# Subject : Turbo Machines

## Unit No:1

## Introduction to Turbo Machinery & Impulse Water Turbines

# SYLLABUS

**Introduction to Turbo Machinery** (08 hrs)

Impulse momentum principle and its applications, Force excreted on fixed plate, moving flat plate and curved vanes, series of plates, velocity triangles and their analysis, work done equations , efficiency.

**Impulse Water Turbines**

Pelton wheel- construction, principle of working, velocity diagrams and analysis, design aspects, governing and performance characteristics, specific speed, selection of turbines, multi-jet.

# Introduction To Turbo Machinery

**Turbo machines:**

It is device that extracts energy from or imparts energy to a continuously moving stream of fluid (liquid or gas)

A turbo machine is a power or head generating machine which employs the dynamic action of a rotating element, the rotor; the action of the rotor changes the energy level of the continuously flowing fluid through the machine.

# Impulse Momentum Principle

When jet of water strikes on a flat plate or vane, it exerts a force in the direction of jet which is equal to rate of change in momentum in that direction.

Force= rate of change in momentum

$$F = \frac{[intial\ momentum - final\ momentum]}{time}$$

$$F = \frac{Mass\ X\ initial\ velocty - Mass\ X\ Final\ velcity}{time}$$

$$F = \frac{mass}{time}\ (intial\ velocity - final\ velocty)$$

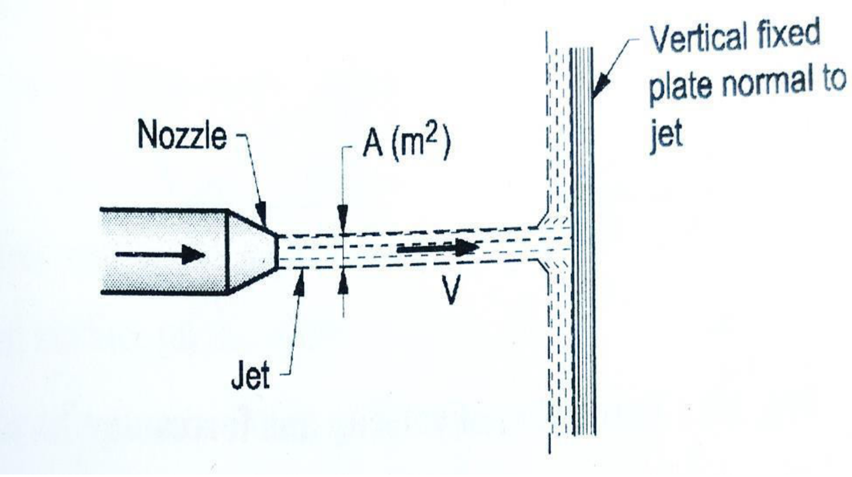
# Force exerted by the jet on stationery vertical plate

Let,

V = Velocity of jet

d = diameter of jet

a = cross section area of jet




The Force exerted by the jet on stationery vertical plate in the direction of jet

F=rate of change of momentum in the direction of force

# Force exerted by the jet on stationery vertical plate

$$F = \frac{initial\ mometum - final\ momntum}{time}$$

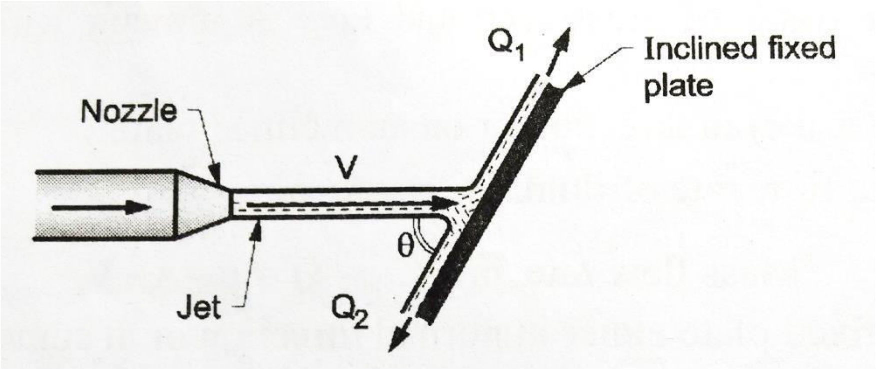
$$F = \frac{mass * initial\ velocity - mass * final\ velocity}{time}$$

$$F = \frac{mass}{time}[initial\ velocity - final\ velocity]$$

$$F = \rho a V(V - 0)$$

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

# Force exerted by the jet on stationery inclined flat plate




Mass of the water striking the plate= $\rho a V$

Let, $\Theta$ = angle between jet and plate

V = Velocity of jet

d = diameter of jet

a = cross section area of jet

The Force exerted by the jet on inclined flat plate in the direction normal to the plate.

# Force exerted by the jet on stationery inclined flat plate

F=mass of the jet striking per second *( (initial velocity of the jet in the direction normal to the plate- final velocity of jet after striking in the normal direction)

$$F = \rho a V\ (V \sin\Theta - 0) = \rho a V^2 \sin\Theta$$

This force can be resolved into two component. One in the direction of jet and other in the perpendicular direction of jet

The force in direction of jet,

$F_x = F \times \cos(90 - \Theta)$

$= F \sin\Theta$

$= \rho a V^2 \sin^2\Theta$……………..

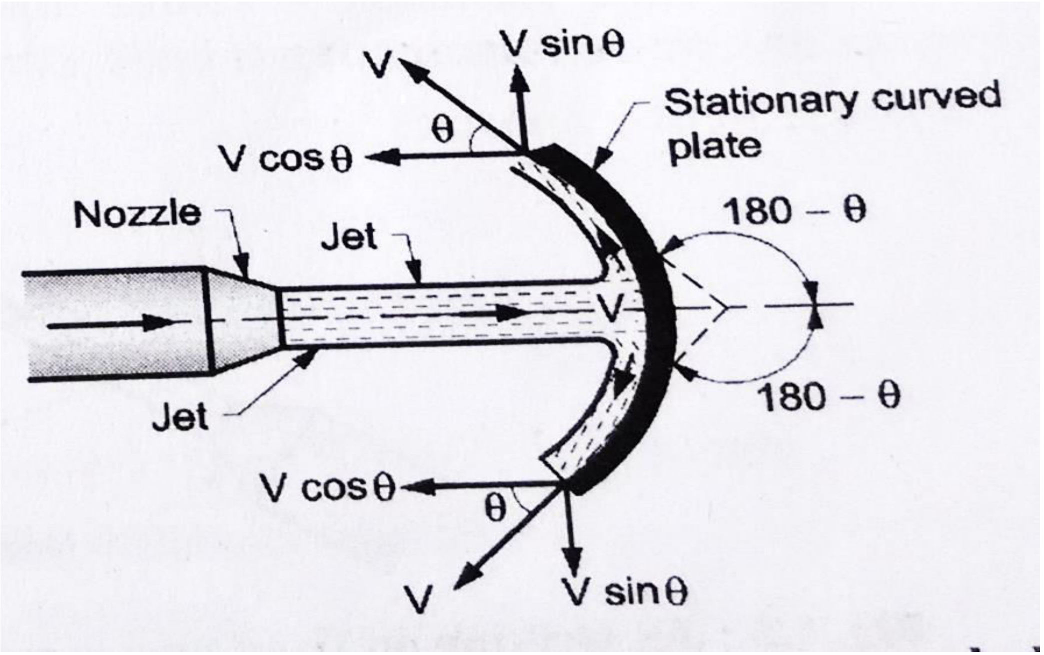
The force in normal direction of jet,

$F_y = F \times \sin(90 - \Theta)$

$= F \cos\Theta$

$= \rho a V^2 \sin\Theta \cos\Theta$……

# Force exerted by a jet on a stationary curved plate




Component of velocity in the direction of jet = -v cosϴ

# Force exerted by a jet on a stationary curved plate

Force exerted by jet in the direction of jet,

Fx = ( mass / sec ) *(initial velocity in the direction of jet – final velocity in the direction of jet)

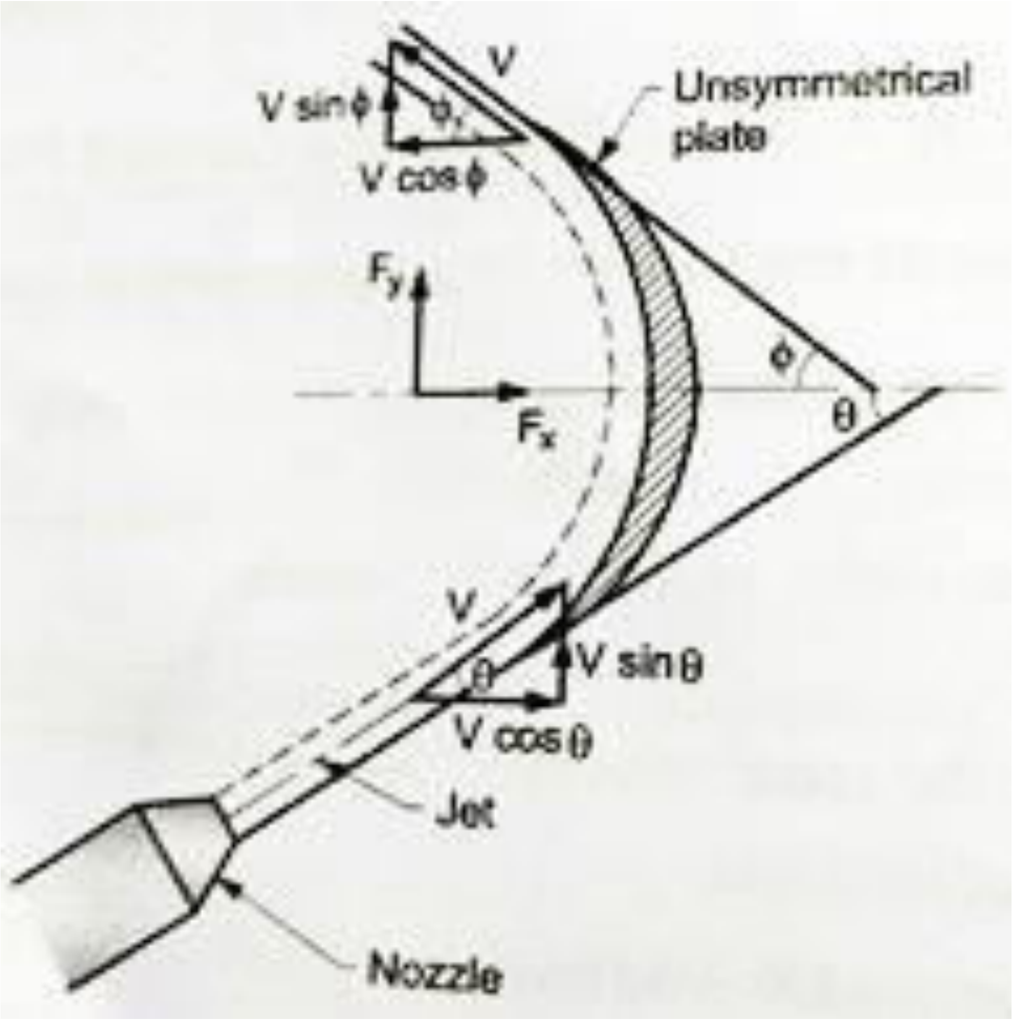
$$Fx = \rho aV [ V - (- V \cos\Theta)]$$
$$= \rho aV^2 [ 1+\cos\Theta]$$

