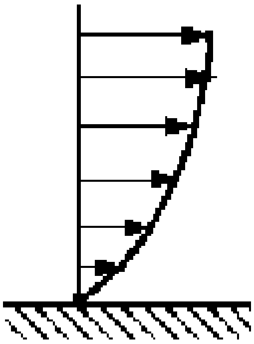
Turbulent flow

- Re > 4000
- 'high' velocity
- Dye mixes rapidly and completely
- Particle paths completely irregular
- Average motion is in the direction of the flow
- Cannot be seen by the naked eye
- Changes/fluctuations are very difficult to detect. Must use laser.
- Mathematical analysis very difficult - so experimental measures are used
- Most common type of flow.

3. Pressure loss due to friction in a pipeline.

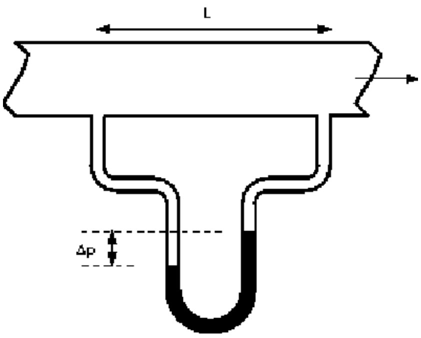
Up to this point on the course we have considered ideal fluids where there have been no losses due to friction or any other factors. In reality, because fluids are viscous, energy is lost by flowing fluids due to friction which must be taken into account. The effect of the friction shows itself as a pressure (or head) loss.

In a pipe with a real fluid flowing, at the wall there is a shearing stress retarding the flow, as shown below.



If a manometer is attached as the pressure (head) difference due to the energy lost by the fluid overcoming the shear stress can be easily seen.

The pressure at 1 (upstream) is higher than the pressure at 2.



We can do some analysis to express this loss in pressure in terms of the forces acting on the fluid.

Consider a cylindrical element of incompressible fluid flowing in the pipe, as shown

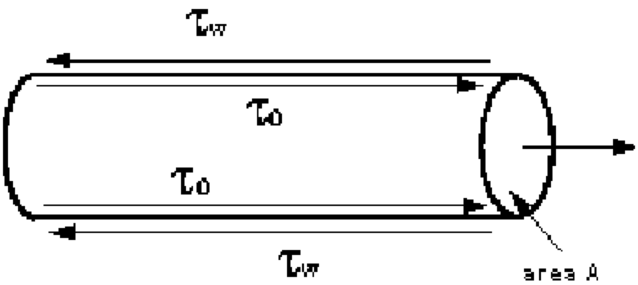


Fig.: Share force

The pressure at the upstream end is p, and at the downstream end the pressure has fallen by p to (p-p).

The driving force due to pressure (F = Pressure x Area) can then be written

Driving force = Pressure force at 1 - pressure force at 2

$$pA - (p - \Delta p)A = \Delta p\, A = \Delta p \frac{\pi d^2}{4}$$

The retarding force is that due to the shear stress by the walls

$= \text{shear stress} \times \text{area over which it acts}$

$= \tau_w \times \text{area of pipe wall}$

$= \tau_w \pi d L$

As the flow is in equilibrium,

Driving force = retarding force

$$\Delta p \frac{\pi d^2}{4} = \tau_w \pi d L$$

$$\Delta p = \frac{\tau_w 4L}{d}$$

Giving an expression for pressure loss in a pipe in terms of the pipe diameter and the shear stress at the wall on the pipe.

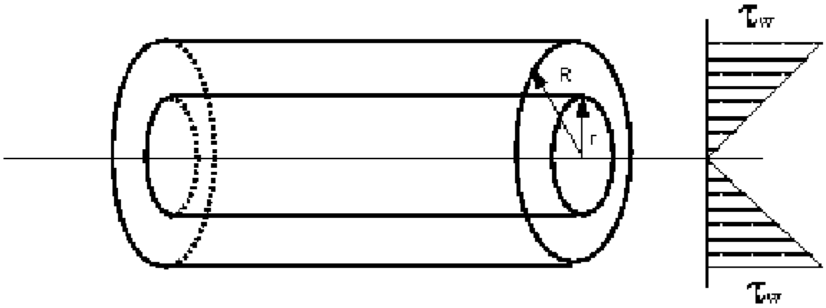


Fig.: Velocity Distribution

The shear stress will vary with velocity of flow and hence with Re. Many experiments have been done with various fluids measuring the pressure loss at various Reynolds numbers. These results plotted to show a graph of the relationship between pressure loss and Re look similar to the figure below:

