Turbine :-

→ It is a device which converts hydro power to shaft power.

Classification :-

1. According to type of energy inlet there are two types of turbine.

(a) Impulse Turbine

At inlet of turbine kinetic Energy of water is available.

Ex:- Pelton Wheel Turbine

(b) Reaction Turbine

At inlet of turbine kinetic energy as well as pressure energy of water is available.

Ex:- Francis Turbine, Kaplan Turbine.

2. According to direction of flow there are four types of turbine --

(a) Tangential Flow Turbine

(b) Axial flow Turbine

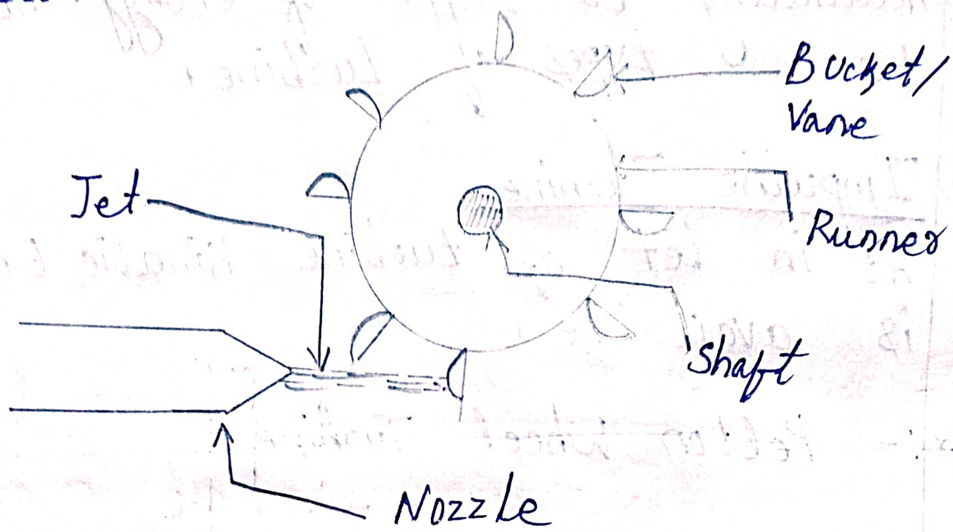
(c) Radial flow Turbine

(d) Mixed (Radial and Axial) Flow Turbine

(a) Tangential Flow Turbine :-

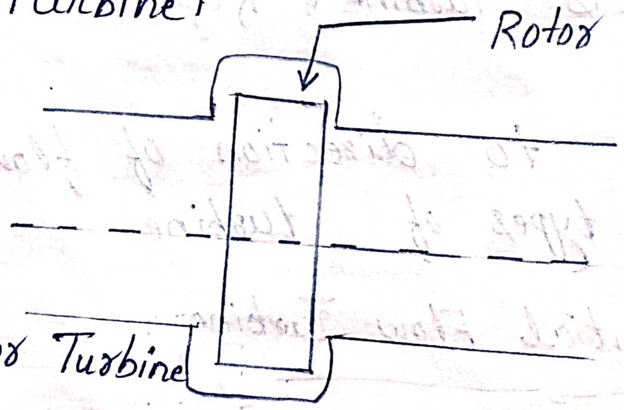
→ Water strikes the roller tangential to the path of rotation of the roller.

Ex:- Pelton wheel Turbine




(b) Axial Flow Turbine :-

→ Water flow in the direction parallel to axis of the turbine.




Ex:- Propetor Turbine

(C) Radial Flow Turbine :-

→ Water flow in the radial direction through the runner.

It devided in to two types

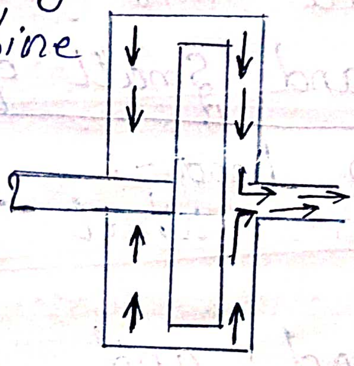
1. Radially Inward flow turbine

2. Radially outward flow turbine

1. Radially Inward flow Turbine :-

Water Coming from outside or outer peripheri and it's moving inside.

