UNIT -1
GENERAL CONCEPTS

Course Objectives:

CO1:Understand and apply the basic concepts and principles employed in fluid machinery like impulse momentum principle, jet impingement, and turbo machinery

TOPICS

- Impulse-Momentum Principle
- Jet impingement on stationary and moving flat plates
- Jet Impingement on stationary or moving vanes with jet striking at the centre and tangentially at one end of the vane
- Calculations for force exerted, work done and efficiency of jet.
- Basic components of a turbo machine and its classification on the basis of purpose,
- Euler's equation for energy transfer in a turbo machine and specifying the energy transfer in terms of fluid and rotor kinetic energy changes.

Impulse-Momentum Principle

From Newton's 2nd Law:

$F = m\ a = m\ (V_1 - V_2)\ /\ t$

Impulse of a force is given by the change in momentum caused by the force on the body.

$Ft = mV_1 – mV_2$ = Initial Momentum – Final Momentum

Force exerted by jet on the plate in the direction of jet, $F = m\ (V_1 – V_2)\ /\ t$

= (Mass / Time) (Initial Velocity – Final Velocity)

$= (\rho Q)\ (V_1 – V_2) =$ $\mathbf{(\rho aV)\ (V_1 – V_2)}$

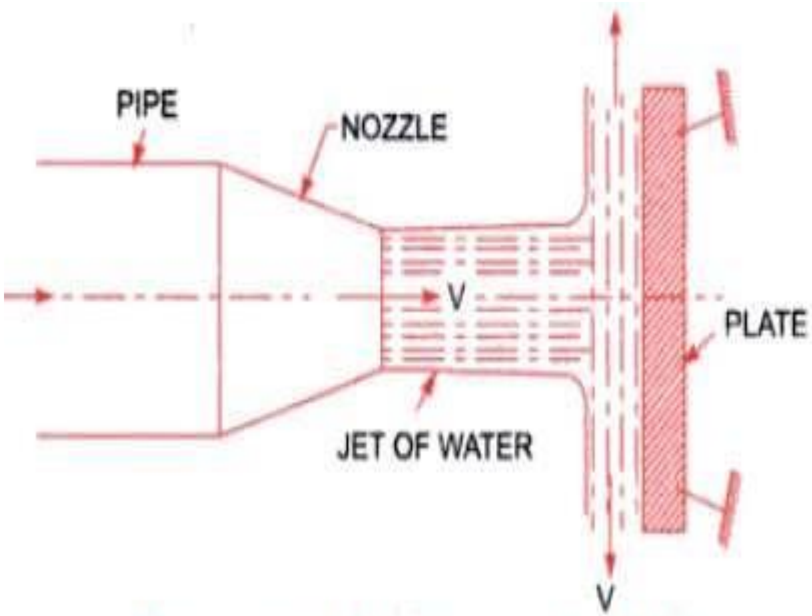
Force exerted by the jet on a stationary plate

Plate is vertical to the jet

$$F = \rho a V^2$$

If Plate is moving at a velocity of ‘U’ m/s,

$$F = \rho a (V-U)^2$$



Force exerted by jet on vertical plate.

Problems:

1. A jet of water 50 mm diameter strikes a flat plate held normal to the direction of jet. Estimate the force exerted and work done by the jet if

a. The plate is stationary

b.The plate is moving with a velocity of 1 m/s away from the jet along the line of jet. The discharge through the nozzle is 76 lps.

2. A jet of water 50 mm diameter exerts a force of 3 kN on a flat vane held perpendicular to the direction of jet. Find the mass flow rate.

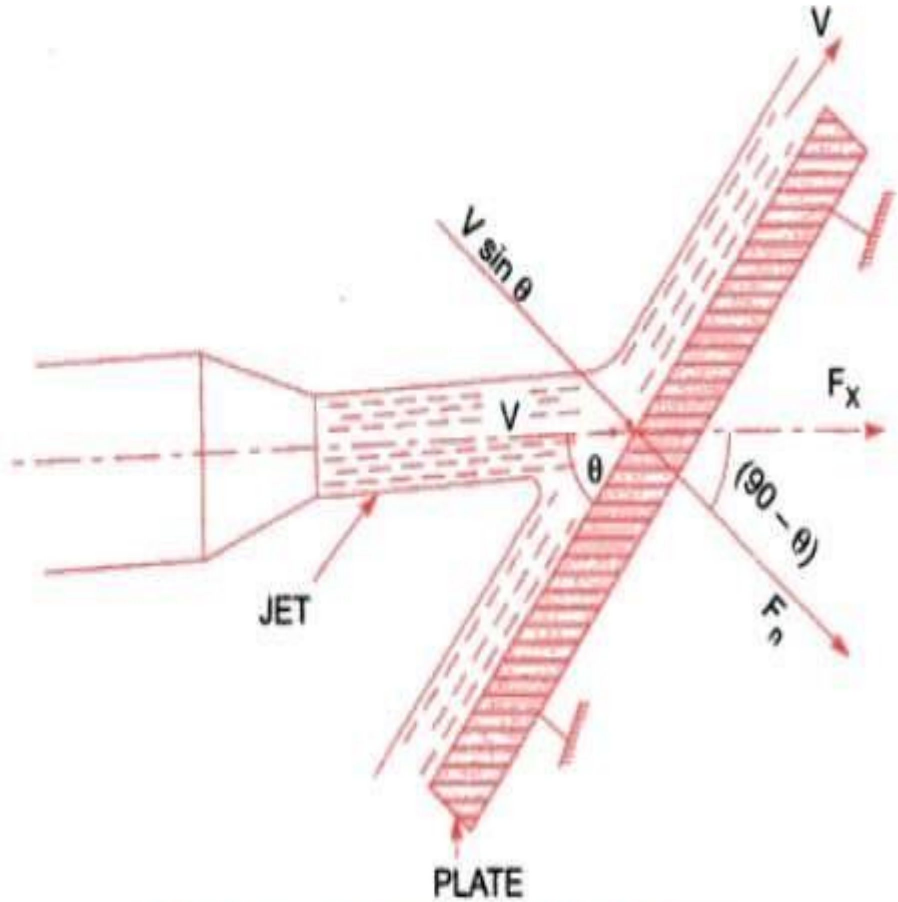
Force exerted by the jet on a stationary plate

Plate is inclined to the jet

$$F_N = \rho a V^2 \sin\theta$$

$$F_x = F_N \sin\theta$$

$$F_x = F_N \cos\theta$$



Jet striking stationary inclined plate.

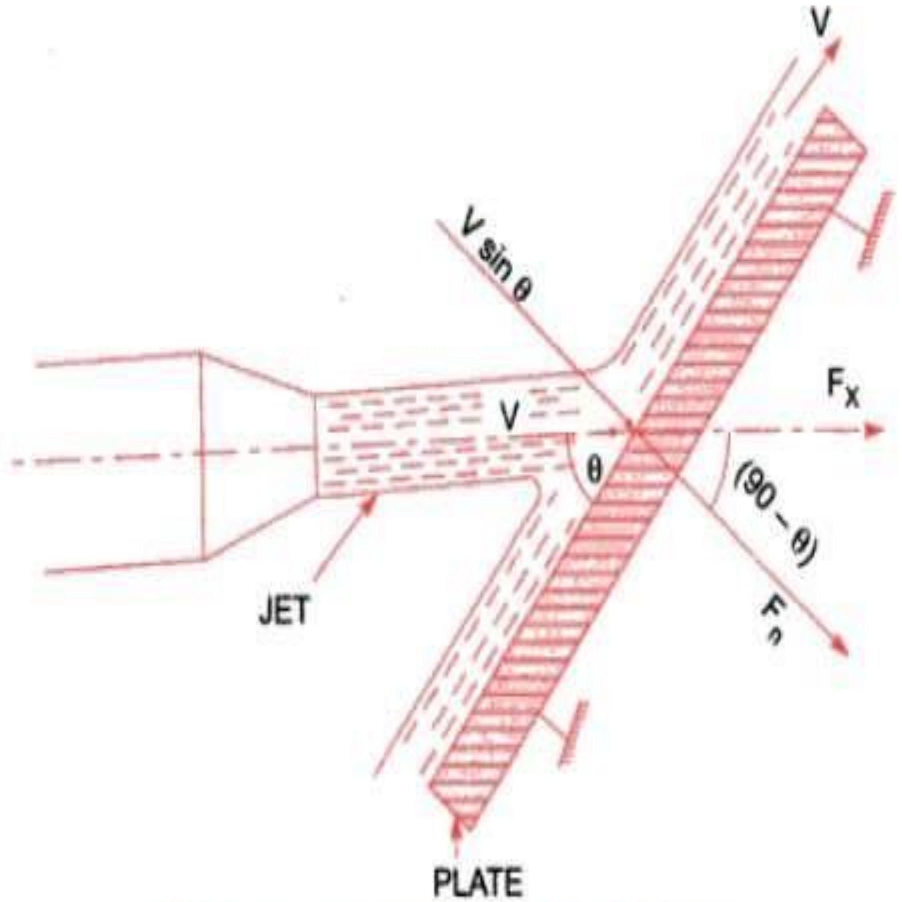
Force exerted by the jet on a moving plate