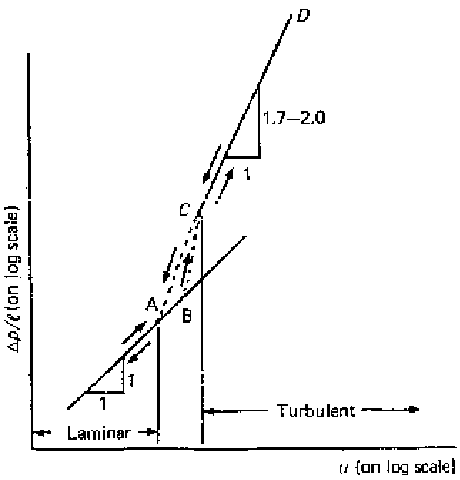


Fig.: Graph B/W Pressure And Re look

This graph shows that the relationship between pressure loss and Re can be expressed as

laminar $\Delta p \propto u$

turbulent $\Delta p \propto u^{1.7 \text{ (or } 2.0)}$

As these are empirical relationships, they help in determining the pressure loss but not in finding the magnitude of the shear stress at the wall ?w on a particular fluid. If we knew ?w we could then use it to give a general equation to predict the pressure loss.

4. Pressure loss during laminar flow in a pipe

In general the shear stress. ?w. is almost impossible to measure. But for laminar flow it is possible to calculate a theoretical value for a given velocity, fluid and pipe dimension.

In laminar flow the paths of individual particles of fluid do not cross, so the flow may be considered as a series of concentric cylinders sliding over each other - rather like the cylinders of a collapsible pocket telescope.

As before, consider a cylinder of fluid, length L, radius r, flowing steadily in the centre of a pipe.

We are in equilibrium, so the shearing forces on the cylinder equal the pressure forces.

$$\tau\, 2\pi r\, L = \Delta p\, A = \Delta p \pi r^2$$

$$\tau = \frac{\Delta p}{L}\frac{r}{2}$$

By Newton's law of viscosity we have $\tau = \mu \frac{du}{dy}$, where y is the distance from the wall. As we are measuring from the pipe centre then we change the sign and replace y with r distance from the centre, giving

$$\tau = -\mu \frac{du}{dr}$$

Which can be combined with the equation above to give

$$\frac{\Delta p}{L}\frac{r}{2} = -\mu \frac{du}{dr}$$

$$\frac{du}{dr} = -\frac{\Delta p}{L}\frac{r}{2\mu}$$

In an integral form this gives an expression for velocity,

$$u = -\frac{\Delta p}{L}\frac{1}{2\mu}\int r\,dr$$

Integrating gives the value of velocity at a point distance r from the centre

$$u_r = -\frac{\Delta p}{L}\frac{r^2}{4\mu} + C$$

At r = 0, (the centre of the pipe), u = u_{max}, at r = R (the pipe wall) u = 0, giving

$$C = \frac{\Delta p}{L}\frac{R^2}{4\mu}$$

So, an expression for velocity at a point r from the pipe centre when the flow is laminar is

$$u_r = \frac{\Delta p}{L}\frac{1}{4\mu}\left(R^2 - r^2\right)$$

Note how this is a parabolic profile (of the form $y = ax^2 + b$) so the velocity profile in the pipe looks similar to the figure below

What is the discharge in the pipe?

$$Q = u_m A$$

$$u_m = \int_0^R u_r \, dr$$

$$= \frac{\Delta p}{L}\frac{1}{4\mu}\int_0^R \left(R^2 - r^2\right) dr$$

$$= \frac{\Delta p}{L}\frac{R^2}{8\mu} = \frac{\Delta p \, d^2}{32\mu L}$$

So the discharge can be written

$$Q = \frac{\Delta p \, d^2}{32\mu L}\frac{\pi d^2}{4}$$

$$= \frac{\Delta p}{L}\frac{\pi d^2}{128\mu}$$

This is the Hagen-Poiseuille equation for laminar flow in a pipe. It expresses the discharge Q in terms of the pressure gradient ($\frac{\partial p}{\partial x} = \frac{\Delta p}{L}$), diameter of the pipe and the viscosity of the fluid.

We are interested in the pressure loss (head loss) and want to relate this to the velocity of the flow. Writing pressure loss in terms of head loss h_f, i.e. p = $\rho g h_f$

$$u = \frac{\rho g h_f d^2}{32\mu L}$$

$$h_f = \frac{32\mu L u}{\rho g d^2}$$

This shows that pressure loss is directly proportional to the velocity when flow is laminar.

It has been validated many time by experiment.

It justifies two assumptions:

1. fluid does not slip past a solid boundary
2. Newton's hypothesis.

Pressure gradient and subsurface shear stress on the neuropathic forefoot.