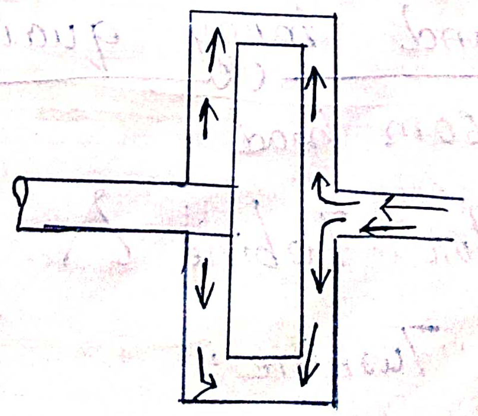
Ex:- Farncis Turbine



2. Radially outward flow Turbine :-

Water is enter at a center path and water is flowing towards the outward direction.

Ex:- Foorneyron Turbine



(d) Mixed (Radial and axial) Flow Turbine :-

Water Flows through the runner in the radial direction but leaves in the direction parallel to axis of rotation.

Ex:- Modern Francis Turbine.

* According to water head and quantity of water its divided into three types.

(a) High head and Small quantity of water flow

Above 250 m head

Ex:- Pelton Wheel Turbine

(b) Medium head and Medium quantity of water flow :-

60 to 250 m head

Ex:- Modern Francis turbine

(c) Low head and largy quaintcity of water flow

Below 60m head.

Ex:- Propelor Turbine &

Kaplan Turbine.

* According to the Spefic Seepd of Turbine :-

(a) Low Specific Speed :-

Specific Speed less then 60.