Plate is inclined to the jet

$$F_N = \rho a(V-U)^2 \sin \theta$$

$$F_x = F_N \sin \theta$$

$$F_x = F_N \cos \theta$$



Jet striking stationary inclined plate.

Problems:

1. A jet of data 75 mm diameter has a velocity of 30 m/s. It strikes a flat plate inclined

- at 45^0 to the axis of jet. Find the force on the plate when.

a. The plate is stationary

b. The plate is moving with a velocity of 15 m/s along and away from the jet.

Also find power and efficiency in case (b)

Problems:

2. A 75 mm diameter jet having a velocity of 12 m/s impinges a smooth flat plate, the normal of which is inclined at 60^0 to the axis of jet. Find the impact of jet on the plate at right angles to the plate when the plate is stationery.

a. What will be the impact if the plate moves with a velocity of 6 m/s in the direction of jet and away from it.

b. What will be the force if the plate moves towards the plate.

Force exerted by the jet on a stationary plate

Plate is Curved and Jet strikes at Centre

$$F = \rho a V^2 (1 + \cos\theta)$$

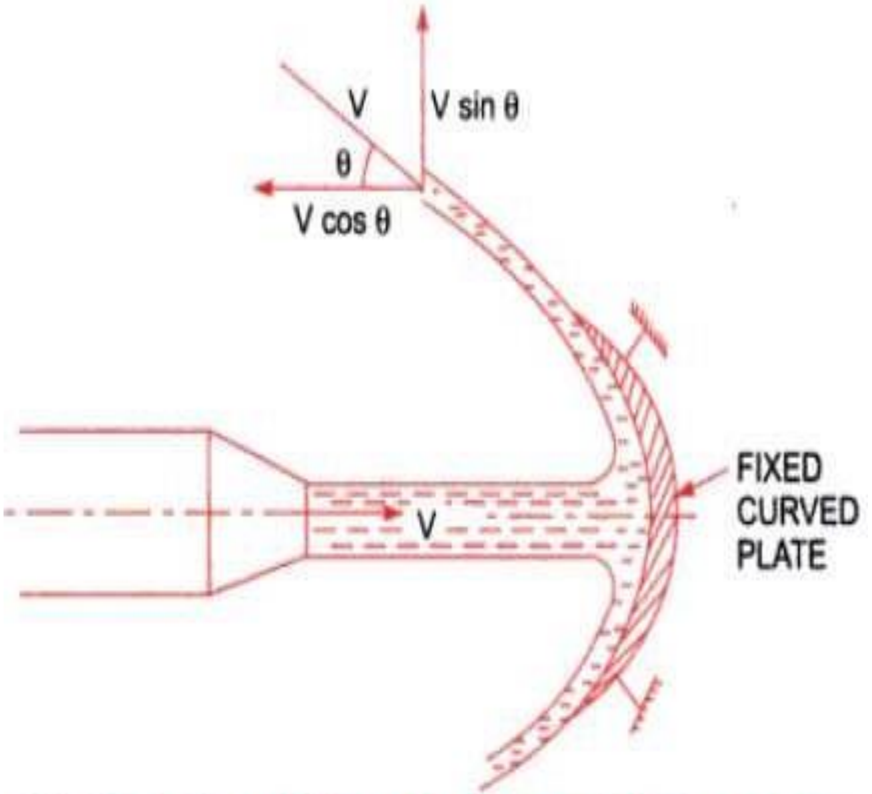
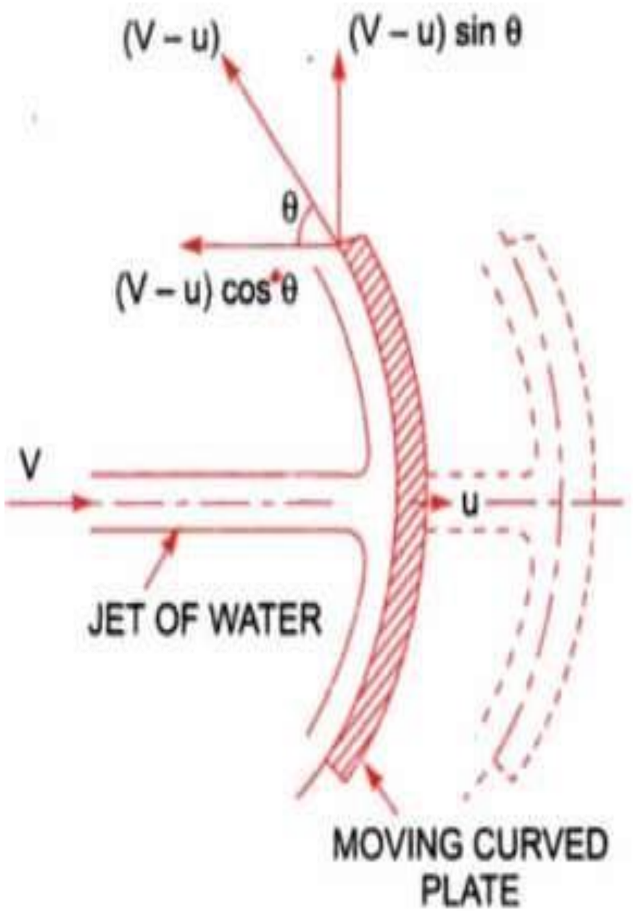


Fig. 17.3 *Jet striking a fixed curved plate at centre.*

Force exerted by the jet on a moving plate

Plate is Curved and Jet strikes at Centre

$$F = \rho a(V-U)^2 (1+ \cos \theta)$$



Force exerted by the jet on a stationary plate (Symmetrical Plate)