Turbulent flow: Laminar and turbulent boundary layers and laminar sublayer, Hydro dynamically smooth and rough boundaries, velocity distribution in turbulent flow, resistance of smooth and artificially roughened pipes, commercial pipes, aging of pipes.
Pipe flow problems : Losses due to sudden expansion and contraction, losses in pipe fittings and valves, concepts of equivalent length, hydraulic and energy gradient lines, siphon, pipes in series, pipes in parallel, branching of pipes.
Pipe Network: *Water Hammer (only quick closure case).transmission of power. *Hardy Cross Method

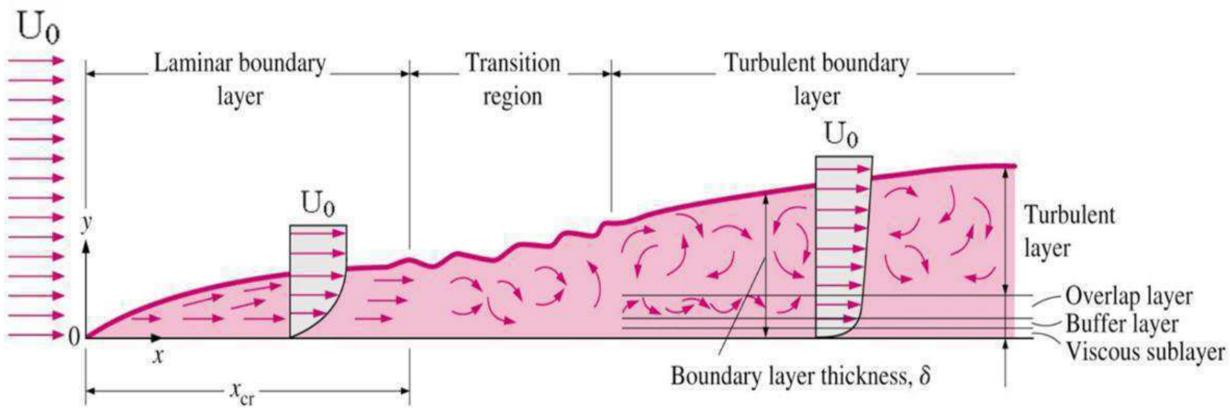
Turbulent flow

Laminar Boundary

The laminar boundary is a very smooth flow, while the turbulent boundary layer contains swirls or "eddies." The laminar flow creates less skin friction drag than the turbulent flow, but is less stable. Boundary layer flow over a wing surface begins as a smooth laminar flow. As the flow continues back from the leading edge, the laminar boundary layer increases in thickness.

Turbulent Boundary

At some distance back from the leading edge, the smooth laminar flow breaks down and transitions to a turbulent flow. From a drag standpoint, it is advisable to have the transition from laminar to turbulent flow as far aft on the wing as possible, or have a large amount of the wing surface within the laminar portion of the boundary layer. The low energy laminar flow, however, tends to break down more suddenly than the turbulent layer.



Laminar sublayer

The laminar sublayer, also called the viscous sublayer, is the region of a mainly-turbulent flow that is near a no-slip boundary and in which the flow is laminar. As such, it is a type of boundary layer. The existence of the laminar sub layer can be understood in that the flow velocity decreases towards the no-slip boundary. Because of this, the Reynolds number decreases until at some point the flow crosses the threshold from turbulent to laminar.

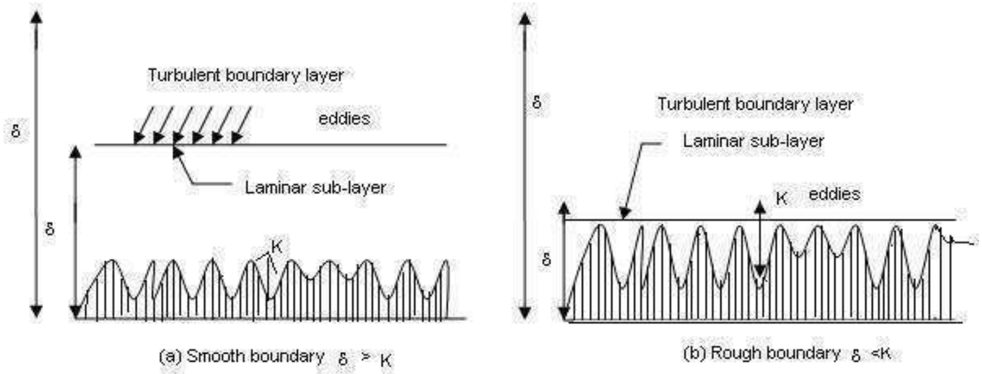
Hydro dynamically smooth and Rough Boundaries

When the average depth k of the surface irregularities is less than laminar sub-layer of the surface δ is called as hydrodynamic ally smooth boundary.