Force exerted by jet in the normal direction of jet,

Fy = ( mass / sec ) * (initial velocity – final velocity in the normal direction of jet)

$$Fx = \rho aV [ 0 - V\sin\Theta)]$$
$$= - \rho aV^2 \sin \Theta$$

# Force exerted by the Jet on a curved plate at one end tangentially when the plate is symmetrical



## Force exerted by the Jet on a curved plate at one end tangentially when the plate is symmetrical

Force exerted by jet in X direction

Fx = ( mass / sec ) * (initial velocity in the direction of X – final velocity in the direction of X)

$$F_x = \rho a V [( V \cos\Theta - (- V \cos\Theta) ]$$

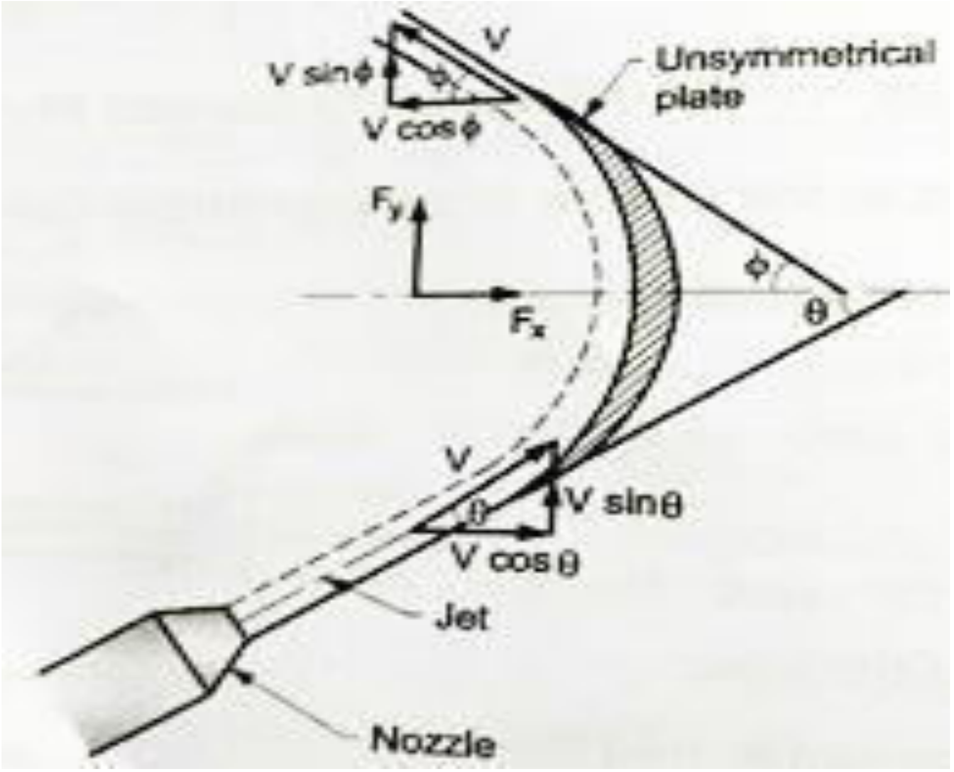
$$= \rho a V [( V \cos\Theta + V \cos\Theta) ]$$

$$= 2\rho a V^2 \cos 2\Theta$$

$$F_y = \rho a V [( V \sin\Theta - V \sin\Theta) ]$$

$$= 0$$

# Force exerted by the Jet on a curved plate at one end tangentially when the plate is unsymmetrical




Let Θ = angle made by the tangent at inlet

Φ = angle made by the tangent at outlet

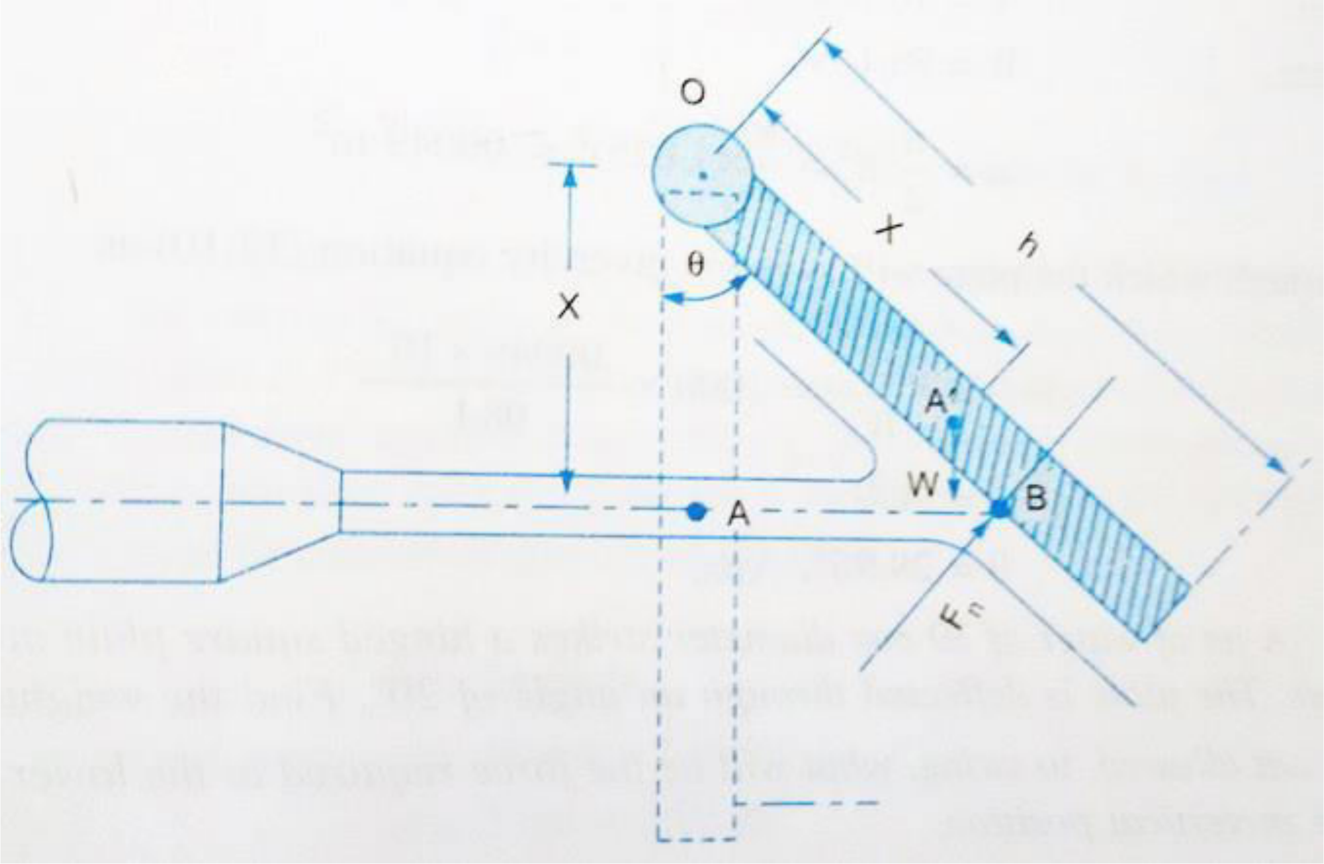
# Force exerted by the Jet on a curved plate at one end tangentially when the plate is unsymmetrical

Fx = ( mass / sec ) * (initial velocity in the direction of X – final velocity in the direction of X)

$$F_x = \rho a V [( V \cos\Theta - (- V \cos \Phi) ]$$
$$= \rho a V [( V \cos\Theta + V \cos \Phi) ]$$
$$= \rho a V^2 (\cos\Theta + \cos \Phi)$$

$$F_y = \rho a V [( V \sin\Theta - V \sin \Phi) ]$$
$$= \rho a V^2 (\sin\Theta - \sin \Phi)$$