Plate is Curved and Jet strikes at tip

$$F_x = 2\rho a V^2 \cos\theta$$

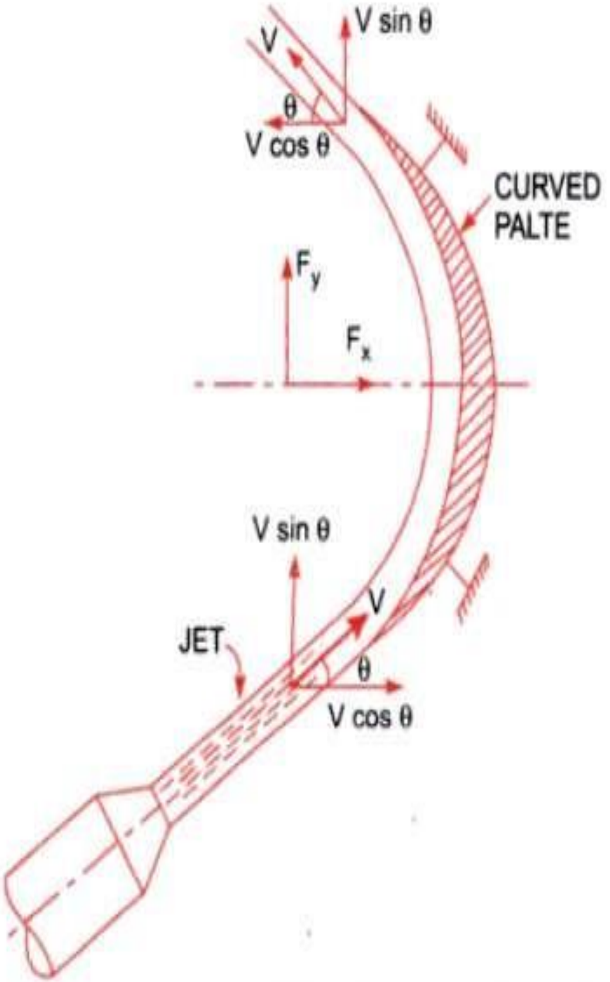
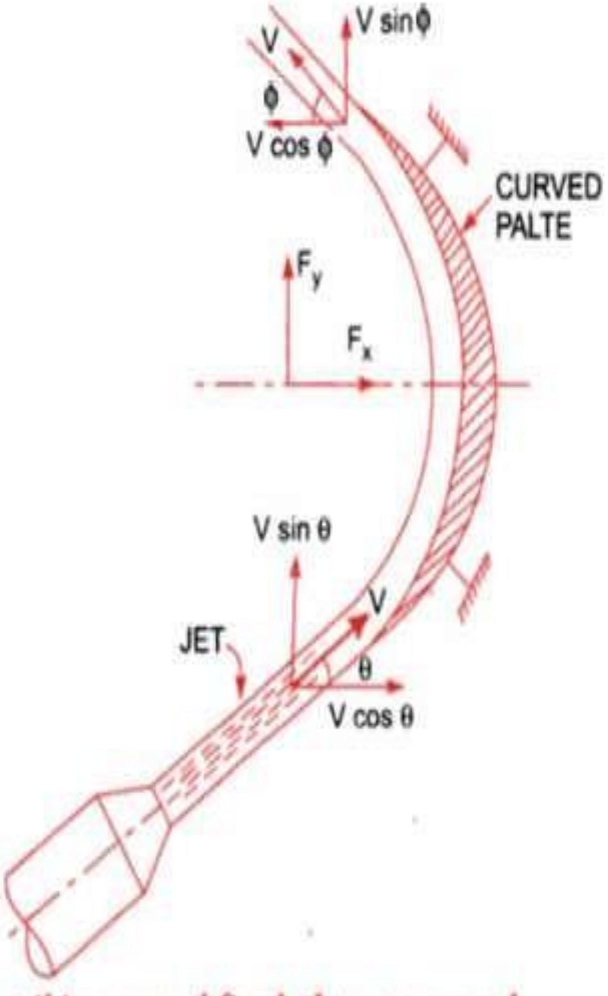


Fig. 17.4 Jet striking curved fixed plate at one end.

Force exerted by the jet on a stationary plate (Unsymmetrical Plate)

Plate is Curved and Jet strikes at tip

$$F_x = \rho a V^2 (\cos\theta + \cos\phi)$$



Jet striking curved fixed plate at one end.

Problems:

1. A jet of water strikes a stationery curved plate tangentially at one end at an angle of 30^0 . The jet of 75 mm diameter has a velocity of 30 m/s. The jet leaves at the other end at angle of 20^0 to the horizontal. Determine the magnitude of force exerted along ‘x’ and ‘y’ directions.

Force exerted by the jet on a moving plate

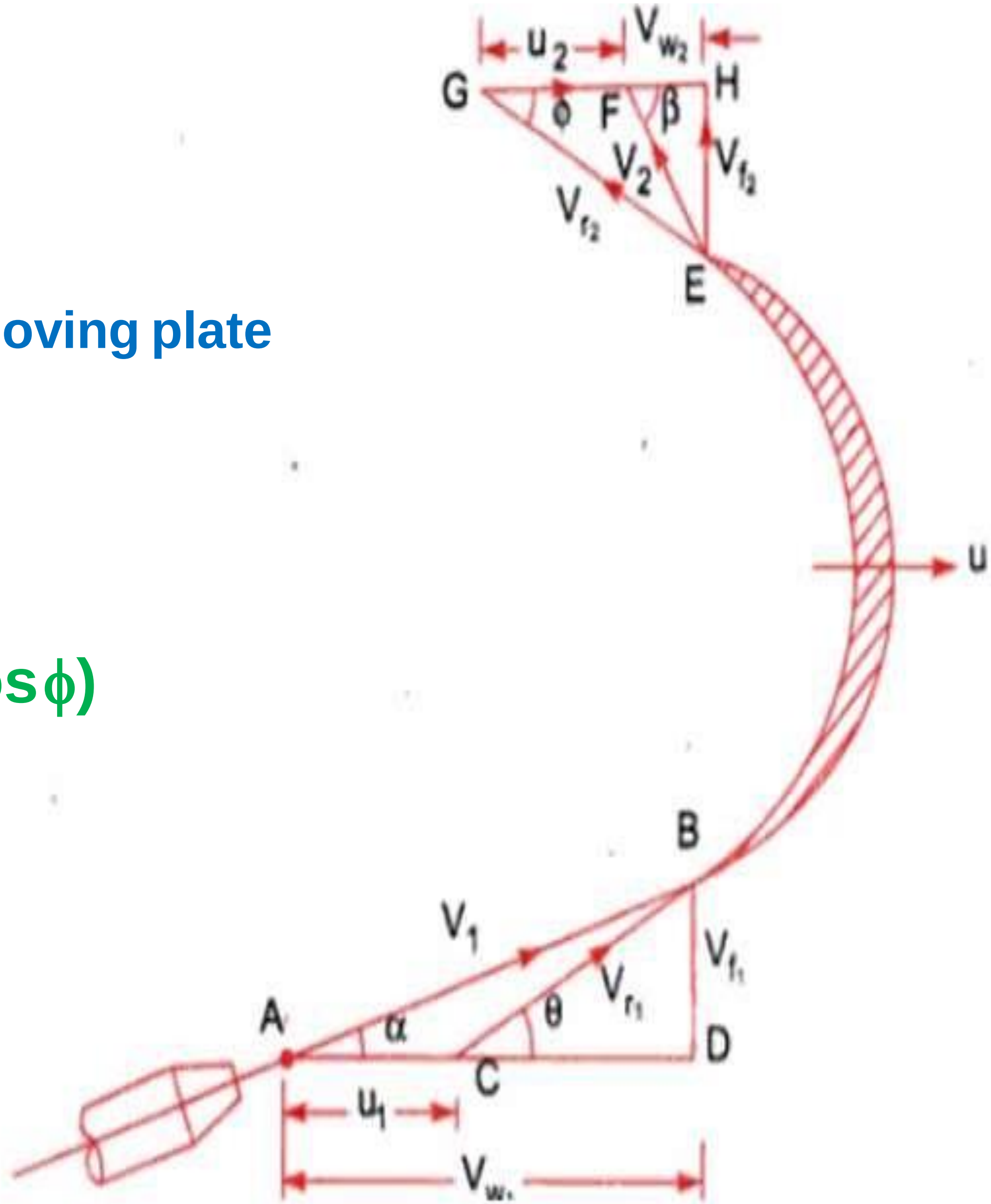
Considering Relative Velocity,

If $\beta < 90^0$

$$F_x = \rho a V_{r1} (V_{r1} \cos\theta + V_{r2} \cos\phi)$$

OR

$$F_x = \rho a V_{r1} (V_{W1} + V_{W2})$$



Jet striking a moving curved vane at one of the tips.