Ex:- Pelton wheel turbine

(b) Medium Specific Speed :-

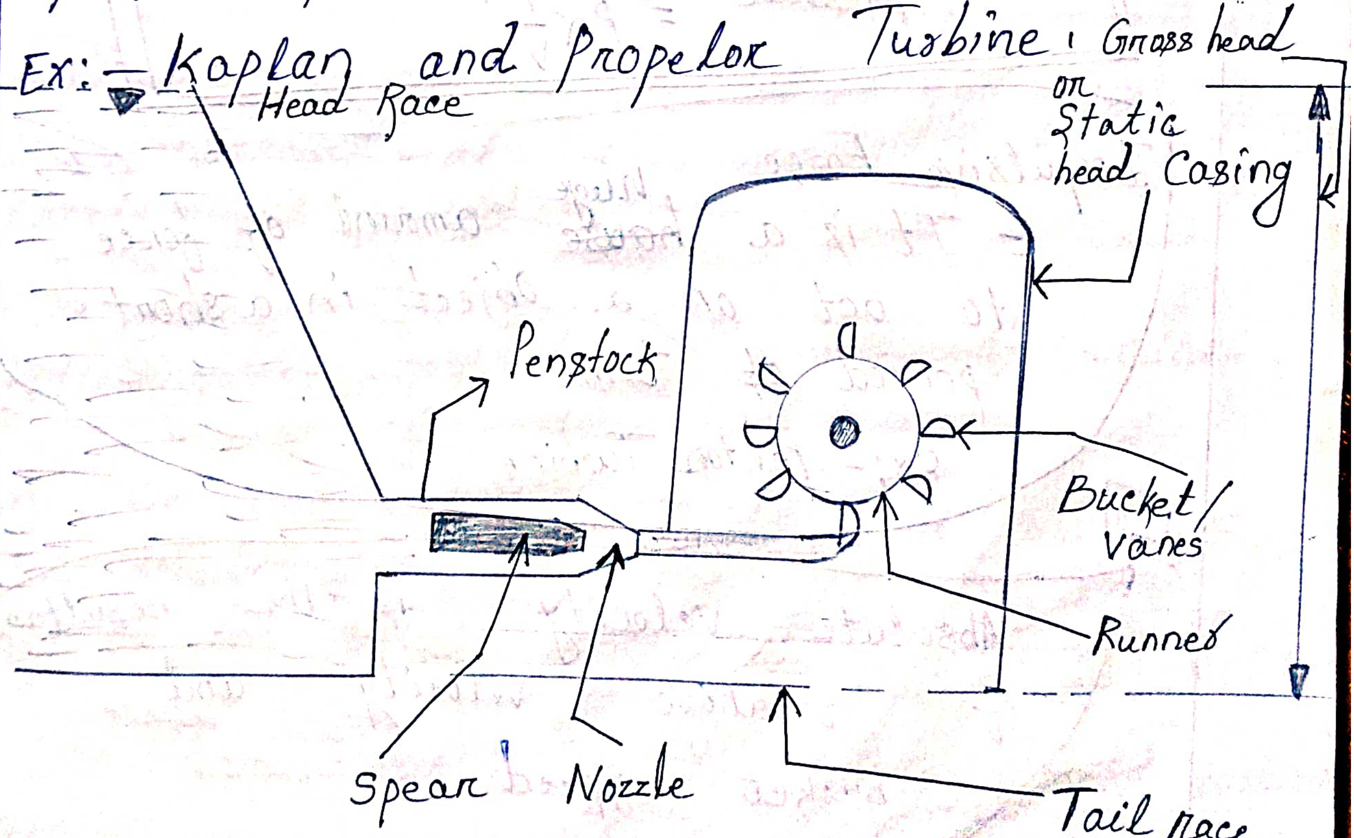
Specific Speed 60 to 400

Ex:- Francis turbine

(c) High Spefic Speed :-

Specific Speed More than 400

Ex:- Kaplan and Propelor Turbine



## Working principle and construction of pelton wheel turbine :-

→ The pelton wheel turbine is a tangential flow impulse turbine.

→ The water strikes the bucket along the tangent of the runner.

→ The energy available at the inlet of th turbine is only kinetic energy.

→ The pressure available at the inlet of the turbine ~~is~~ ~~only~~ and outlet of the turbine is atmospheric.

→ The turbine is used for heigh heads.

→ The water from the reserves flows throug the penstrokes at the outlet of which a nozzle is fitted.

→ The nozzle increases the K.E of water following through penstrok.

→ At the out let of nozzle the water comes out in the from of the jet and it's strikes the bucket (vanes) of the runner.

→ The main parts of the pelton wheel turbine are

(i) Nozzle and Flow regulating arrangement (Spear)

(ii) Runner and buckets

(iii) Casing

(iv) Breaking jet

(i) Nozzle and Flow regulating arrangement (Spear)

→ The amount water striking the buckets of the runner is controled by providing the spear in the nozzle.

→ The spear is a conical needle that is operated either by a hand wheel or automatically in an axial direction.

→ When the spher is pushed forward into the nozzle the amount of water striking the runner is reduce.

→ On the other hand if the spher is pushed back, the amount of water striking the runner increases.

(ii) Runner and Buckets

→ It consists of a circular disc on the periphery of which a number of buckets are fixed.

→ The shape of the buckets is of a double hemispherical cup or bowl.

→ Each bucket is devided into 2 semetrical parts. By a deviding wall which is known as spliter.

→ ~~Each Bucket is~~ The spliter devides it into two equal parts and the jet comes out at the outer edge of the bucket.

→ The buckets are shape in such a way that the jet gets diflected through 160° or 170°.

→ The buckets are made of cast iron, cast steel, bronze or stainless steel dipending upon the head at the inlet of the turbine.

(iii) Casing :-

→ The function of the casing is to prevent the splashing of the water and to discharge water to tail race.

→ It also acts as a safe guard against accident.

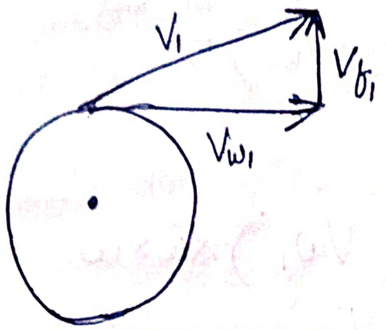
→ It is made up cast iron or febricated steel plates.

→ The casing of the pelton wheel does not perform any hydrolic function.

(iv) Breaking jet :-

→ When the nozzle is completely close by the move of spear in the forward direction the amount of water striking the runner reduces to zero. But the runner due to inertia goes on revolving for along time to stop the runner in a short time a small nozzle is provided which directs the jet of water on the back of the vanes. This jet of water is called breacking jet.