# Force exerted by a jet on a hinged plate



# Force exerted by a jet on a hinged plate

X= distance if the centre if jet from hinge O

$\Theta$ = angle of swing about hinge

W = weight o the plate acting at C.G. of the plate

$\Theta'$ = angle between jet and plane

At equilibrium , two forces are acting on the plate, normal to the plate

1.force due to jet of water

$$Fn = \rho a V^2 \sin\Theta'$$

2. Weight of the plate, W

# Force exerted by a jet on a hinged plate

Moment of the Fn about hinge= Fn X OB= $\rho a V^2 \sin\Theta'$ X OB

$= \rho a V^2 \sin(90-\Theta)$ X OB

$= \rho a V^2 \cos\Theta$ X OB

$= \rho a V^2 \cos\Theta \times \frac{OA}{\cos\theta}$

$= \rho a V^2 \times x$

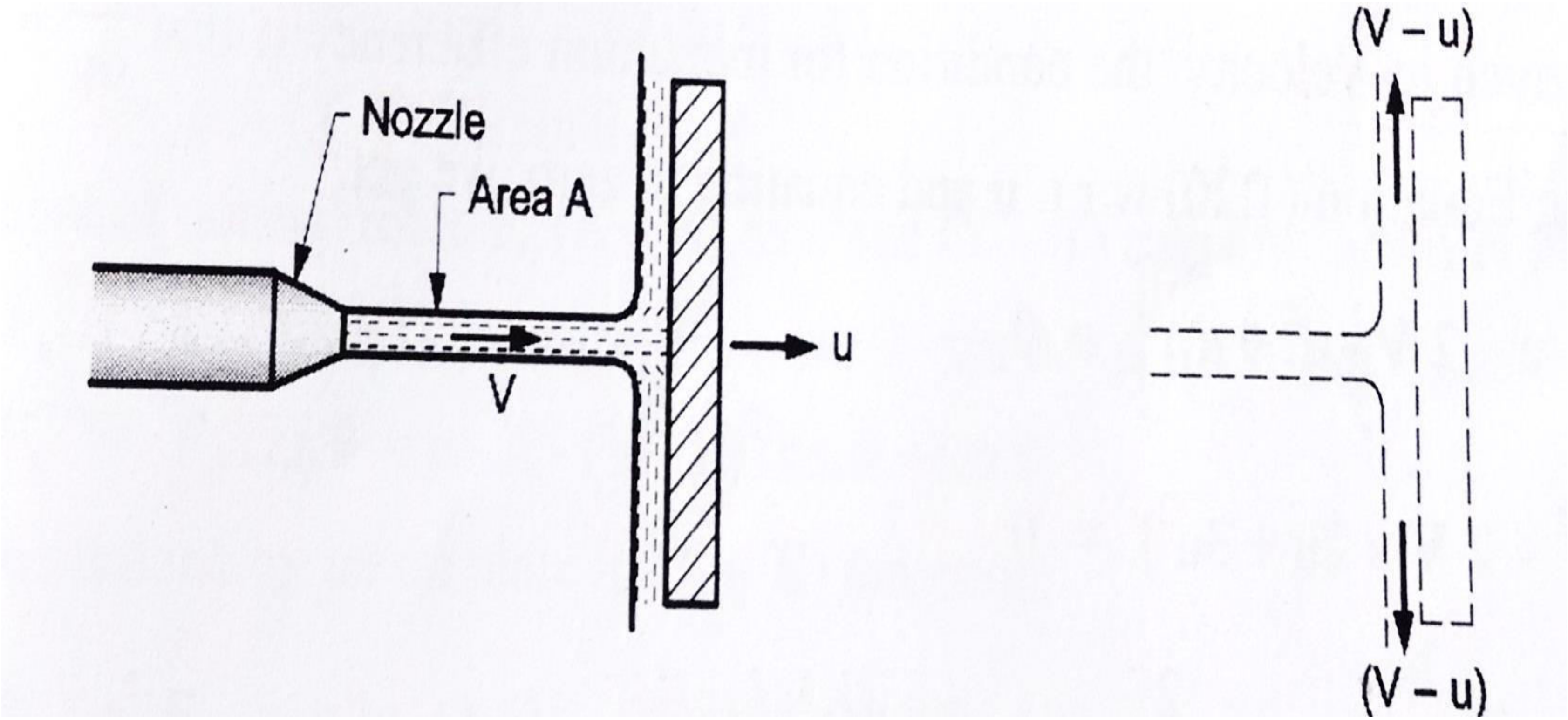
Moment of weight w about hinge = W X OA' sin Θ

= W X xX sin Θ

For equilibrium of the plate, $W \times x \times \sin\Theta = \rho a V^2 \times x$

$$\sin\Theta = \frac{\rho a V2}{W}$$

# Force exerted by a jet on a moving plate in the direction of jet



## Force exerted by a jet on a moving plate in the direction of jet

Let, V = absolute velocity of the jet

a = cross section area of the jet

u = velocity of the flat plate

Jet does not strike the plate with velocity V but with a relative velocity.

Relative velocity of the jet with respect to plate = V- u

Mass of the water striking the plate per sec = $\rho a(V-u)$

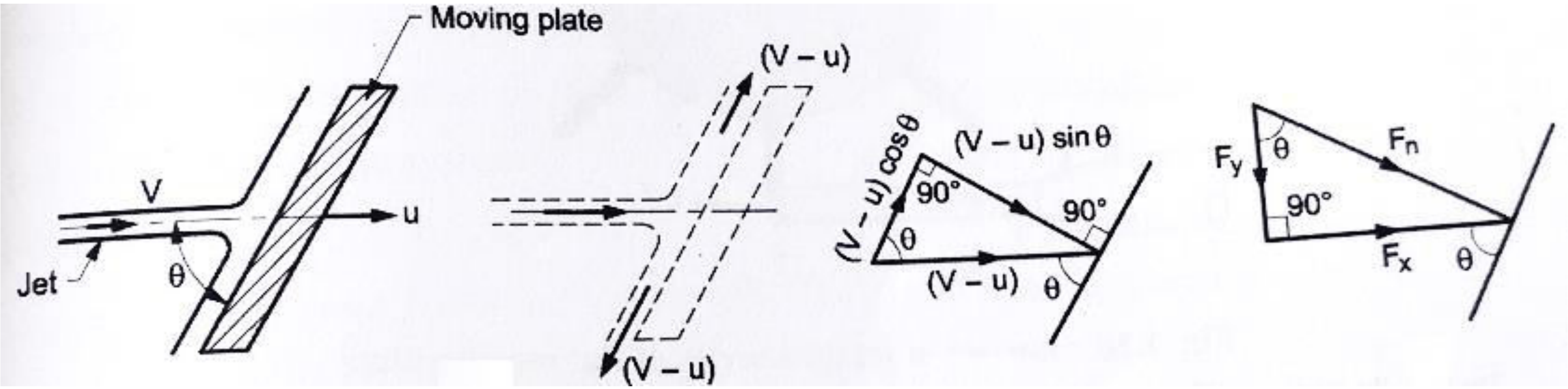
Force exerted by jet on the moving plate in the direction of jet

= mass of water striking per sec X [ initial velocity with which water strikes- final velocity ]

$= \rho a(V-u)[ (V-u) – 0 ]$

$= \rho a(V-u)^2$

# Force exerted by a jet on a moving inclined plate in the direction of jet




Let,

V = absolute velocity of the jet

a = cross section area of the jet

u = velocity of the flat plate

Θ = angle between the plate and jet

# Force exerted by a jet on a moving inclined plate in the direction of jet

Relative velocity of the jet with respect to plate = V- u

Mass of the water striking the plate per sec = ρa(V-u)

Force exerted by jet on the moving plate in the normal direction of plate = mass of water striking per sec X [ initial velocity with which water strikes in the direction normal to the plate- final velocity ]

$$Fn = \rho a(V-u)[\ (V-u)\sin \Theta - 0\ ]$$

$$Fn = \rho a(V-u)^2 \sin \Theta$$

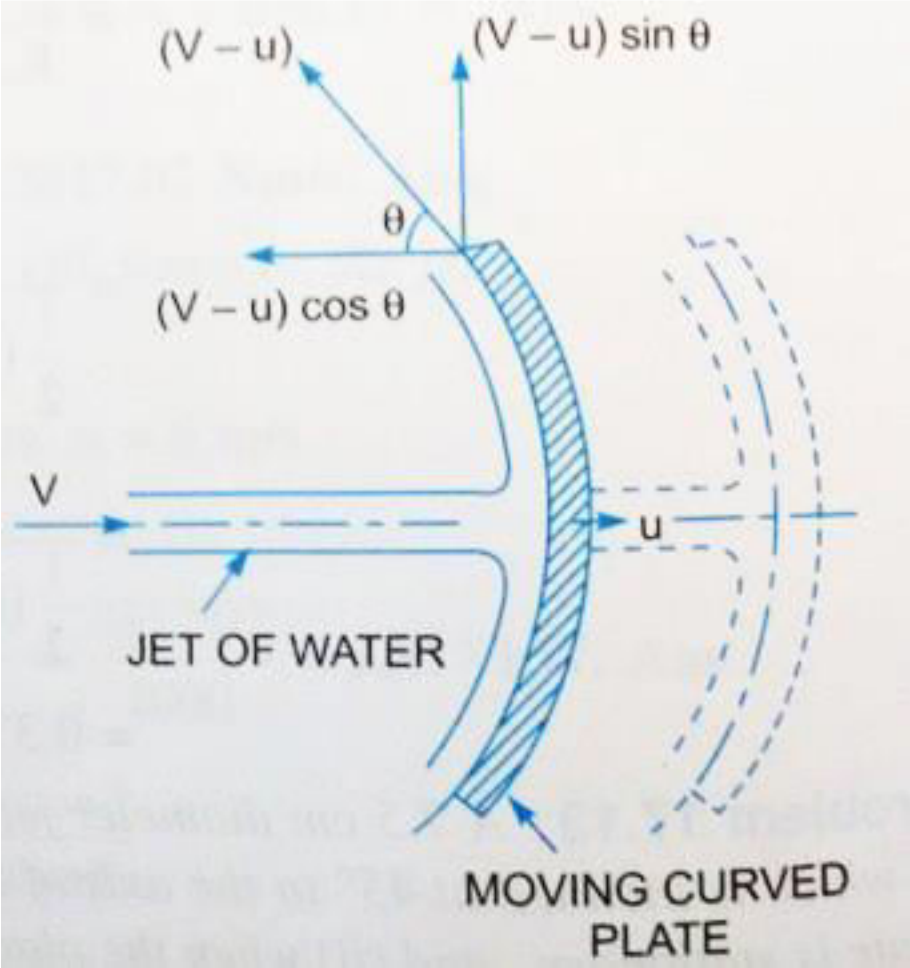
$$Fx = Fn \sin\Theta = \rho a(V-u)^2 \sin \Theta \sin \Theta$$