- The eddy which formed outside of the laminar sub-layer try to penetrate in the laminar sub-layer boundary is called as smooth boundary as shown in

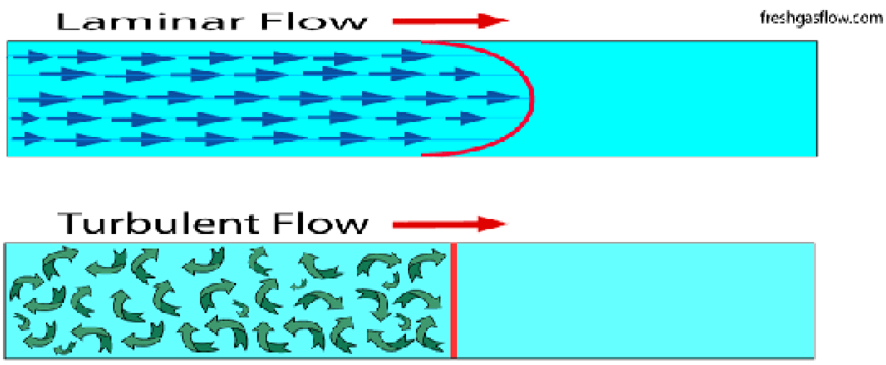
- When the average depth k of the surface irregularities is greater than laminar sub-layer of surface δ is called as hydrodynamic ally rough boundary.

- The eddy which formed outside of the laminar sub layer penetrates into the laminar sub-layer. Such boundary is called as rough boundary as shown in.



Velocity distribution in turbulent flow

The velocity gradient at the wall, and hence also the wall shear stress, τw, is not so large as in the turbulent case of part (b) representing the (time) mean flow for fully developed turbulence. This inner layer is termed as the viscous sublayer velocity varies linearly with distance from the wall.



Losses Due to Sudden Enlargement

If the cross-section of a pipe with fluid flowing through it, is abruptly enlarged (Fig. 14.2a) at certain place, fluid emerging from the smaller pipe is unable to follow the abrupt deviation of the boundary.

The streamline takes a typical diverging pattern (shown in Fig. 14.2a). This creates pockets of turbulent eddies in the corners resulting in the dissipation of mechanical energy into intermolecular energy.

Basic mechanism of this type of loss

The fluid flows against an adverse pressure gradient. The upstream pressure p_1 at section a-b is lower than the downstream pressure p_2 at section e-f since the upstream velocity V_1 is higher than the downstream velocity V_2 as a consequence of continuity.

The fluid particles near the wall due to their low kinetic energy cannot overcome the adverse pressure hill in the direction of flow and hence follow up the reverse path under the favorable pressure gradient (from p_2 to p_1).

This creates a zone of recirculating flow with turbulent eddies near the wall of the larger tube at the abrupt change of cross-section, as shown in Fig. 14.2a, resulting in a loss of total mechanical energy.

For high values of Reynolds number, usually found in practice, the velocity in the smaller pipe may be assumed sensibly uniform over the cross-section. Due to the vigorous mixing caused by the turbulence, the velocity becomes again uniform at a far downstream section e-f from the enlargement (approximately 8 times the larger diameter).

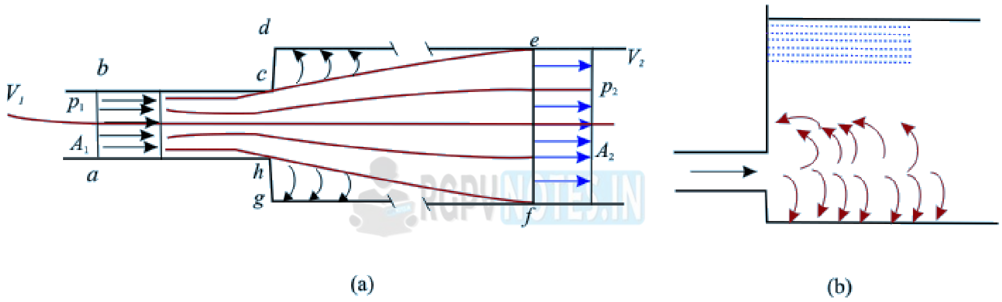


Fig 14.2 (a) Flow through abrupt but finite enlargement

(b) Flow at Infinite enlargement (Exit Loss)

A control volume abcdefgh is considered (Fig. 14.2a) for which the momentum theorem can be written as

$$p_1A_1 + p'(A_2 - A_1) - p_2A_2 = \rho Q(V_2 - V_1) \qquad (14.20)$$

Where A_1, A_2 are the cross-sectional areas of the smaller and larger parts of the pipe respectively, Q is the volumetric flow rate and p' is the mean pressure of the eddying fluid over the annular face, gd. It is known from experimental evidence, the $p' = p_1$.