**STEADY FLOW:-** Whose properties doesn't change at any section with respect to time.

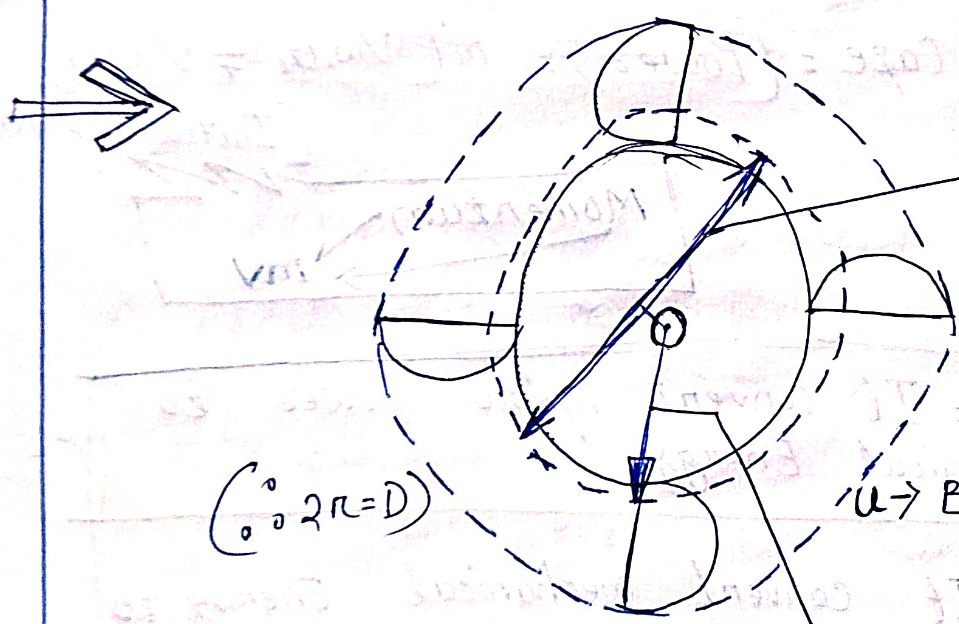



$V_1$ = Actual/Absolute Velocity

$V_{f_1}$ = Flow Velocity

$V_{w_1}$ = Whirl Velocity

Whirl Velocity = It rotate the rotor




$(\because 2r = D)$

$u = r\omega$

$= r \times \frac{2\pi N}{60}$

$$\boxed{u = \frac{\pi D N}{60}} \text{ m/s}$$

Torque = Rate of change of tangential angular momentum

$T = F \cdot r$

$\Rightarrow T = ma \cdot r$

$\Rightarrow T = m\left(\frac{V-u}{t}\right) \cdot r \quad \Rightarrow T = \frac{m}{t}(\text{Final} - \text{Initial}) \cdot r$

$\Rightarrow T = \dot{m}(V_{w_2} - V_{w_1})\, r$

Power = $T \cdot \omega$

$= \dot{m}(V_{w_2} - V_{w_1}) \times r \times \omega \qquad [r \times \omega = u]$

$= \dot{m}(V_{w_2} - V_{w_1}) \times u$ W/s

Pump Power = $\dot{m}(V_{w_2}u_2 - V_{w_1}u_1)$ W/s [Final - Initial]

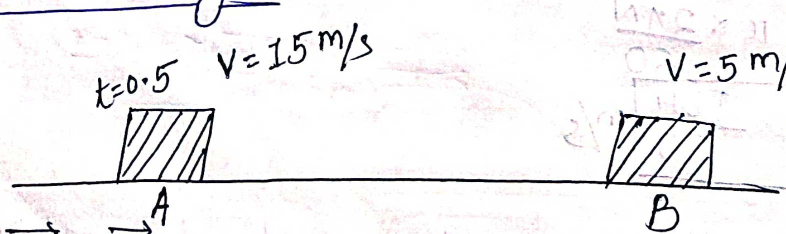
In Turbine Case = (Power) = $\dot{m}(V_{w_1}u_1 \mp V_{w_2}u_2)$
[Initial - Final]

Momentum $\rightarrow mv$

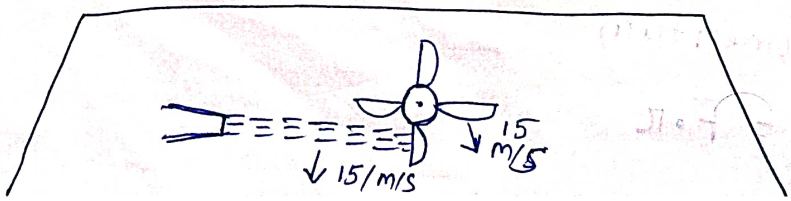
Turbine = It convert hydro power to mechanical Energy.

Pump = It convert mechanical Energy to hydro power.