Force exerted by the jet on a moving plate

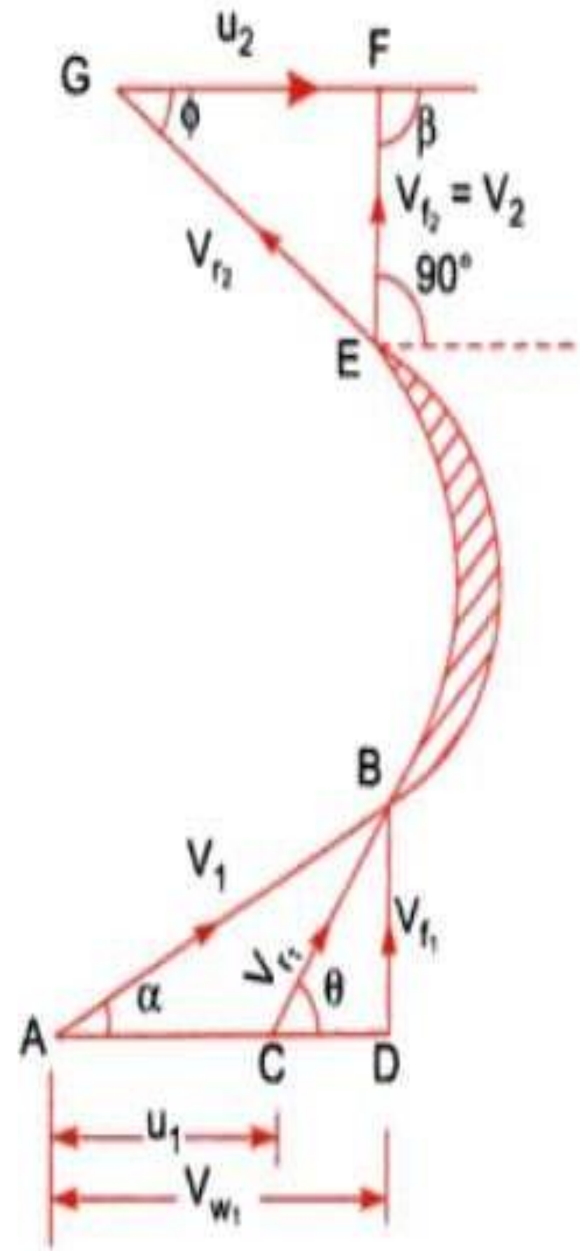
Considering Relative Velocity,

If $\beta = 90^0$

$$F_x = \rho a V_{r1} (V_{r1} \cos\theta - V_{r2} \cos\phi)$$

OR

$$F_x = \rho a V_{r1} (V_{W1})$$



Force exerted by the jet on a moving plate

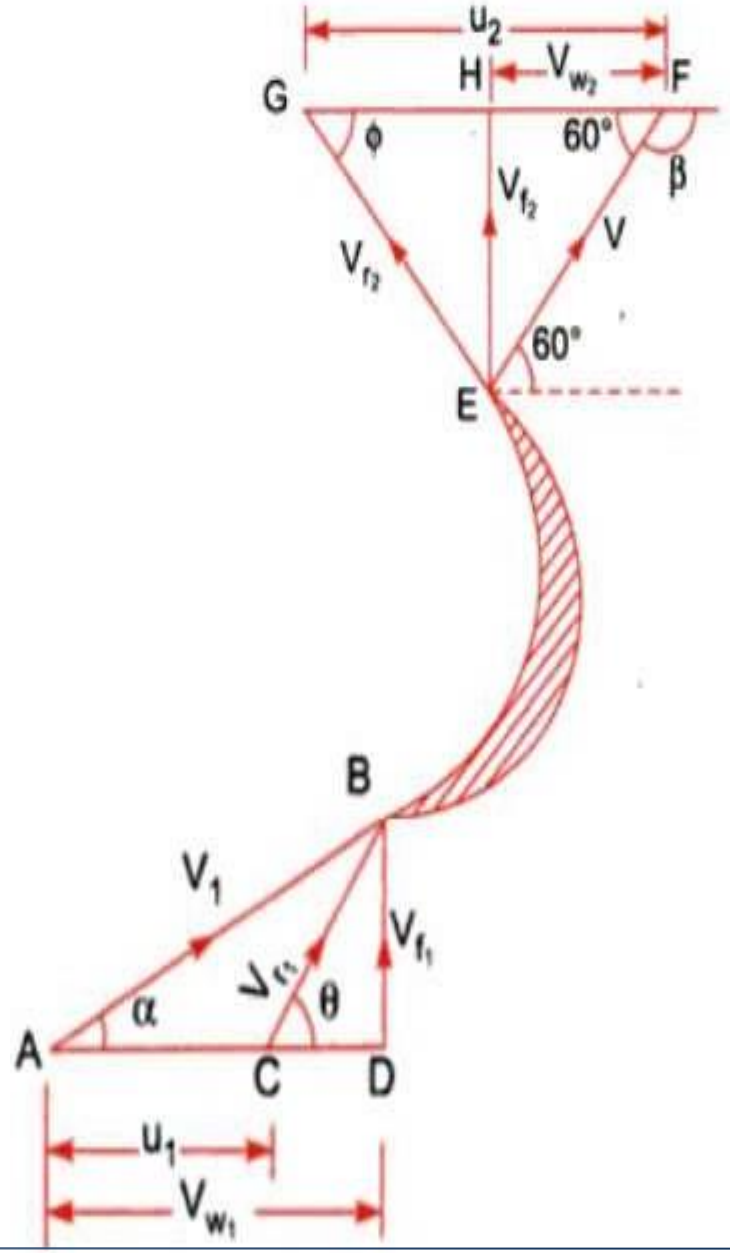
Considering Relative Velocity,

If $\beta = 90^0$

$$F_x = \rho a V_{r1} (V_{r1} \cos \theta - V_{r2} \cos \phi)$$

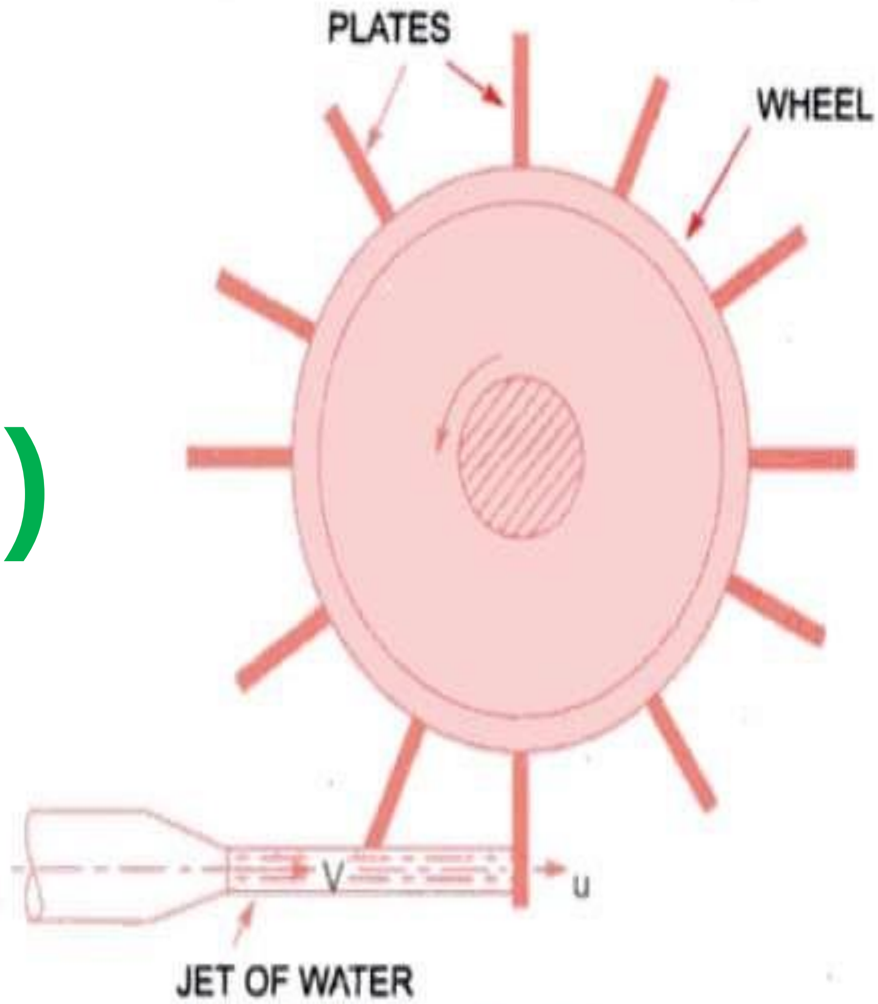
OR

$$F_x = \rho a V_{r1} (V_{W1} - V_{W2})$$



Impact of jet on a series of flat vanes mounted radially on the periphery of a circular wheel