Hence the Eq. (14.20) becomes

$$(p_2 - p_1)A_2 = \rho Q(V_1 - V_2) \qquad \textbf{(14.21)}$$

From the equation of continuity

$$Q = V_2 A_2 \qquad \textbf{(14.22)}$$

With the help of Eq. (14.22), Eq. (14.21) becomes

$$p_2 - p_1 = \rho V_2(V_1 - V_2) \qquad \textbf{(14.23)}$$

Applying Bernoulli's equation between sections ab and ef in consideration of the flow to be incompressible and the axis of the pipe to be horizontal, we can write

$$\frac{p_1}{\rho} + \frac{V_1^2}{2} = \frac{p_2}{\rho} + \frac{V_2^2}{2} + gh_L$$

$$\frac{p_2 - p_1}{\rho} = \frac{V_1^2 - V_2^2}{2} - gh_L \qquad \textbf{(14.24)}$$

where h_L is the loss of head. Substituting ($p_2 - p_1$) from Eq. (14.23) into Eq. (14.24), we obtain

$$h_L = \frac{(V_1 - V_2)^2}{2g} = \frac{V_1^2}{2g}\left[(1-(\frac{A_1}{A_2})\right]^2 \qquad \textbf{(14.25)}$$

In view of the assumptions made, Eq.(14.25) is subjected to some inaccuracies, but experiments show that for coaxial pipes they are within only a few per cent of the actual values.

Back to original slide - "Losses due to geometric changes"

Exit Loss

If, in Eq.(14.25), $A_2 \to \infty$, then the head loss at an abrupt enlargement tends to $V_1^2/2g$. The physical resemblance of this situation is the submerged outlet of a pipe discharging into a large reservoir as shown in Fig.14.2b.

Since the fluid velocities are arrested in the large reservoir, the entire kinetic energy at the outlet of the pipe is dissipated into intermolecular energy of the reservoir through the creation of turbulent eddies.

In such circumstances, the loss is usually termed as the exit loss for the pipe and equals to the velocity head at the discharge end of the pipe.

Losses Due to Sudden Contraction

An abrupt contraction is geometrically the reverse of an abrupt enlargement (Fig. 14.3). Here also the streamlines cannot follow the abrupt change of geometry and hence gradually converge from an upstream section of the larger tube.

However, immediately downstream of the junction of area contraction, the cross-sectional area of the stream tube becomes the minimum and less than that of the smaller pipe. This section of the stream tube is known as vena contracta, after which the stream widens again to fill the pipe.

The velocity of flow in the converging part of the stream tube from Sec. 1-1 to Sec. c-c (vena contracta) increases due to continuity and the pressure decreases in the direction of flow accordingly in compliance with the Bernoulli's theorem.

In an accelerating flow,under a favourable pressure gradient, losses due to separation cannot take place. But in the decelerating part of the flow from Sec. c-c to Sec. 2-2, where the stream tube expands to fill the pipe, losses take place in the similar fashion as occur in case of a sudden geometrical enlargement. Hence eddies are formed between the vena contracta c-c and the downstream Sec. 2-2.

The flow pattern after the vena contracta is similar to that after an abrupt enlargement, and the loss of head is thus confined between Sec. c-c to Sec. 2-2. Therefore, we can say that the losses due to contraction is not for the contraction itself, but due to the expansion followed by the contraction.

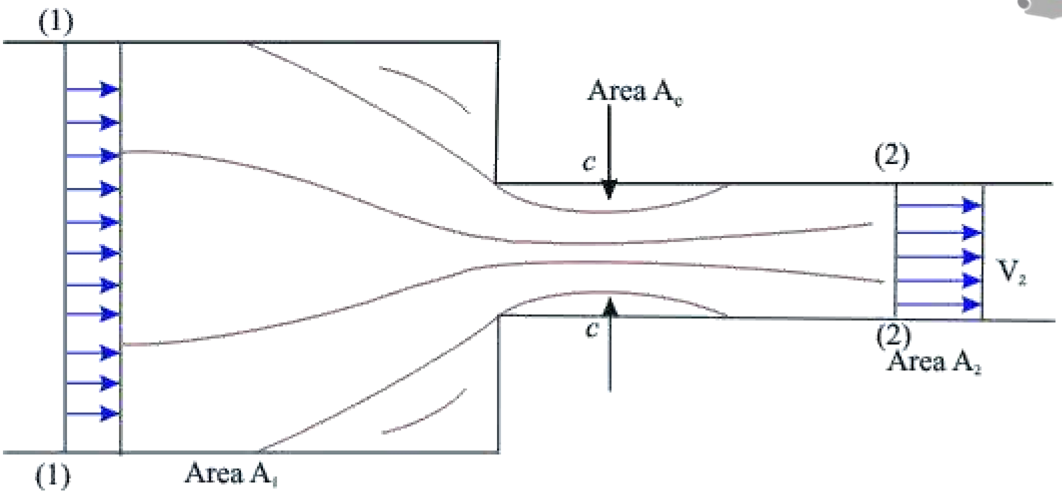


Fig 14.3 Flow through a sudden contraction

- **Following Eq. (14.25), the loss of head in this case can be written as**

$$h_L = \frac{V_2^2}{2g}\left[\left(\frac{A_2}{A_c}\right) - 1\right]^2 = \frac{V_2^2}{2g}\left[\left(\frac{1}{C_c}\right) - 1\right]^2$$