$$Fx = \rho a(V-u)^2 \sin^2 \Theta$$

$$Fy = \underline{Fn \cos}\Theta = \rho a(V-u)^2 \sin \Theta \cos \Theta$$

$$\underline{Fy =} \rho a(V-u)^2 \sin \Theta \cos \Theta$$

# Force exerted by a jet on a moving curved plate in the direction of jet



# Force exerted by a jet on a moving curved plate in the direction of jet

Component of velocity in the direction of jet = $-(V-u)\cos\Theta$

Force exerted by jet in the direction of jet,

Fx = ( mass / sec ) * (initial velocity in the direction of jet – final velocity in the direction of jet)

$$F_x = \rho a(V-u)\,[(V-u) - (-V\cos\Theta)]$$

$$= \rho a(V-u)^2\,[1+\cos\Theta]$$

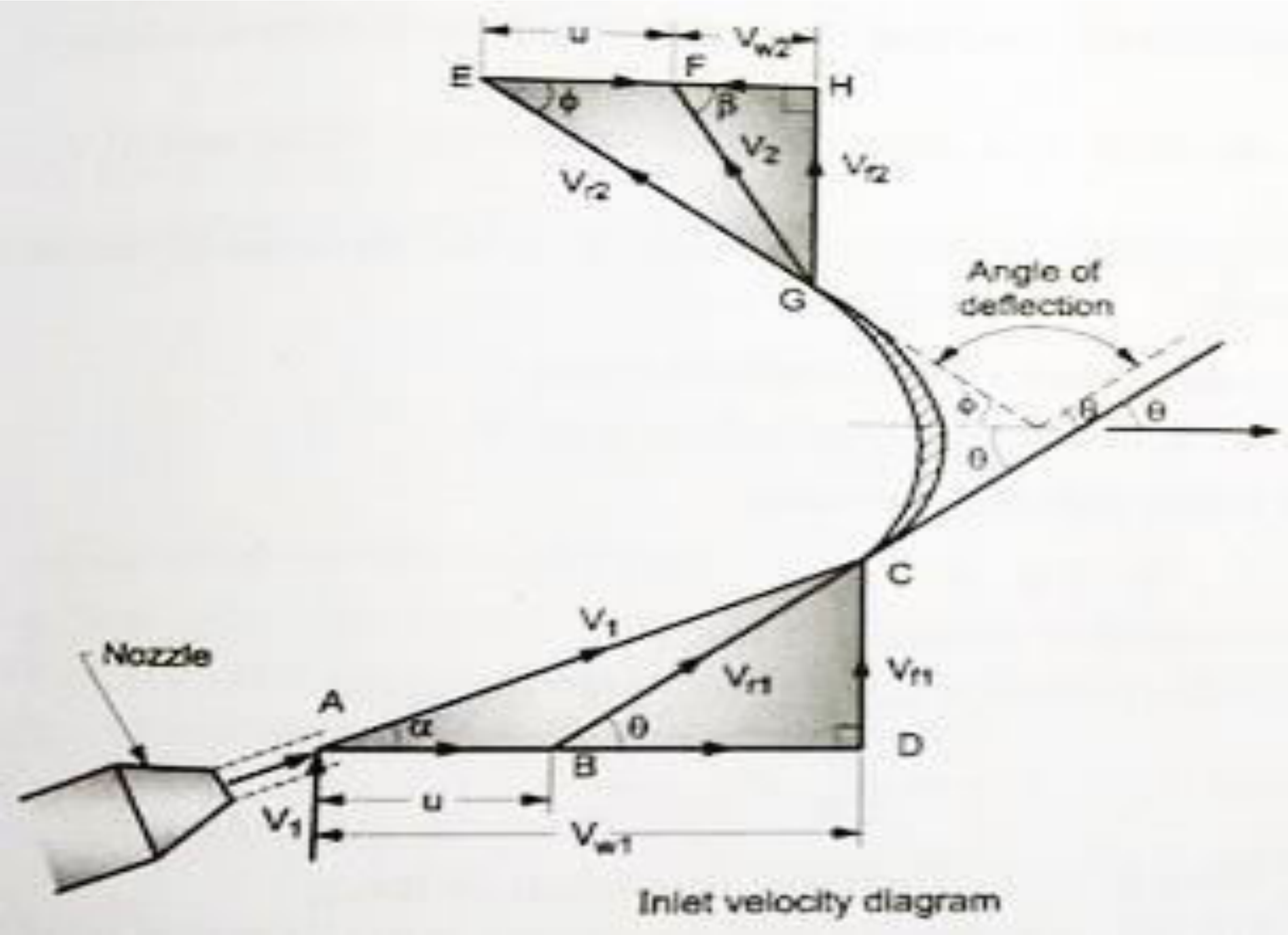
Force exerted by jet in the normal direction of jet,

Fx = ( mass / sec ) * (initial velocity in the normal direction of jet – final velocity in the normal direction of jet)

$$F_x = \rho a(V-u)\,[0 - (V-u)\sin\Theta]$$

$$= -\rho a(V-u)^2 \sin\Theta$$

# Force exerted by a jet on an unsymmetrical moving curved plate when jet strikes tangentially at one of the tips



# Force exerted by a jet on an unsymmetrical moving curved plate when jet strikes tangentially at one of the tips

$V_1$ = Velocity of the jet at inlet

$u_1$ = velocity of the vane at inlet

$Vr_1$ = relative velocity of the jet and plate at inlet

$\alpha$ = angle between the direction of the jet and direction of motion of the plate ( Guide blade angle)

$\Theta$ = angle made by the relative velocity with direction of motion at the inlet ( Vane angle at inlet)

$Vw_1$ = velocity of whirl at inlet ( component of $V_1$ in the direction of motion)

$Vf_1$ = velocity of flow at inlet ( component of $V_1$ in the direction perpendicular of motion)

## Force exerted by a jet on an unsymmetrical moving curved plate when jet strikes tangentially at one of the tips

Similarly,

$V_2$ = Velocity of the jet at outlet

$u_2$ = velocity of the vane at outlet

$Vr_2$ = relative velocity of the jet and plate at outlet

$\beta$ = angle between the direction of the jet and direction of motion of the plate ( Guide blade angle)

$\Phi$ = angle made by the relative velocity with direction of motion at the outlet ( Vane angle at outlet)

$Vw_2$ = velocity of whirl at outlet ( component of V2 in the direction of motion)

$Vf_2$ = velocity of flow at outlet

(component of V2 in the direction perpendicular of motion)

# Force exerted by a jet on an unsymmetrical moving curved plate when jet strikes tangentially at one of the tips

Inlet velocity Triangle:

$AC = V_1$ , $AB = u_1$, $BC = Vr_1$, $AD = Vw_1$, $BD = Vf_1$

Outlet velocity triangle:

$GF = V_2$ , $EF = u_2$, $EG = Vr_2$, $FH = Vw_2$, $GH = Vf_2$

As water glides smoothly ,
therefore neglecting friction between vane and water
$Vr1 = Vr2$

Also tip velocity at inlet and outlet are same.
$u1 = u2$

# Force exerted by a jet on an unsymmetrical moving curved plate when jet strikes tangentially at one of the tips

Force exerted by the jet in the direction of motion

= mass of water striking per sec X (initial velocity with which jet strikes the water in the dir. Of jet – final velocity in Direction of jet)

$$F= \rho a Vr_1 \, [\, (Vw_1 - u_1) - (-u_2 + Vw_2)]$$

$$= \rho a Vr_1 \, [\, (Vw_1 - u_1 + u_2 + Vw_2)]$$

$$F = \rho a Vr_1 \, [\, Vw_1 + Vw_2]$$

If $\beta = 90^0$ then $Vw_2 = 0$ ……….$F= \rho a Vr_1 \, [\, Vw_1]$

If $\beta > 90^0$ then $Vw_2 =$ ……….$F= \rho a Vr_1 \, [\, Vw_1 - Vw_2]$

# Force exerted by a jet on an unsymmetrical moving curved plate when jet strikes tangentially at one of the tips

In general, $F=\rho aVr_1[Vw_1 \pm Vw_2]$

## Work Done:

Work done per sec by the jet = Force X Distance per sec

W.D. = F X $\frac{distance}{time}$

= $F=\rho aVr_1\ [Vw_1 \pm Vw_2]$ X u

# Force exerted by a jet on an unsymmetrical moving curved plate when jet strikes tangentially at one of the tips

Work Done :

Work done per sec per unit weight of striking per sec

= Force  X Distance per sec / weight of water stinking per sec

$$F = \frac{\rho a Vr_1 [Vw_1 \pm Vw_2] Xu}{g \ X \ \rho a Vr_1}$$

$$F = \frac{[Vw_1 \pm Vw_2] Xu}{g X} \cdots m$$

# Force exerted by a jet on an unsymmetrical moving curved plate when jet strikes tangentially at one of the tips

Efficiency :

It is a ratio of work done per sec to initial K.E. of Work done per sec per unit weight of striking per sec of jet

$$\eta = \frac{\rho a V r_1 [V w_1 \pm V w_2] X u}{\frac{1}{2} X m V_1^{2}}$$

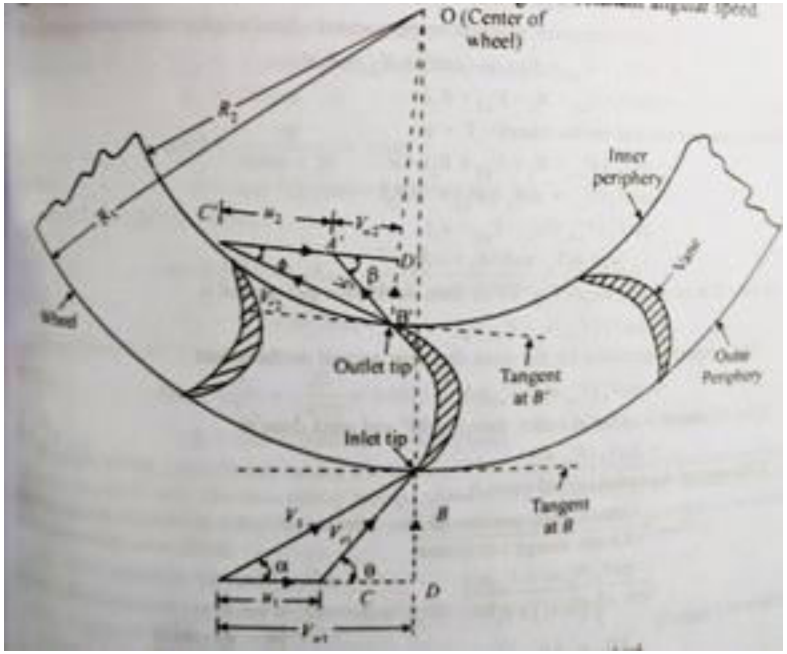
# Force exerted on series of curved vanes