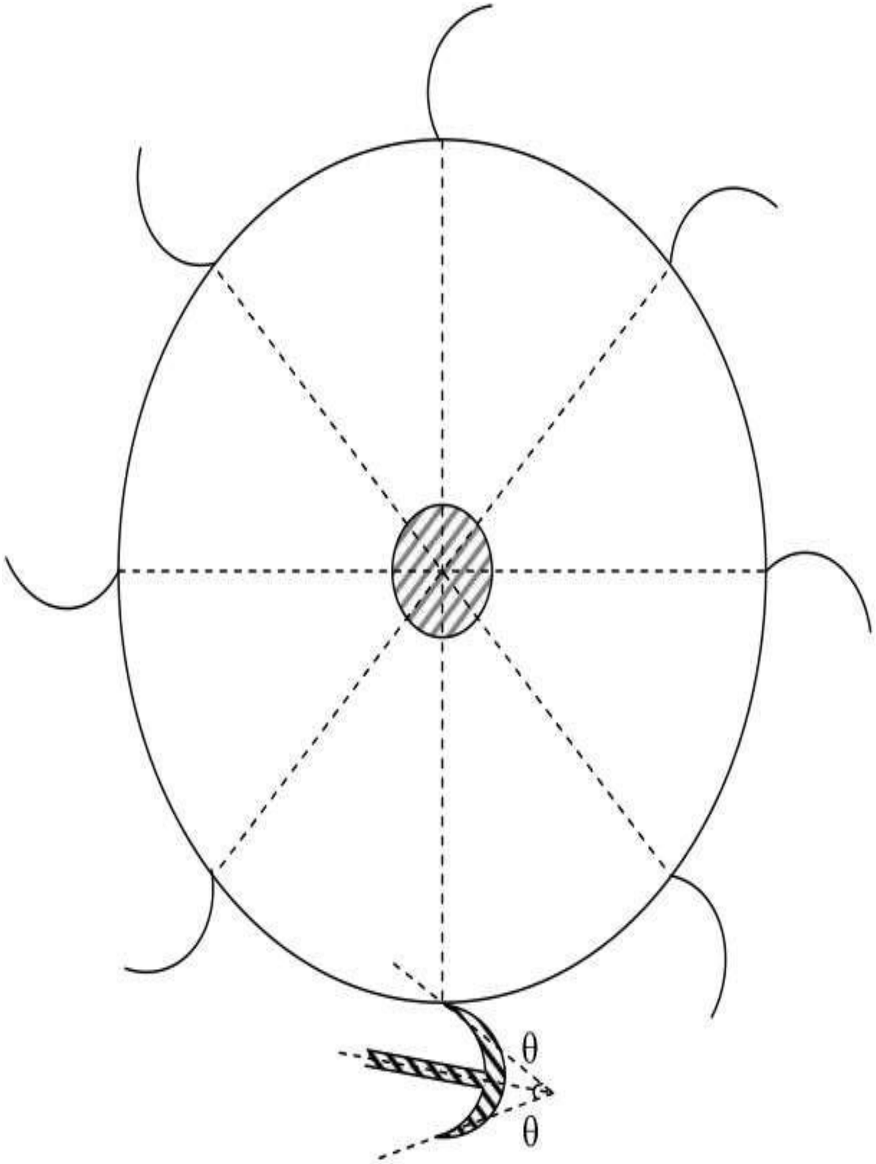
$$F = \rho a V (V - U)$$



Jet striking a series of vanes.

Impact of jet on a series of flat vanes mounted radially on the periphery of a circular wheel

$$F = \rho a V (V-U)(1+\cos\theta)$$



Problems:

- 1. A jet of water of diameter 75 mm strikes a curved plate at its centre with a velocity of 25 m/s. The curved plate is moving with a velocity of 10 m/s along the direction of jet. If the jet gets deflected through 165^0 in the smooth vane, compute.

a)Force exerted by the jet.

b)Power of jet.

c)Efficiency of jet.

Problems:

- 2. A jet of water impinges a curved plate with a velocity of 20 m/s making an angle of 20^0 with the direction of motion of vane at inlet and leaves at 130^0 to the direction of motion at outlet. The vane is moving with a velocity of 10 m/s. Compute.

i)Vane angles, so that water enters and leaves without shock.

ii)Work done per unit mass flow rate

Force exerted by the jet on a moving plate (PELTON WHEEL)

Considering Relative Velocity,

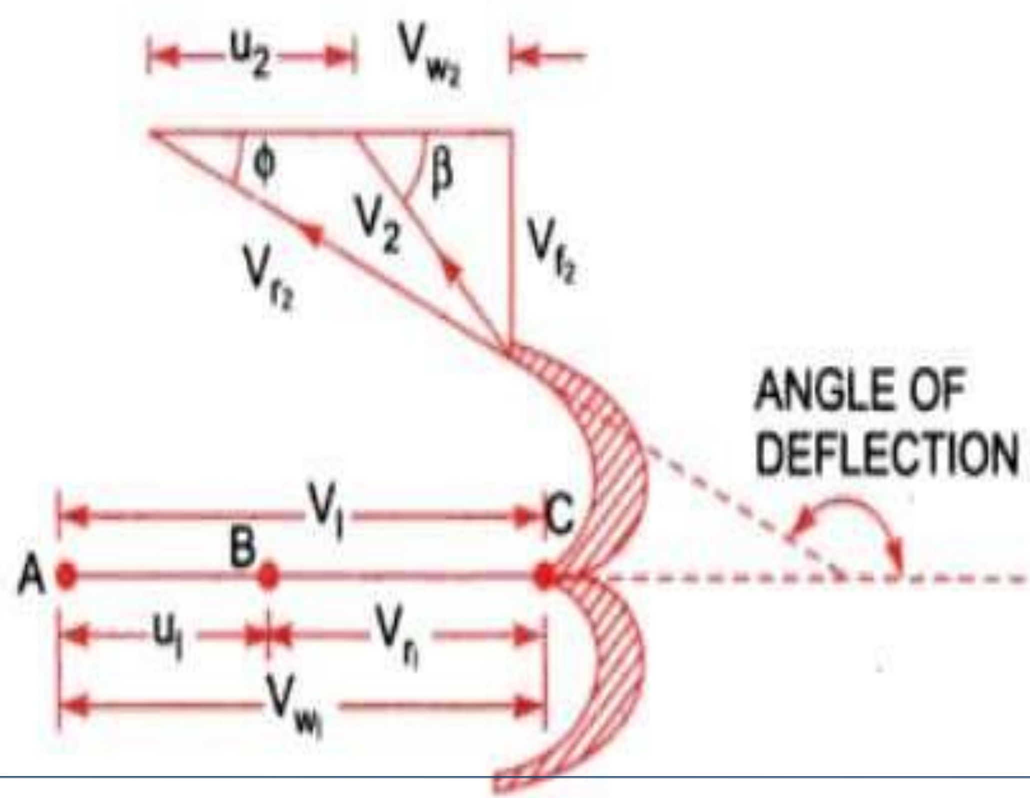
$$F_x = \rho a V_{r1} (V_{r1} - V_{r2} \cos \phi)$$

OR

$$F_x = \rho a V_{r1} (V_{W1} - V_{W2})$$

Work done / sec = F.U

Power = F. U



$$\text{Efficiency} = \frac{F.U}{\frac{1}{2} m V^2}$$

Problems:

1. A jet of water having a velocity of 35 m/s strikes a series of radial curved vanes mounted on a wheel. The wheel has 200 rpm. The jet makes 20^0 with the tangent to wheel at inlet and leaves the wheel with a velocity of 5 m/s at 130^0 to tangent to the wheel at outlet. The diameters of wheel are 1 m and 0.5 m. Find

i) Vane angles at inlet and outlet for radially outward flow turbine.