(14.26)

where Ac represents the cross-sectional area of the vena contracta, and Cc is the coefficient of contraction defined by

$$C_c = \frac{A_c}{A_2} \qquad (14.27)$$

Equation (14.26) is usually expressed as

$$h_L = K\frac{V_2^2}{2g} \qquad (14.28)$$

where,

$$K = \left[\left(\frac{1}{C_c}\right) - 1\right]^2$$

(14.29)

•Although the area A1 is not explicitly involved in the Eq. (14.26), the value of Cc depends on the ratio A2/A1. For coaxial circular pipes and at fairly high Reynolds numbers. Table 14.1 gives representative values of the coefficient K.

Table 14.1

A2/A1	0	0.04	0.16	0.36	0.64	1.0
K	0.5	0.45	0.38	0.28	0.14	0

Back to original slide - "Losses due to geometric changes"

Entry Loss

- As $A_1 \rightarrow \infty$, **the value of K in the Eq. (14.29) tends to 0.5 as shown in Table 14.1. This limiting situation corresponds to the flow from a large reservoir into a sharp edged pipe, provided the end of the pipe does not protrude into the reservoir (Fig. 14.4a).**

- **The loss of head at the entrance to the pipe is therefore given by** $0.5\frac{V_2^2}{2g}$ **and is known as entry loss.**

- **A protruding pipe (Fig. 14.4b) causes a greater loss of head, while on the other hand, if the inlet of the pipe is well rounded (Fig. 14.4c), the fluid can follow the boundary without separating from it, and the entry loss is much reduced and even may be zero depending upon the rounded geometry of the pipe at its inlet.**

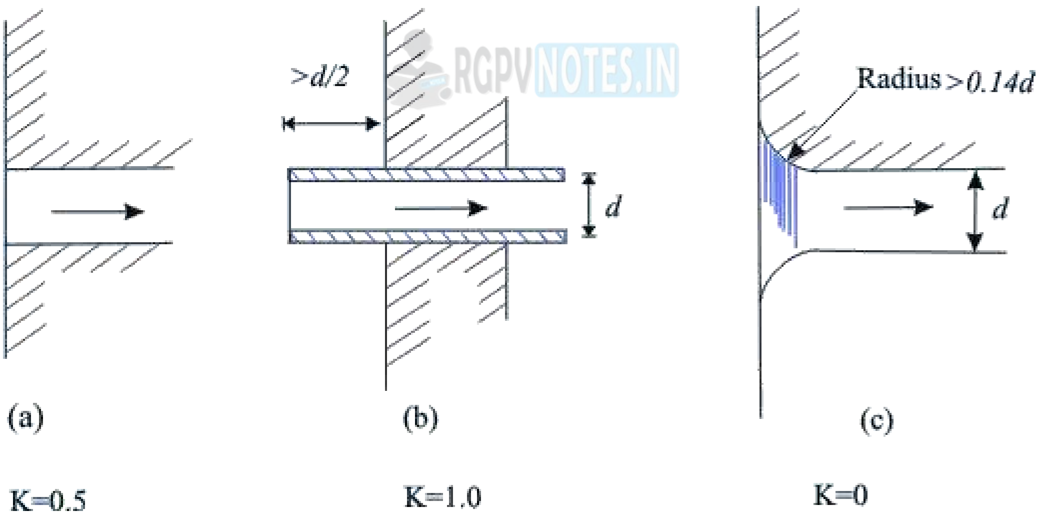


Fig 14.4 Flow from a reservoir to a sharp edges pipe

Aging of pipes

The process of change in the properties of a material occurring over a period, either spontaneously or through deliberate action

Pipe flow problems

Losses in Pipe: - It is often necessary to determine the head loss, hL that occur in a pipe flow so that the energy equation, can be used in the analysis of pipe flow problems. The overall head loss for the pipe system consists of the head loss due to viscous effects in the straight pipes, termed the major loss and denoted hL-major. The head loss in various pipe components, termed the minor loss and denoted hL-minor.

That is; hL = hL-major + hL-minor

The head loss designations of "major" and "minor" do not necessarily reflect the relative importance of each type of loss. For a pipe system that contains many components and a relatively short length of pipe, the minor loss may actually be larger than the major loss.