Mass of water striking the vanes per sec= $\rho a V_1$

moment of water striking in vanes in the tangential direction per sec at the inlet =
mass of water X component of $V_1$ = $\rho a V_1$ X $Vw_1$
Similarly moment of water at outlet per sec = $\rho a V_1$ X (- $Vw_1$

Angular momentum per second at inlet
= momentum at inlet X radius = $\rho a V_1$ X $Vw_1$ X $R_1$
Angular momentum per second at outlet
= momentum at inlet X radius = $-\rho a V_1$ X $Vw_2$ X $R_2$

# Force exerted on series of curved vanes




Let, R1= radius of vane at the inlet of vane

R1= radius of vane at the outlet of vane

$\omega$= angular speed of the wheel

$u_1 = R_1\,\omega$ $\qquad u_2 = R_2\omega$

# Force exerted on series of curved vanes

Torque exerted by the water on the runner,

T= rate of change of angular momentum

$= (\rho a V_1 \ X \ Vw_1 \ X \ R_1)\text{-}(-\rho a V_1 \ X \ Vw_2 \ X \ R_2 \ )$

$= (\rho a V_1 \ ) \ X \ (Vw_1 \ X \ R_1 + Vw_2 \ X \ R_2 \ )$.......................

Work Done per sec = Torque X angular velocity

$= (\rho a V_1 \ ) \ X \ (Vw_1 \ X \ R_{1+} Vw_2 \ X \ R_2 \ ) \ x \ \omega$

$= (\rho a V_1 \ ) \ X \ (Vw_1 \ X \ R_1 \ x \ \omega + Vw_2 \ X \ R_2 \ x \ \omega)$

W.D. $= (\rho a V_1 \ ) \ X \ (Vw_1 \ X \ u_1 + Vw_2 \ X \ u_2)$

If angle $\beta = 90^0$, then W.D.$= (\rho a V_1 \ ) \ X \ (Vw_1 \ X \ u_1 \ )$

If angle $\beta > 90^0$, then W.D.$= (\rho a V_1 \ ) \ X \ (Vw_1 \ X \ -Vw_2 \ X \ u_2$

# Force exerted on series of curved vanes

## Efficiency of radial curve vane

$$\eta = \frac{work\ done\ per\ second}{kinetic\ energy\ per\ second}$$

$$\eta = \frac{\rho a v_1 [Vw_1 u_1 \pm Vw_2 u_2]}{\frac{1}{2} m V_1^2}$$

$$\eta = \frac{2[Vw_1 u_1 \pm Vw_2 u_2]}{V_1^2}$$

$$\eta = \frac{2[Vw_1 u_1 \pm Vw_2 u_2]}{V_1^2}$$

# Force exerted on series of curved vanes

Efficiency of radial curve vane

Also

W.D.per sec= change in K.E

$$\eta = \frac{change\ in\ kinetic\ energy\ per\ second}{kinetic\ energy\ per\ second}$$

$$\eta = (1 - \frac{V_2^2}{V_1^2})$$

# Impulse Water Turbines

Hydraulic Machines:

-Machine

- Hydraulic Machine

Types of Hydraulic Machines

- Turbine

(Converts Hydraulic energy into mechanical energy)

- Pump

(Converts mechanical energy into Hydraulic energy)

# Classification of Hydraulic Turbine

1. Depending upon energy available at the inlet of turbine
   1. Impulse
   2. Reaction
2. According to the flow direction of flow through runner
   a. Tangetial flow
   b. Axial flow
   c. Radial flow
   d. Mixed flow

Impulse Water Turbines

# Classification of Hydraulic Turbine

3. Depending upon head available at the inlet of turbine
    1. Low head T
    2. High head T
    3. Medium head T
4. According to the specific speed of the turbine
    a. Low specific speed turbine
    b. High specific speed turbine
    c. Medium specific speed turbine

## Impulse Water Turbines

# Classification of Hydraulic Turbine

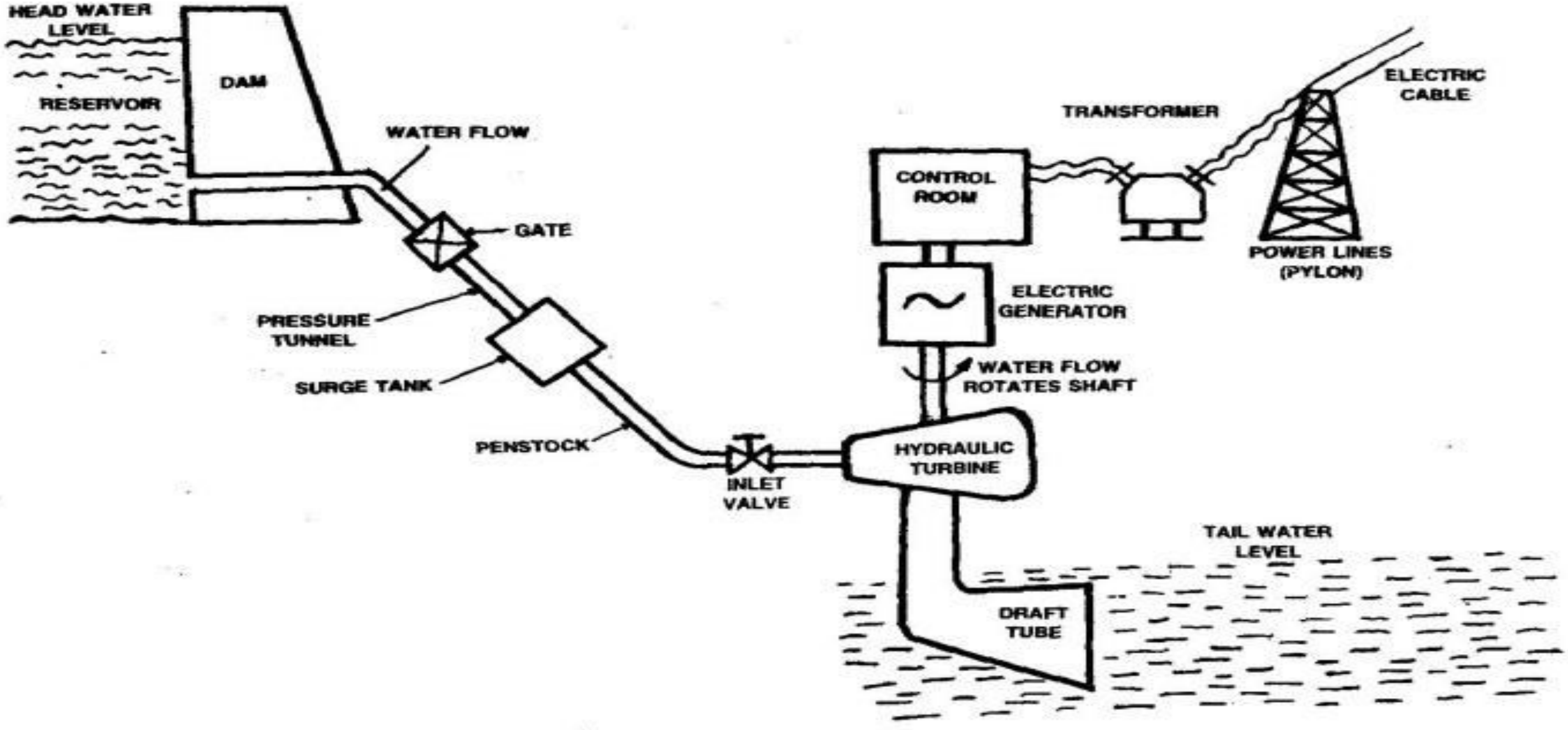
5. Depending upon position of shaft
    1. Vertical shaft T
    2. Horizontal shaft T