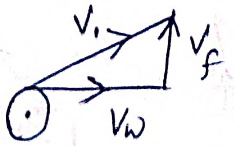
→ Relative Velocity :-




$\vec{V}_{AB} = \vec{V}_A - \vec{V}_B = 15 - 5 = 10$ m/s



Velocity -




← In Angle Condition

$V_f$ = Flow Velocity

$V_w$ = Wheel Velocity

$V_1$ = Velocity of jet

## Tangential Force Acting on the Wheel

$$\text{Power} = \dot{m}\,(V_{w_1}V_1 - V_{w_2}u_2)$$

$$\text{Power} = T \times \omega$$

$$\text{Torque}(T) = f_t \times r$$

$$P = f_t \times r \times \omega$$

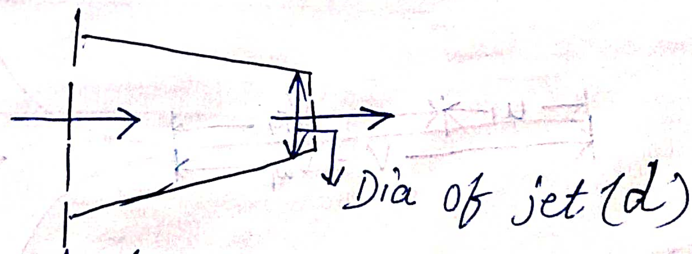
$$\Rightarrow F_t \times r \times \omega = \dot{m}\,(V_{w_1}U_1 - V_{w_2}u_2)$$

$$\Rightarrow F_t \times u = \dot{m}\,(V_{w_1}U_1 - V_{w_2}u_2) \qquad u = \frac{\pi N}{60}$$

$$\Rightarrow F_t = \frac{\dot{m}\,u\,(V_{w_1} - V_{w_2})}{u} \qquad [u = u_1 = u_2]$$