ii) Work done

iii) Efficiency of the system

Applications to Radial Flow Turbines

$V_{W1} = V_{r1} \cos\theta$ & $V_{W2} = V_{r1} \cos\phi$

Considering Angular Momentum Principle,

Torque (T) = Rate of Change of Angular Momentum

$T = \rho Q(V_{W1} R_1 - V_{W1} R_2)$

Power (P) = Torque x Angular Velocity

$P = T\omega$

If $\beta < 90^0$

$P = \rho Q\,[V_{W1} (R_1 . \omega) - V_{W2} (R_2 . \omega))$

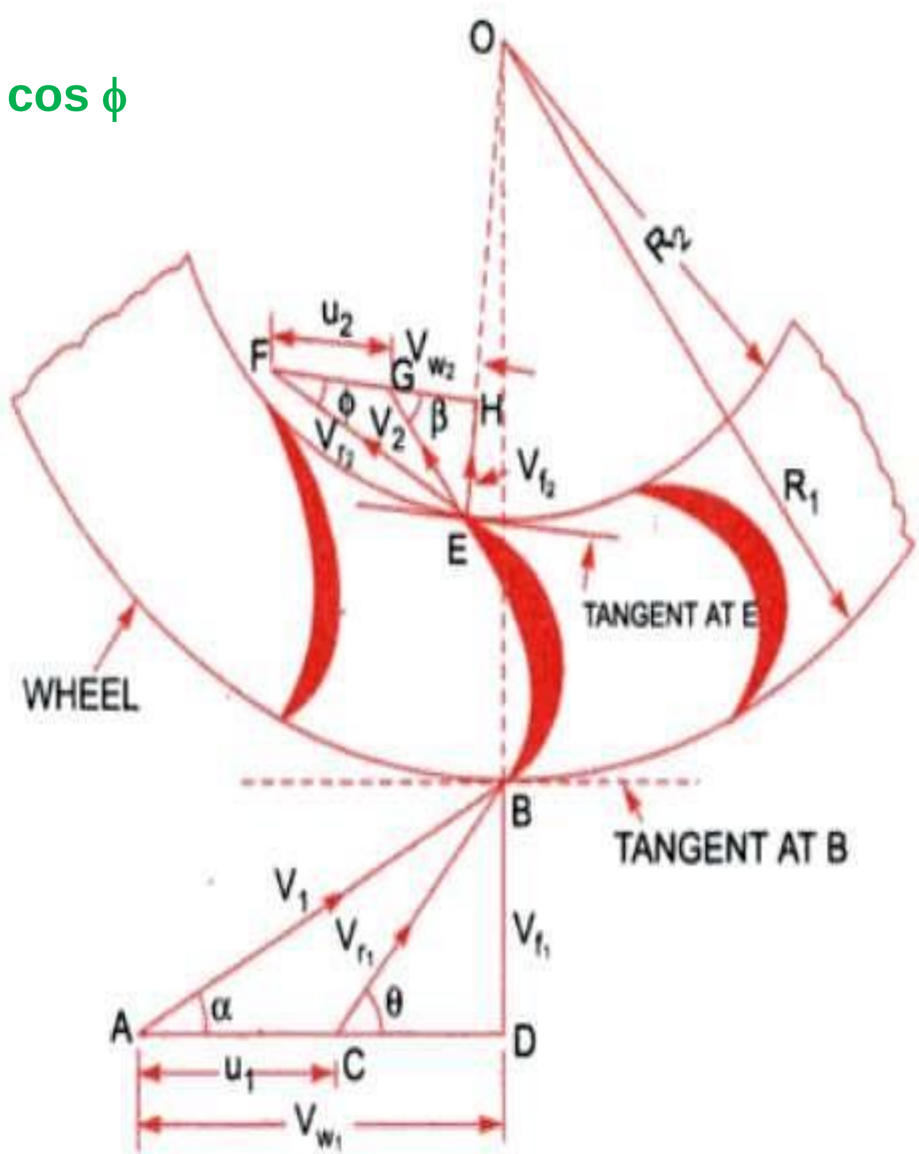
$P = \rho Q\,(V_{W1} U_1 - V_{W2} U_2)$

If $\beta = 90^0$

$P = \rho Q\,(V_{W1} U_1)$

If $\beta > 90^0$

$P = \rho Q\,(V_{W1} U_1 + V_{W2} U_2)$



Series of radial curved vanes mounted on a wheel.

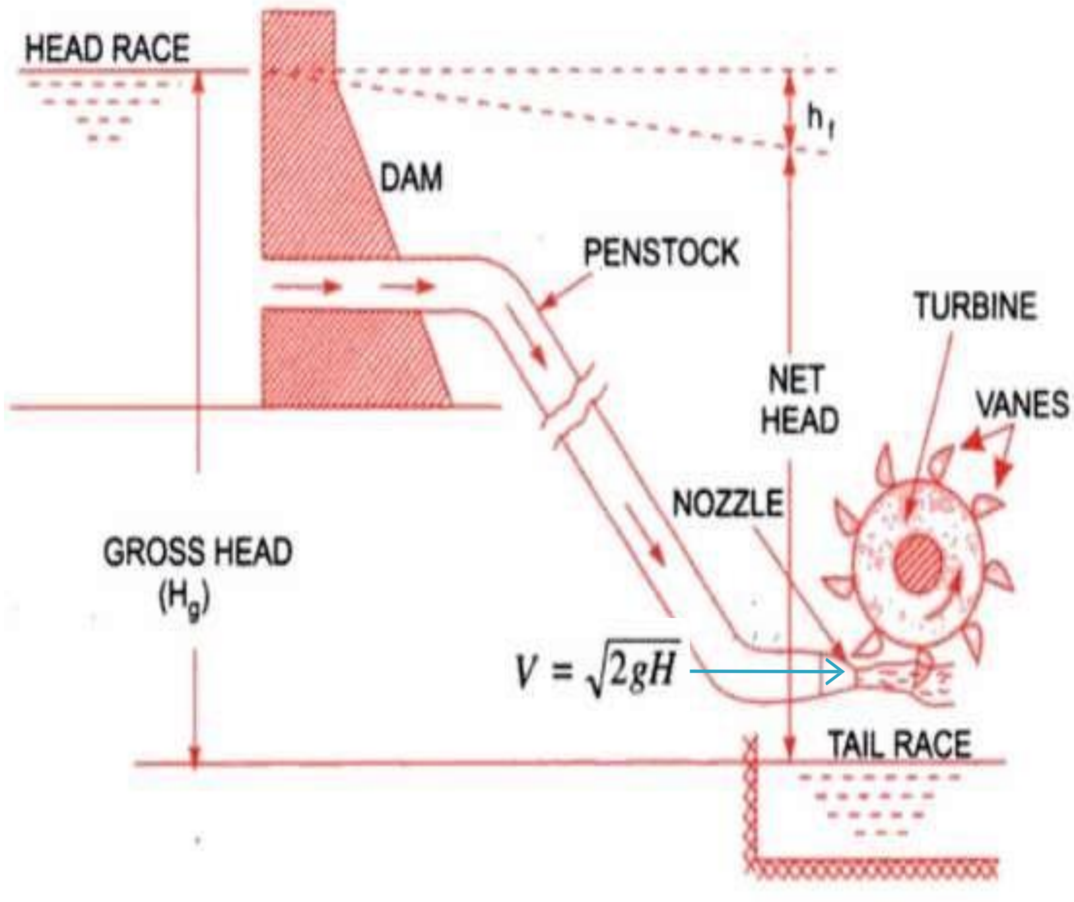
Layout of Hydropower Installation

H_g = Gross Head
h_f = Head Loss due to Friction

$$= \frac{4 \times f \times L \times V^2}{D \times 2g}$$

Where
V = Velocity of Flow in Penstock
L = Length of Penstock
D = Dia. of Penstock