6. According to Name of Inventor
    a. Pelton turbine
    b. Kaplan turbine
    c. Fransis turbine

# Impulse Water Turbines

# Pelton Wheel or Pelton Turbine

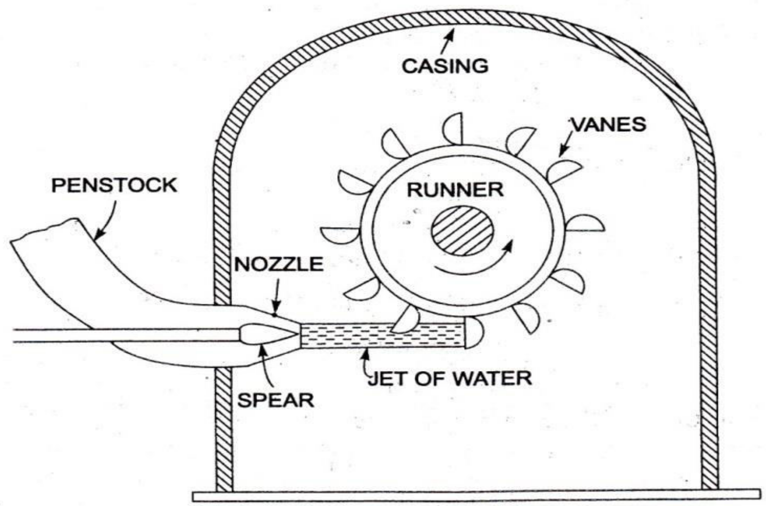
General Layout of hydraulic turbine



# Impulse Water Turbines

## Pelton Wheel or Pelton Turbine

## Construction and working of pelton wheel.




*Pelton turbine.*

# Construction and working of pelton wheel

1. Nozzle and flow regulating arrangement
2. Runner and bucket
3. Casing
4. Breaking jet

# velocity Triangle for pelton wheel

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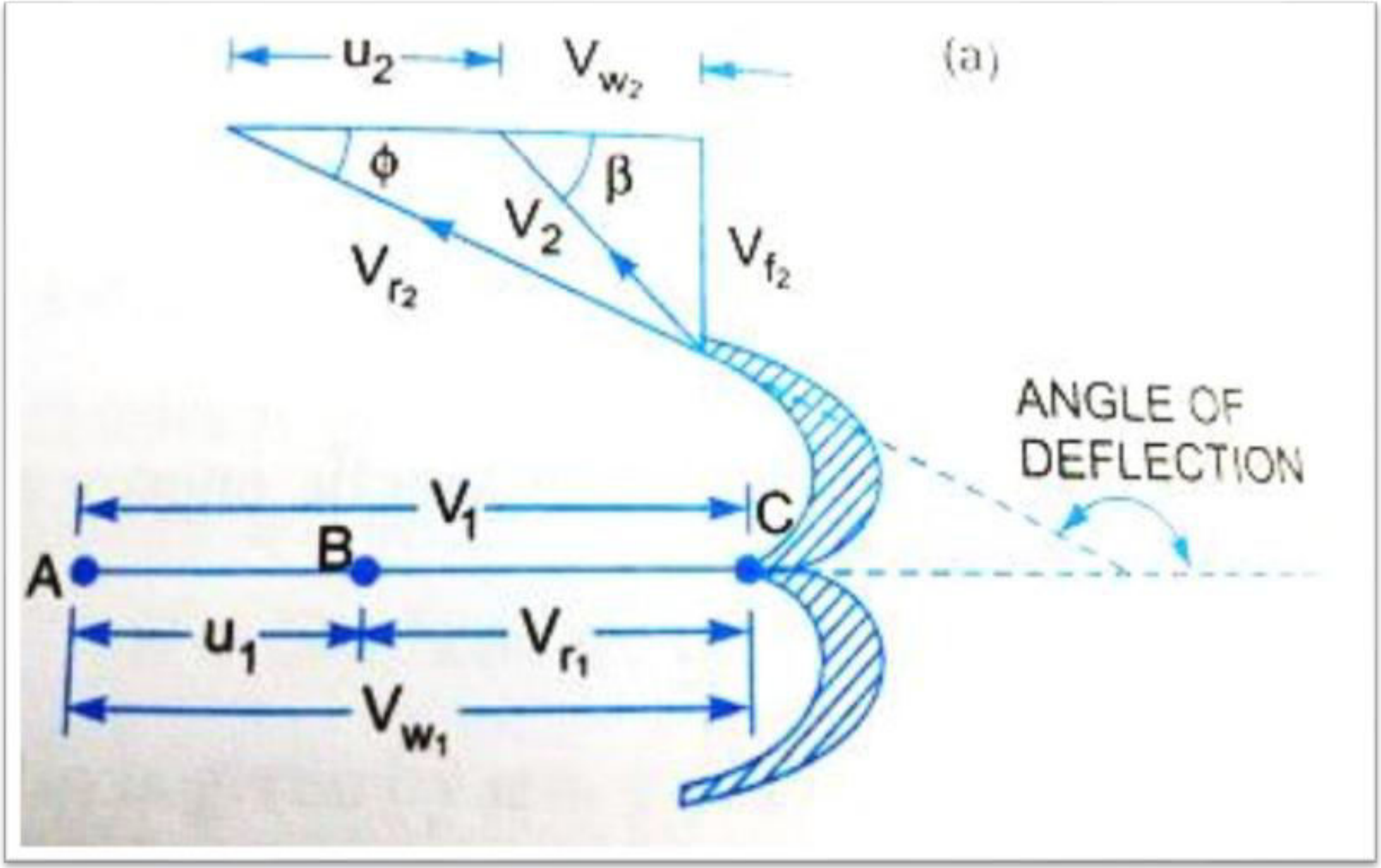


# Velocity Triangle for of Pelton wheel

Let,

H= net head available at the inlet of the turbine

D= diameter of the runner

d= diameter of jet

a = c/s area of jet

N = speed of runner / wheel in RPM

$V_1$ = Velocity of jet at inlet = $\sqrt{2gH}$

Or

$V_1 = Cv\sqrt{2gH}$ Cv= Coefficient of velocity

Velocity of Blade= $u_1 = u_2 = \frac{\pi d N}{60}$

# Velocity Triangle for of Pelton wheel

## Inlet Triangle

Inlet triangle at inlet will be at straight line

- $Vr_1 = V_1 - u_1 = V_1 - u$
- $Vw_1 = V_1$
- $\alpha = o, \ \Theta = 0$

## Outlet Triangle

As vane surface is smooth, neglecting friction

- $Vr_1 = Vr_2$
- $Vw_2 = Vr_2 \cos \Theta - u_2$

# Work Done for Pelton wheel

<u>Force Exerted:</u>

the Force exerted jet of water in direction of motion

$F = \rho a Vr_1 [ Vw_1 + Vw_2 ]$...........for single vane

$F = \rho a V_1 [ Vw_1 + \pm Vw_2 ]$...........for series of vane

** When $\beta < 90°$ then $F = \rho a Vr_1 [ Vw_1 + Vw_2 ]$

$\beta = 90°$ then $F = \rho a Vr_1 [ Vw_1 ]$

$\beta > 90°$ then $F = \rho a Vr_1 [ Vw_1 - Vw_2 ]$

<u>Work Done:</u>

Work done per sec by the jet = Force X Distance per sec

$$W.D. = F \times \frac{distance}{time}$$

$$= F = \rho a V_1 [Vw_1 \pm Vw_2] \times u$$

# Work Done for Pelton wheel

Work Done :

Work done per sec per unit weight of striking per sec

= Force X Distance per sec / weight of water stinking per sec

Work Done:

Work done per sec by the jet = Force X Distance per sec

$$W.D. = F \; X \; \frac{distance}{time}$$

$$= F = \rho a V_1 [Vw_1 \pm Vw_2] \; X \; u$$

$$F = \frac{\rho a V_1 [Vw_1 \pm Vw_2] Xu}{g X \rho a V_1} \qquad F = \frac{[Vw_1 \pm Vw_2] Xu}{g} \cdots m$$

# Efficiencies for Pelton wheel

## (A) Hydraulic efficiency ηh

$$\eta = \frac{work\ done\ per\ second}{K.E.of\ jet\ per\ sec}$$

.

$$\eta = \frac{work\ done\ per\ second}{K.E.of\ jet\ per\ sec}$$

$$\eta = \frac{\sigma a V_1 [Vw_1 + Vw_2] X u}{\frac{1}{2}(\sigma a V_1) x V_1^2}$$

$$\eta = \frac{[Vw_1 + Vw_2] X u}{V_1^2}$$

# Hydraulic efficiency for Pelton wheel

Maximum Hydraulic efficiency η

differentiating and equating it to zero.

We get,

.

$$u = \frac{V_1}{2}$$

Efficiency of the Pelton wheel is maximum when the velocity of the wheel is the half the velocity of the

$$\eta_m = \frac{1 + \cos\varphi}{2}$$

# Hydraulic efficiency for Pelton wheel

Maximum Hydraulic efficiency η

differentiating and equating it to zero.

We get,

.

$$u = \frac{V_1}{2}$$

Efficiency of the Pelton wheel is maximum when the velocity of the wheel is the half the velocity of the

$$\eta_{max} = \frac{1 + \cos\varphi}{2}$$

# Hydraulic efficiency for Pelton wheel

Hydraulic efficiency η

$$\eta_h = \frac{runner\ power_1}{water\ power}$$

.

$$water\ power = \frac{\rho g Q H}{1000} kW$$

Water power

$$water\ power = \frac{\rho g Q H}{1000} kW$$

# Hydraulic efficiency for Pelton wheel

## Mechanical efficiency η

$$\eta_m = \frac{shaft\ power}{runner\ power}$$

.

## Volumetric efficiency

$$\eta_{vol} = \frac{volume\ of\ water\ actual\ striking\ the\ runner}{volume\ of\ water\ sup\ plied\ to\ the\ runner}$$

# Hydraulic efficiency for Pelton wheel

Overall efficiency η

$$\eta_o = \frac{shaft\ power}{runner\ power} x \frac{runner\ power}{water\ power}$$

.

$$\eta_o = \frac{shaft\ power}{water\ power} x \frac{runner\ power}{runner\ power}$$

$$\eta_o = \eta_h x \eta_m$$

# Design aspect of Pelton wheel

1. Velocity of jet V1= Cv$\sqrt{2gH}$Cv= coefficient of velocity
2. Velocity of Wheel u = $\Phi\sqrt{2gH}$ ... ... .Φ= speed ratio
3. The angle of deflection 165° ( If not given)
4. Jet ratio m=(D/d)
5. Number of bucket Z= 15 + (D /2d)
6. Number of jet = ratio of total rate of flow through the turbine to rate of water through single jet

# Performance of Pelton wheel

Turbines are designed to work under a given head ,discharge and output. To check performance of turbine under different working condition following parameters are observed.