When a fluid is flowing through a pipe, the fluid experiences some resistance due to which some of the energy of the fluid is lost. This loss of energy is classified as:

1) Major energy losses: The viscosity causes loss of energy in the flows, which is known as frictional loss or major energy loss and it is calculated by the following formula;

(a)Darcy-weisbach formula

The loss of head can be measured by the following equations

$h_f = 4f\,L\,V^2 / (2gD)$

Where hf = Loss of head due to friction

f = Co-efficient of friction which is a function of Reynolds number

$f = 64/R_e$ (for Re <2000) (laminar flow)

L = Length of pipe

V = mean velocity of flow

D = Diameter of pipe

2) Minor energy losses: The loss of energy due to change of velocity of the flowing fluid in magnitude or direction is called minor loss of energy. The minor loss of energy includes the following cases

(a) Sudden expansion of pipe:

The head loss due to sudden expansion equation is

$$he = (V_1 - V_2)^2 / 2g$$

Where V_1 is the velocity at section 1

V_2 is the velocity at section 2

(b)Sudden contraction of pipe:

The head loss due to sudden contraction equation is

$$hc = k\,(V_2^2 / 2g)$$

Where $k = ((1/C_c)-1)^2$

V_2 is the velocity at section 2

(c) Bending in pipe:

The head loss due to bending equation is

$$h_b = k\,(V^2/2g)$$

Where V is the velocity of the flow.

k is the co-efficient of the bend ,which depends on the angle of the bend, radius of curvature of bend and diameter of the pipe

Concepts of equivalent length

The resistance of a duct or pipe elbow, valve, damper, orifice, bend, fitting, or other obstruction to flow, expressed in the number of feet of straight duct or pipe of the same diameter that would have the same resistance.

Hydraulic and energy gradient lines

Just assume those lines are simple graphical representation of how the flow energy behaves along a direction. The rough idea that lies behind flow energy is unless a flow is inviscid (zero viscosity), the whole amount of available energy will decrease because of friction. Friction create head losses, thus energy decrease.

For practical purposes, I will assume energy is expressed in terms of head, expressed in meters. The total energy available in a flow, at a specific position, noted HH can be written as follows:

$$H = P/\rho g + Z + V^2/2g + H = P/\rho g + V^2/2g$$

As you can see, this total energy head is a sum of three energy heads:

- A pressure head, $P/\rho g$
- A potential head, z
- A kinetic head, $V^2/2g$
-

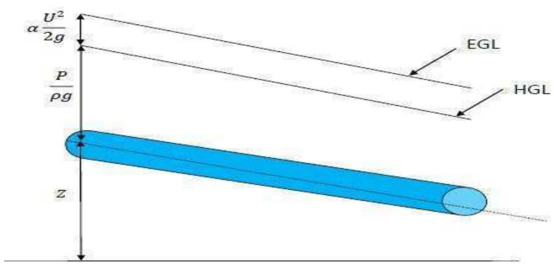
The Total Energy Line, also commonly referred as the Energy Grade Line (EGL) is a graphical representation of the aforementioned total head H.

Now consider a flow standing still. Which is not moving at all. In that case, the kinetic head becomes zero. The remaining head is somehow referred as "static head". It is just the total energy head minus the velocity head.

$H_{static} = P\rho g + z = H - V^2/2g$ $H_{static} = P\rho g + z = H - V^2/2g$

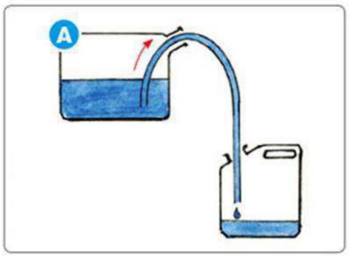
The Hydraulic Grade Line (HGL) is just a graphical representation of this static head. Therefore one can make the following deductions:

- The Hydraulic Grade Line (HGL) lies one velocity head below the Energy Grade Line (EGL)
- In case the cross section is constant along the streamline and the flow steady, discharge remains constant and also so does velocity. Therefore, velocity head remains the same aswell. In that case, HGL will always remain parallel to EGL.