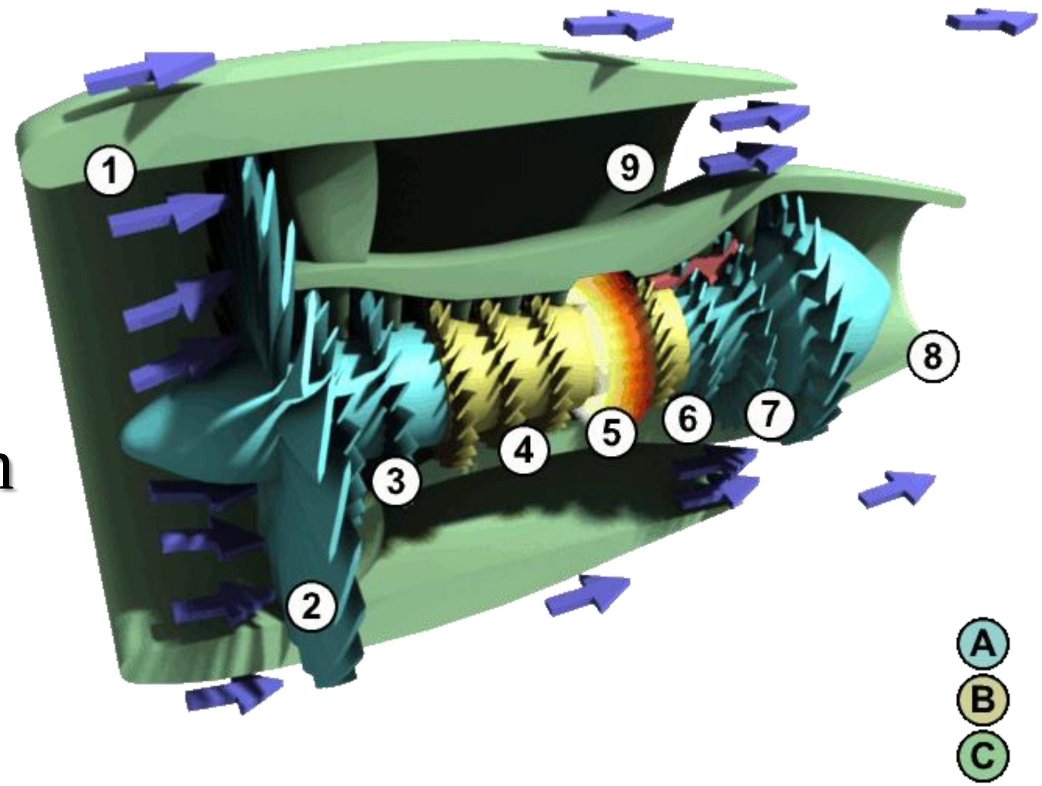
H = Net Head
= $H_g - h_f$



Layout of a hydro-eletric power plant.

What are Turbo Machines?

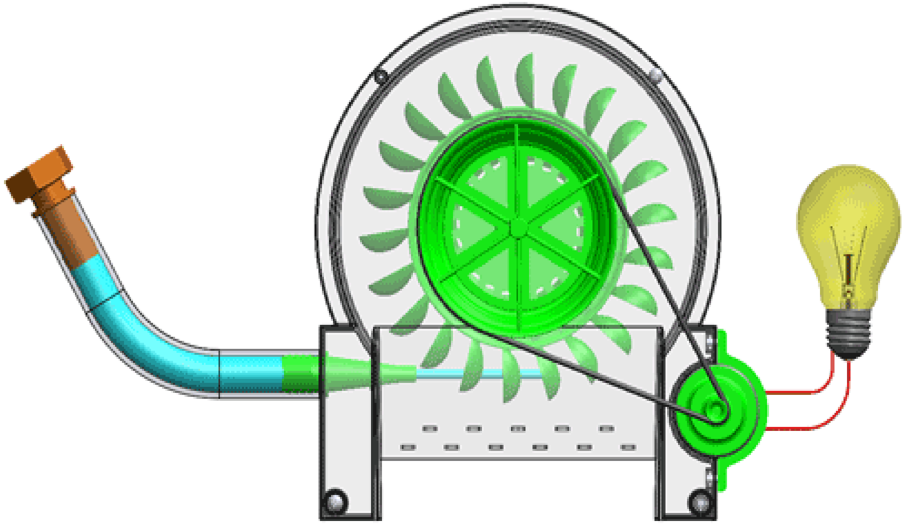
A Turbo machine is a device in which energy transfer occurs between a flowing fluid and the rotating element due to dynamic action resulting in change in pressure and momentum of fluid.

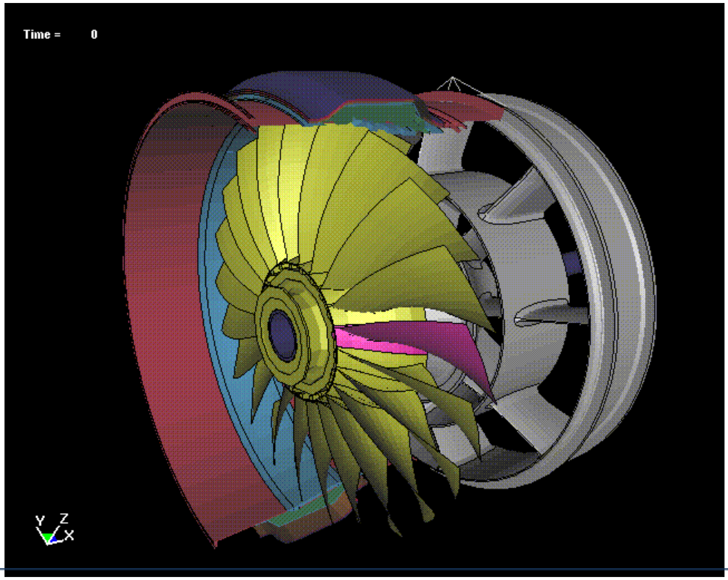


Uses of Turbomachines

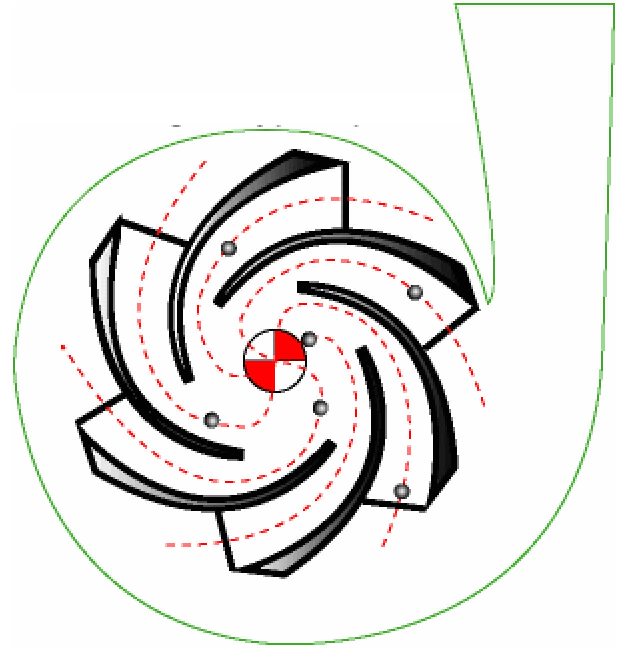
Turbomachines have several applications including