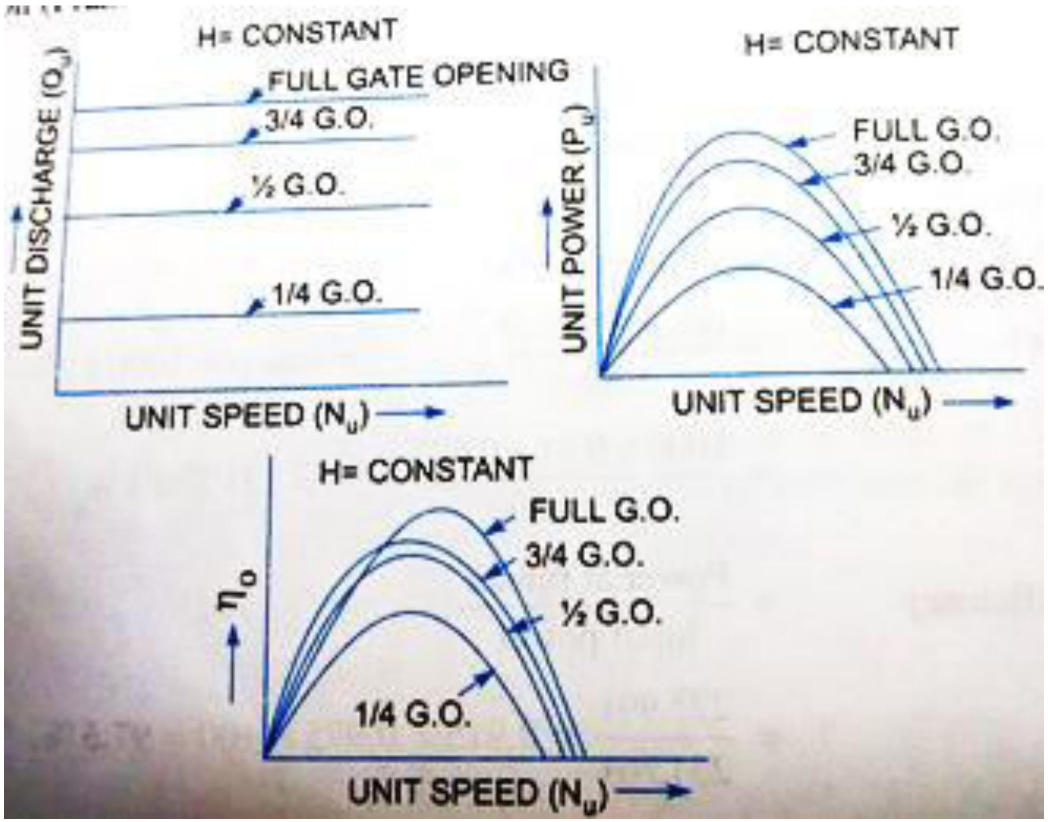
1. Speed
2. Head
3. Discharge
4. Power
5. Overall efficiency

By keeping one independent parameter constant, variation of the parameters are plotted.
These curves are called characteristic curve.

# Characteristic Curve

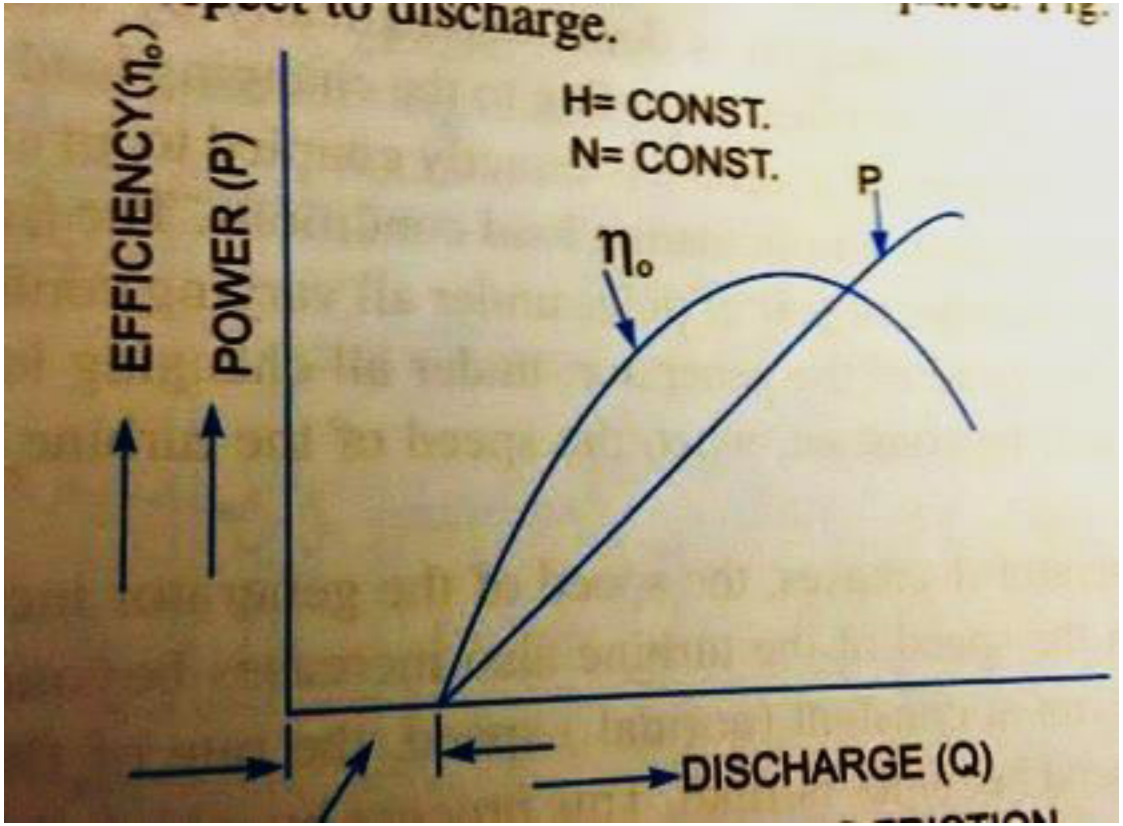
1. Main characteristic curve or constant head curve
2. Operating characteristic curve or constant speed curve
3. constant efficiency curve

