Quadrant II – Transcript and Related Materials

Programme : F.Y.B.Sc

Subject : Physics

Paper Code : PYC102

Paper Title : Properties of Matter & Acoustics

Unit : Flow of liquids and Viscosity

Module Name : Streamline flow, Turbulent flow, Critical Velocity

Module No : 10

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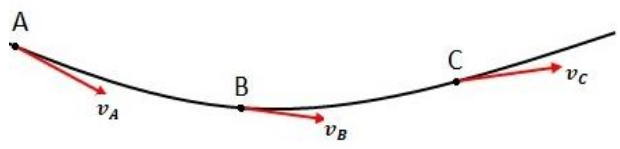
Notes:

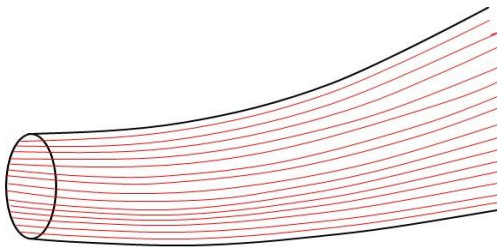
Flow of liquids & viscosity

Streamline flow and Turbulent flow

The flow of an ideal liquid (incompressible and non-viscous) occurs at low velocities when the flow is steady, i.e. flow pattern doesn't change with time.

Imagine a particle of liquid passing through point A with vel. $\boldsymbol{v_A}$ and tracing path ABC…any other particle following it will have the same velocity when passing through A and will follow the same path.





If the first particle now passes through the point B with velocity $\boldsymbol{v_B}$, the particle following it will also have velocity $\boldsymbol{v_B}$ and so on.

Velocity of the particle at a particular point in the liquid is constant even though it may not be the same at all points. The curve ABC.. is called **line of streamline**.

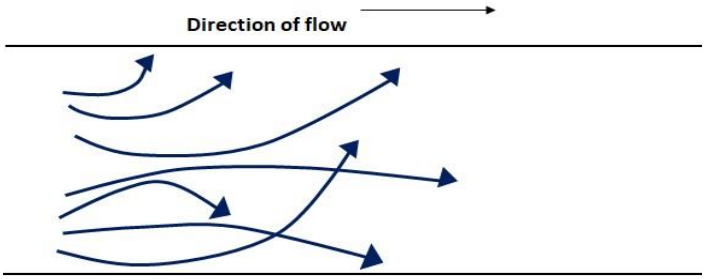
A **streamline** can be defined as the path, the tangent to which at any point gives the direction of the flow of liquid at that point.

Tube of flow: A bundle of streamlines forming a tubular region is called a tube of flow.

Streamline flow: When a liquid flows such that each particle of the liquid passing a given point moves along the same path and has the same velocity as its predecessor, the flow is called streamline flow or steady flow.

Streamline flow is possible only if the liquid velocity does not exceed a limiting value called **critical velocity.**

Turbulent flow : When the liquid velocity exceeds a certain limiting value , called critical velocity, the liquid flow is zig-zag i.e. the path and the velocity of a liquid particle changes continuously, haphazardly.



e.g water flowing from a tap has a smooth texture when flow rate is low, but as the flow rate is increased, after critical velocity disturbances can be seen in.

Critical Velocity :

The critical velocity of a liquid is that limiting value of its velocity of flow upto which the flow is streamlined and above which the flow becomes turbulent.

The critical velocity v_c of a liquid flowing through the tube depends on

i. Coefficient of viscosity of liquid ($\boldsymbol{\eta}$)
ii. Density of liquid ($\boldsymbol{\rho}$)
iii. Radius of the tube (**r**)

The expression for v_c can be deduced by the method of dimensions :

$\mathbf{v_c}$ depends on η , ρ & r : $\boldsymbol{v_c \alpha\ \eta^a \rho^b r^c}$

$$v_c = k\,\eta^a \rho^b r^c \qquad (k = constant)$$

$$[LT^{-1}] = [ML^{-1}T^{-1}]^a [ML^{-3}]^b [L]^c$$

$$[LT^{-1}] = [M^{a+b} L^{-a-3b+c} T^{-a}]$$

$$a + b = 0 \qquad ---(i)$$

$$-a - 3b + c = 1 \qquad ---(ii)$$

$$-a = -1 \qquad ---(iii)$$

Adding (i) and (iii), we have $\boldsymbol{b = -1}$

From (iii) , $\boldsymbol{a = 1}$

Substituting values of a and b in (ii), we have $\boldsymbol{c = -1}$

$$v_c = k\,\eta^1 \rho^{-1} r^{-1}$$

$$\boldsymbol{v_c = \frac{k\,\eta}{\rho\, r}}$$; where k= Reynold's number

$$(Osborne\ Reynold's\ formula)$$

- The flow of liquids of higher viscosity and lower density through narrow pipes tends to be streamlined.
- The flow of liquids of lower viscosity and higher density through broad pipes tends to become turbulent, because in that case critical velocity will be small.

Reynold's number : It is dimensionless parameter whose value decides the nature of flow of a liquid through a pipe.