- ➢Fluid transfer
- ➢Electrical Power generation.
- ➢Aircraft propulsion





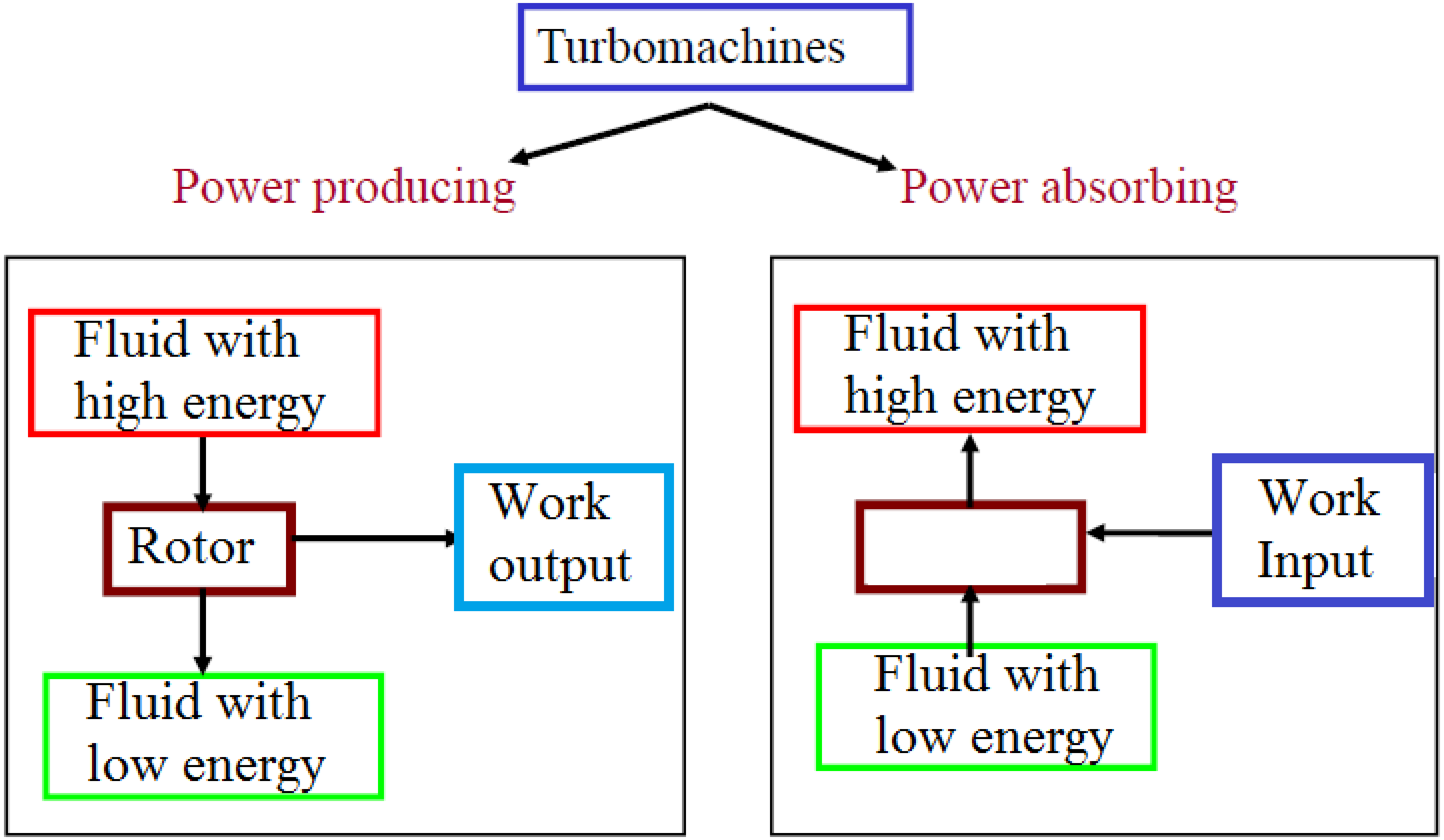
Classification



I. On basis of purpose
II. On the basis of direction of flow
III. On the basis of type of fluid




•On the basis of purpose



•On the basis of direction of fluid flow

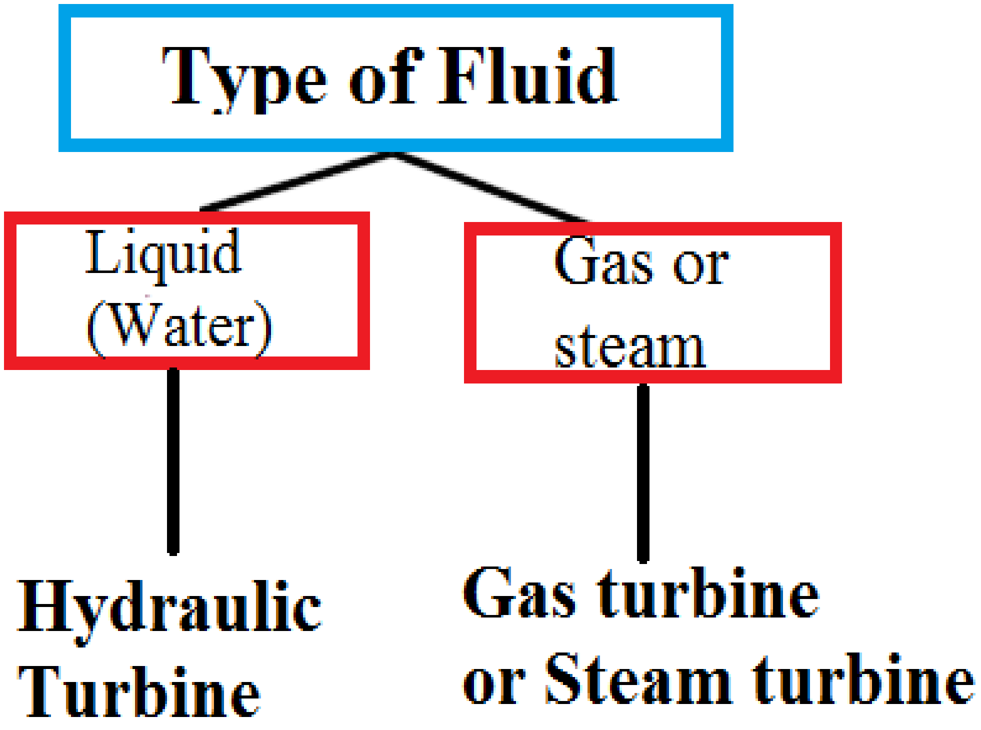
- On the basis of direction of flow:

(i) Radial flow: The fluid flows in radial direction

In turbines the fluid flows towards the centre and in pumps the fluid flows away from the centre.

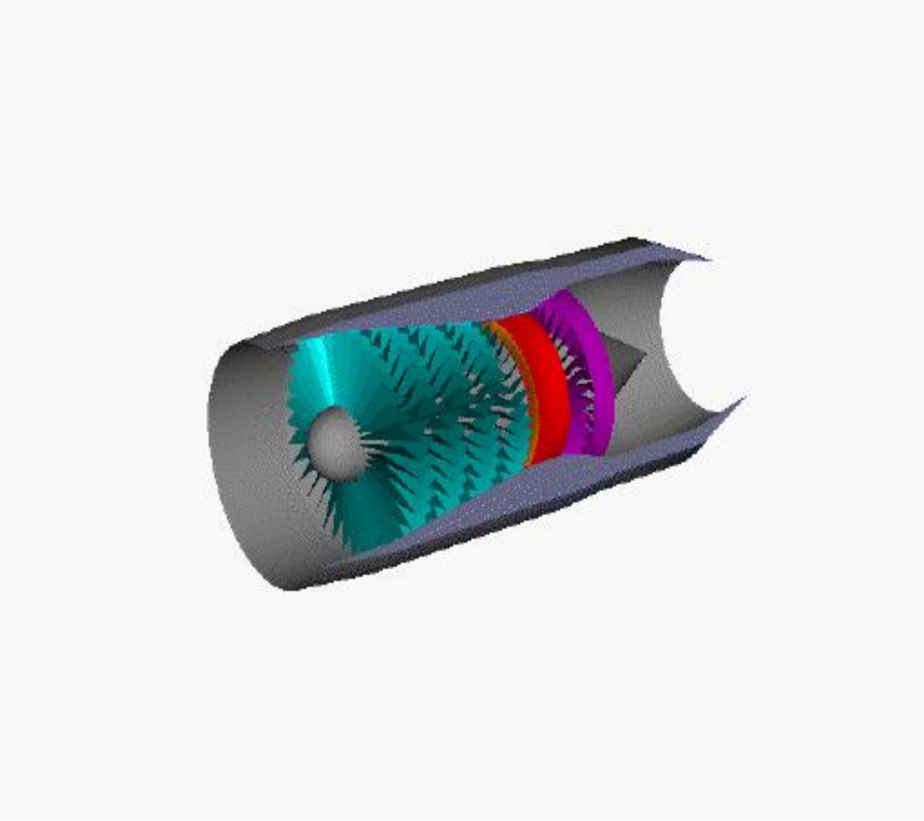
(i) Axial flow: The fluid flows parallel to the axis of the rotor.

•On the basis of type of fluid



Principal Components of Turbomachines

i. Rotating element carrying guideways.
ii. Stator.
iii. Input/Output shaft.
iv. Housing or Casing.



References

- **A Textbook of Fluid Mechanics and Hydraulic Machines**
Dr. R. K. Bansal, Laxmi Publications

- **NPTEL VIDEO LECTURES**