Main characteristic curve or constant head curve



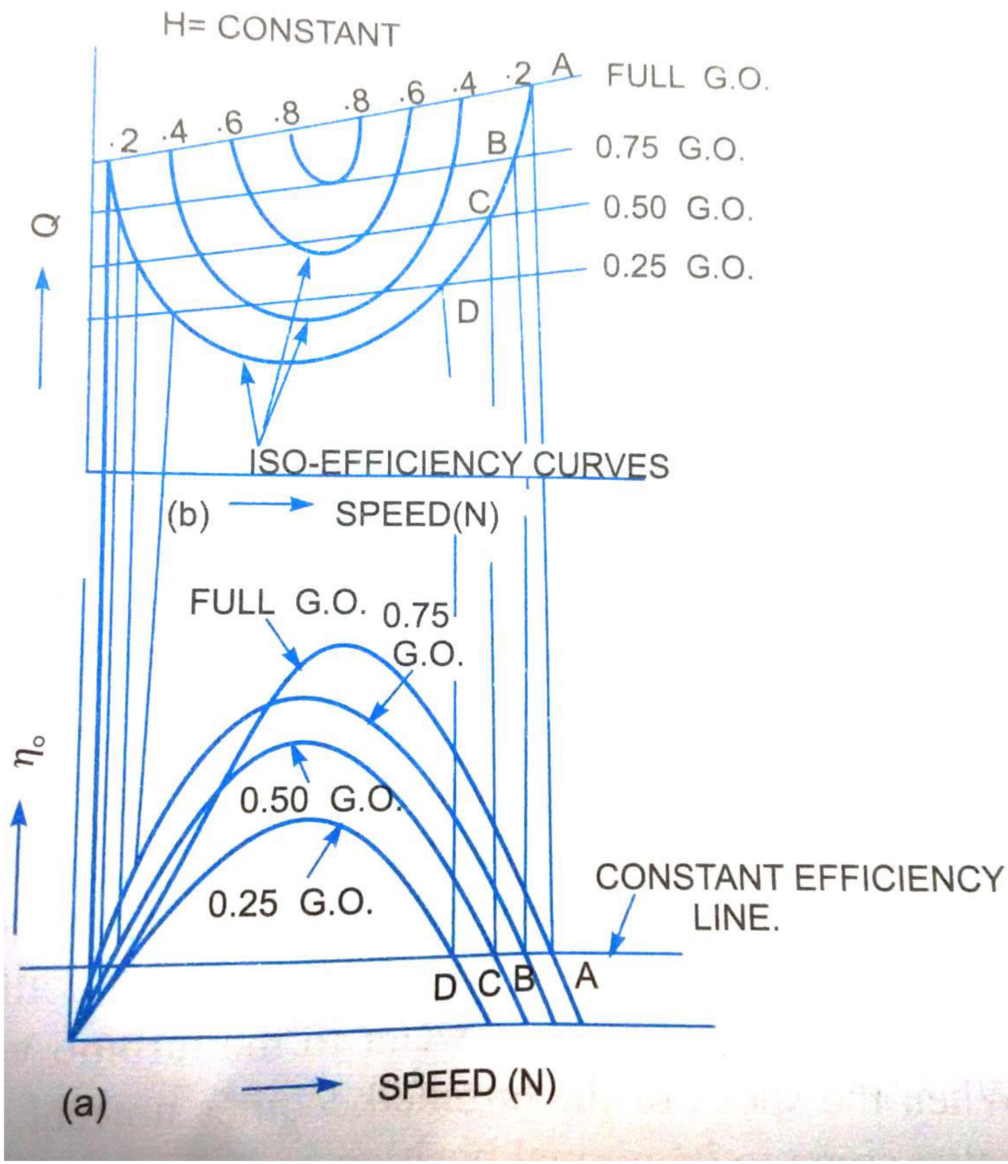
# Characteristic Curve

1. Operating characteristic curve or constant speed curve



# Characteristic Curve

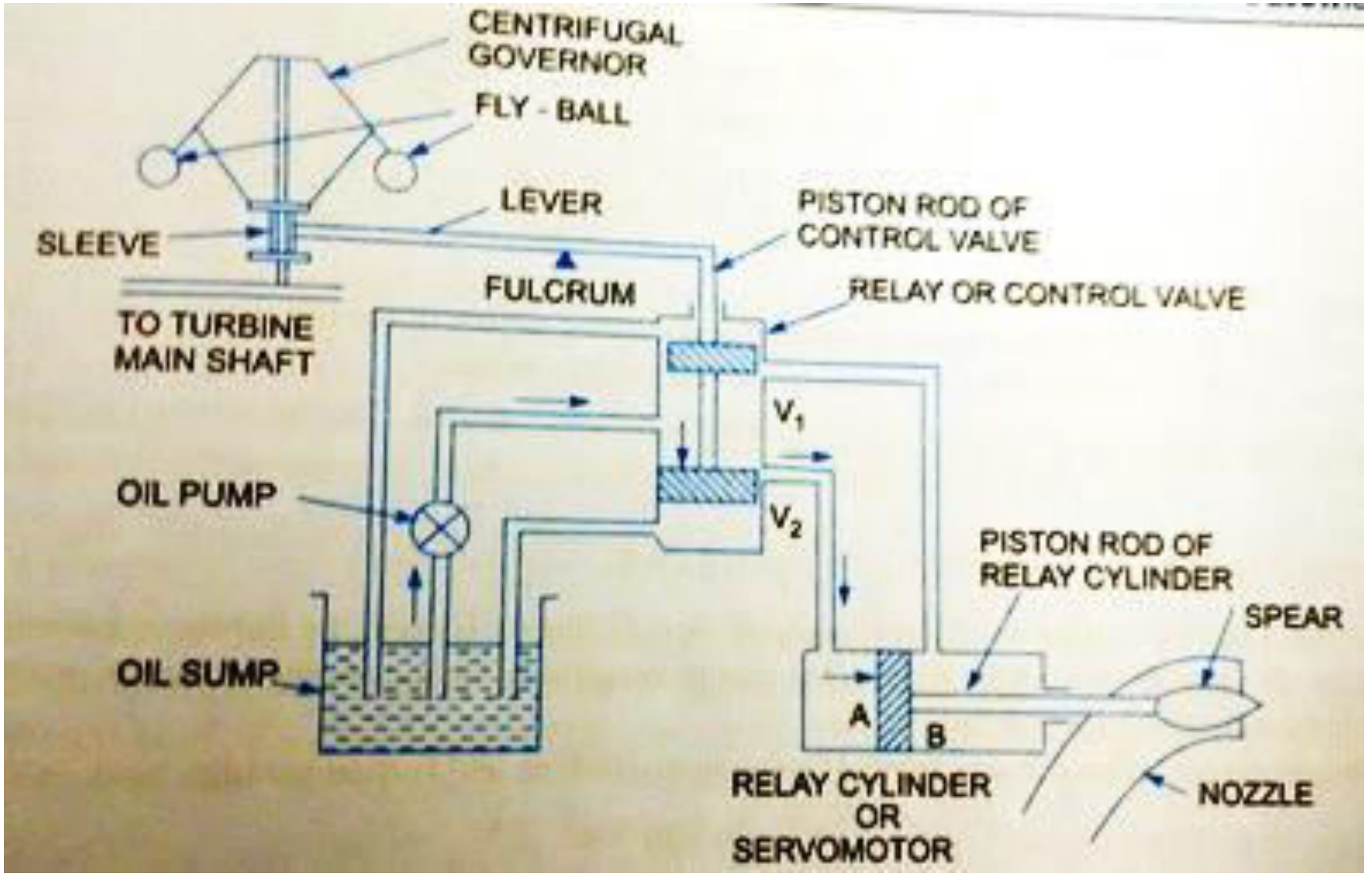
Constant efficiency curve



# Governing of Pelton wheel

Process by which speed of the turbine is kept constant at all operating condition

Oil pressure governor



# Specific speed of Pelton wheel

It is speed of turbine which is identical in shape ,geometrical dimension ,blade angle with the actual turbine But of small size so it will develop unit power working under unit head

$$N_s = \frac{N\sqrt{P}}{H^{\frac{5}{4}}}$$

## Application of specific speed

| Sr. No, | Specific speed in MKS | Specifc speed in SI | Type of Turbine |
|---|---|---|---|
| 1 | 10-35 | 8.5-30 | Pelton wheel with single jet |
| 2 | 35-60 | 30-51 | Pelton wheel with two jet |
| 3 | 60-300 | 51-225 | Fransis turbine |
| 4 | 00-1000 | 225-860 | Kaplan turbine |

# Solved Numerical

Q.1A Pelton wheel has a mean bucket speed of 10 m/sec with jet of water flowing at the rate of 700 lit /s under a head of 30 meters. The buckets deflects the jet trough an angle of $160^0$ . Calculate the power given by water to the runner and the hydraulic efficiency of the turbine. Assume coefficient of velocity as 0.98

Given Data:Speed of the bucket, $u_1=u_2=u=10$ m/s

Discharge Q= 700 lit /s $m^3$ /s

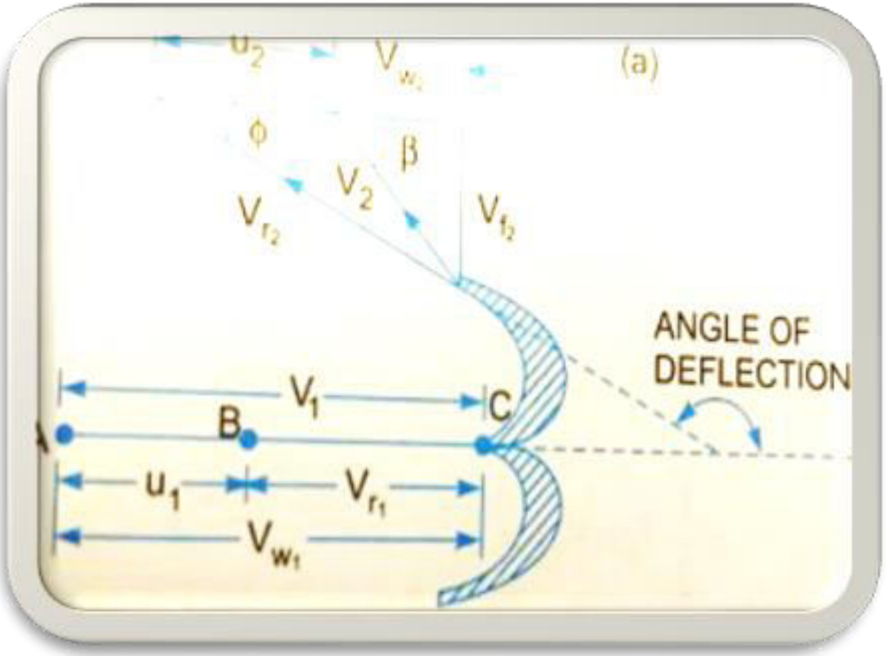
Head of the water H=30 m

Angle of deflection =160

Angle $\Phi = 180-160=20^0$

coefficient of velocity = 0.98

# Solution




the velocity of the jet

$= V_1 = Cv\sqrt{2gh} = 23.77$ m/s

$Vr_1 = V_1 - u_1 = 23.77 - 10 = 13.77$ m/s

$Vw_1 = V_1 = 23.77$ m/s

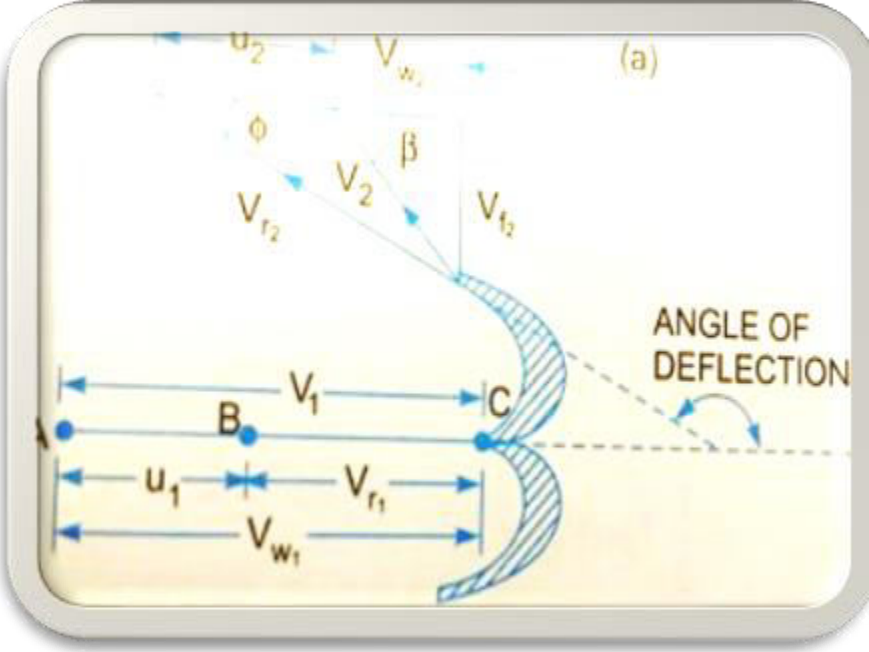
From outlet velocity triangle

$Vr_1 = Vr_2 = 13.77$ m/s

$Vw_2 = -Vr2\cos\Phi - u_2$

$= 13.77 \cos 20^0 - 10 = 2.94$ m/s

# Solution




W.D./sec

W.D./sec $= \rho a V_1 (Vw_1 + Vw_2]$ X u

$= 1000 * 0.7 * [23.77 + 2.94] * 10$

$= 186970$ Nm /s

Power Given to the turbine,

P = 186970 /1000 = 186.97 kW

The hydraulic efficiency of the turbine given by the equatio

$\eta_h = 2$ [vw1 =vw2]*u $/V_1^2$

=0.9454=94.54%

# Solved Numerical-2

Q. Two jets strikes the bucket of pelton wheel which having shaft power as 15450 KW. The diameter of each jet is given as 200 m. if the net head at the turbine is 400 m, find the overall efficiency of the turbine. Take Cv = 1.

Given Number of jet =2
Shaft power = p =15450 KW
Diameter of jet= d= 200mm =0.20m
Area of the jet =a = 0.31416 m2
Net head = H= 400m
Cv =1

# Solution

Velocity of the jet =

$V_1 = Cv\sqrt{2gh}$

$= 1 \sqrt{2 * 9.81 * 400}$

$= 88.58$ m/s

discharge of each jet

$= q = a * V_1 = 2.78\ m^2$

Total discharges

= Q= 2*2.78

= 5.56 $m^3/s$

Power at the inlet of the turbine ,

WP= ρgQH /1000 kW

=1000*9.81* 5.56*400 /1000

= 21817.44 kW

Overall efficiency is given as =

$\eta_0 = SP/WP$

=15450 /21817.44

= 70.8

Thank you !!!