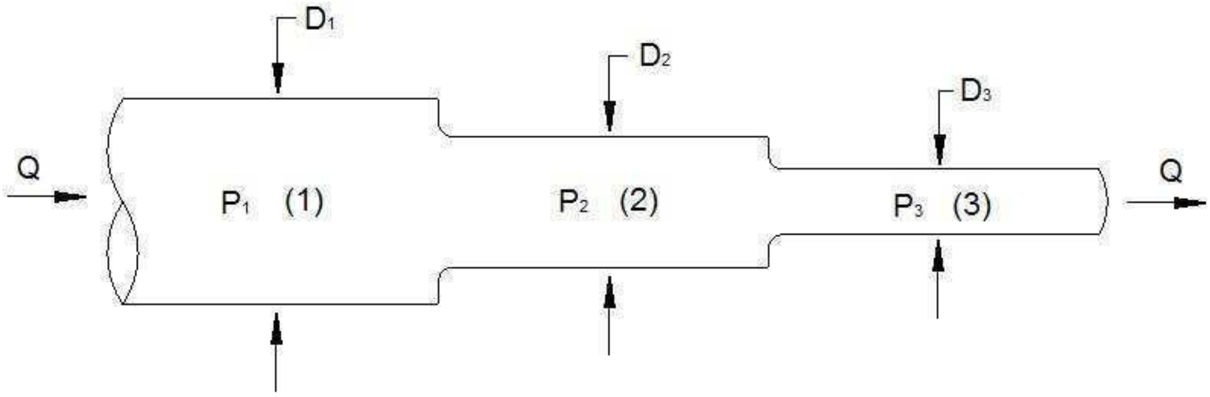
Siphon

A tube used to convey liquid upwards from a reservoir and then down to a lower level of its own accord. Once the liquid has been forced into the tube, typically by suction or immersion, flow continues unaided.



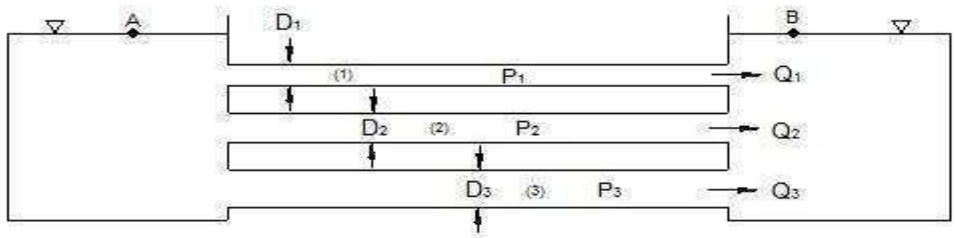
Pipes in series

In addition to this, there could be cases where there is a resistance to the fluid flow due to a valve that was partially closed or possibly build up on a pipe. Elbows and turns in a pipe can also cause a pressure loss. All of these losses will sum up to a total loss for apipe that is in series.



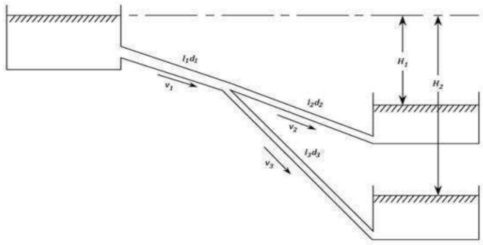
Pipes in Parallel

Pipes that are in parallel will experience the same pressure loss across each pipe. ... Equation 1 is only for a pipe system that is in parallel that has the same fluid flowing through each pipe. However, there can be cases when the fluid flowing through each pipe is not the same.



Branching of pipes

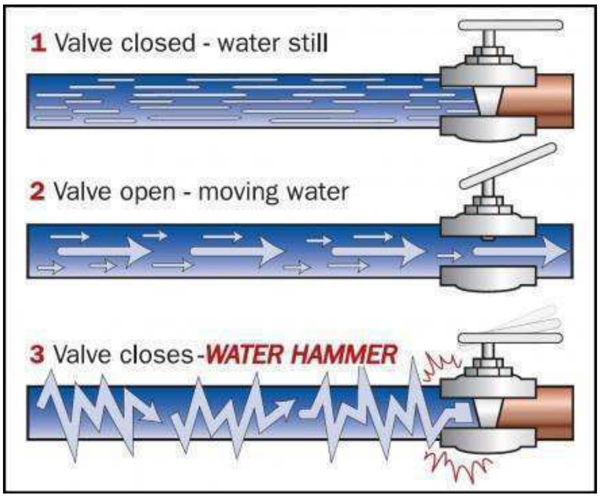
It is common for a pipeline to be branched and for the system to be feeding more than one reservoir.



Pipe Network

Water Hammer: - Water hammer is pressure surge or wave caused when a fluid in motion is forced to stop or change direction suddenly (momentum change). A water hammer commonly occurs when a valve closes suddenly at an end of a pipeline system, and a pressure wave propagates in the pipe. It is also called hydraulic shock.

This pressure wave can cause major problems, from noise and vibration to pipe collapse. It is possible to reduce the effects of the water hammer pulses with accumulators, expansion tanks, surge tanks, and other features.



Hardy Cross method:-The Hardy Cross method is an iterative method for determining the flow in pipe network systems where the inputs and outputs are known, but the flow inside the network is unknown.