$$\Rightarrow F_t = \dot{m}\,(V_{w_1} - V_{w_2})$$

## Discharge through Nozzle



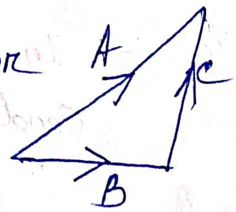

$$\text{Discharge}(Q) = A \times V$$

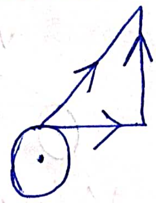
$$= \frac{\pi}{4} d^2 V_1$$

No of Nozzle $= n$

$$Q = n \times \frac{\pi}{4} d^2 \times V_1$$

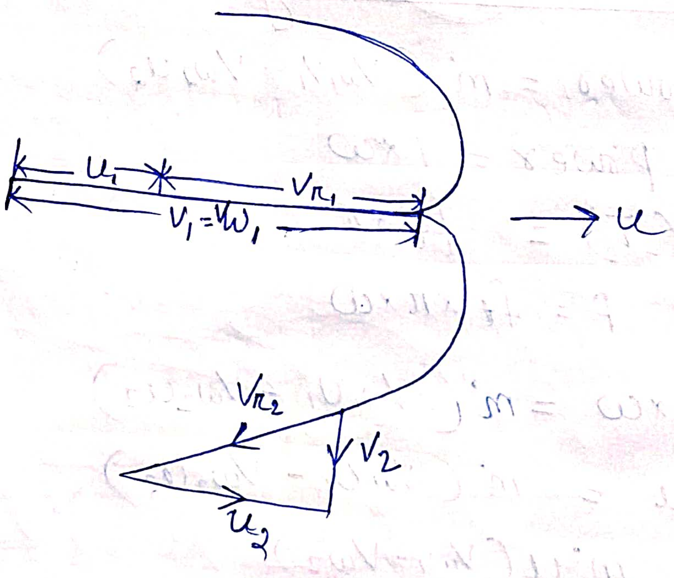
Triangle law of Vector Adition



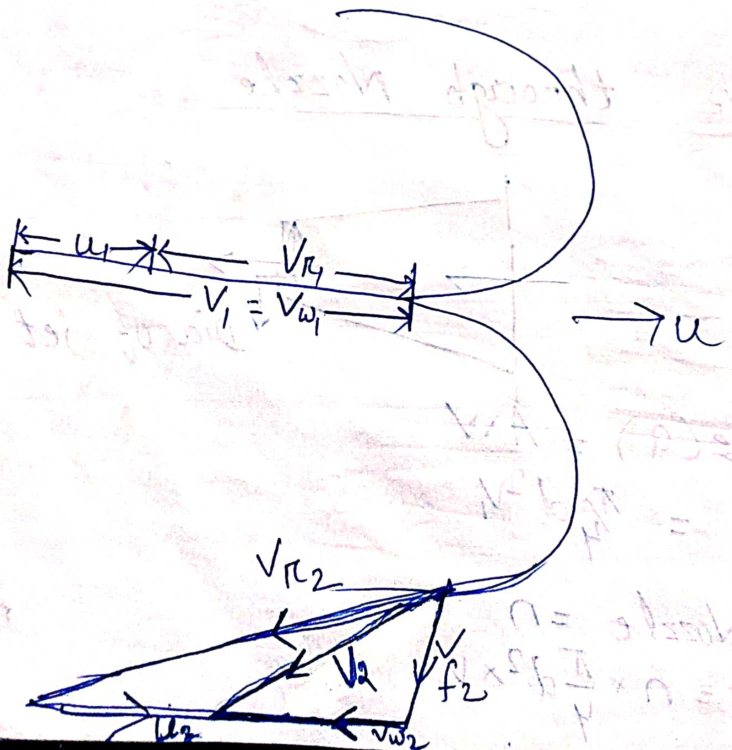



## 3 Possibility

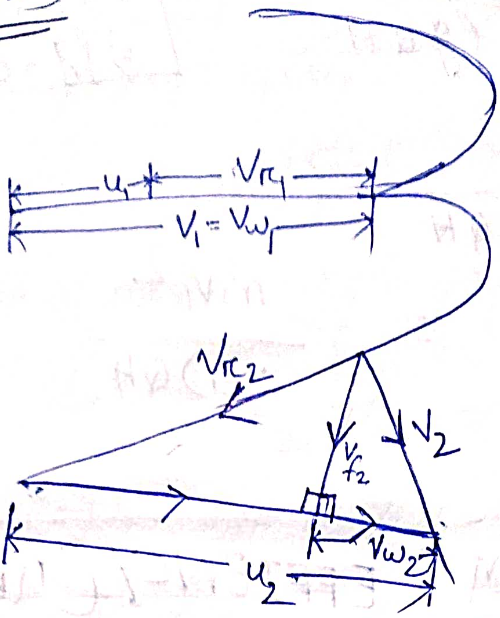
### Case 1




### Case 2



Case-3



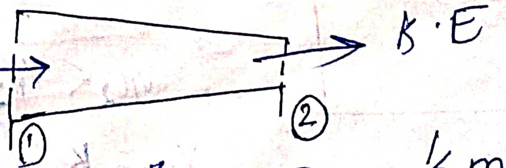

**Effiencicy ($\eta$) :-** It is the ratio of the useful work performed by a meachine,

$$\eta = \frac{\text{Out Put}}{\text{In Put}}$$

1. Nozzle Effiencicy
2. Blading / Diagram Effiencicy
3. Hydroulic Effiencicy
4. Mechanical Effiencicy

**1. Nozzle Effiencicy ($\eta$) :-**

Hydro power or water Power




Hydro Power = $\rho g Q H$ and K·E = $\frac{1}{2} m v^2$

$$\eta_N = \frac{\text{out put}}{\text{In Put}} = \frac{\frac{1}{2} m V_1^2}{\rho g Q H}$$

Specific weight
$\Rightarrow \rho g = \omega$

$$= \frac{m V_1^2}{2} \times \frac{1}{\rho g Q H}$$

$$= \frac{m V_1^2}{2 \rho g Q H} = \frac{m V_1^2}{2 \omega Q H}$$

## BLADING/DIAGRAM EFFIENCY ($\eta_b$):-

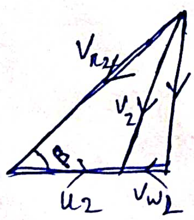
$$\eta_b = \frac{O/P}{I/P} = \frac{\text{Power Devloped by the runner}}{\text{Kinetic Enenagy}}$$

$$= \frac{\dot{m}(V_{w_1} u_1 - V_{w_2} u_2)}{\frac{1}{2} \dot{m} V_1^2}$$

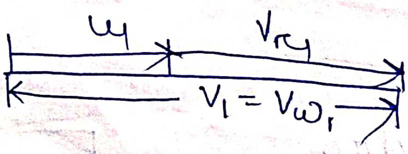
$$= \frac{2(V_{w_1} u_1 - V_{w_2} u_2)}{V_1^2}$$

In Max. Effiency, $\eta_{b\,max} = \frac{2(V_{w_1} + V_{w_2})u}{V_1^2}$

In Second Case




Blade Coefficient of fririction (K)




$\therefore V_{r_2} < V_{r_1}$

$\frac{V_{r_2}}{V_{r_1}} = K \Rightarrow V_{r_2} = V_{r_1} K$

When Smooth Surface (K) 1

$V_1 = u_1 + V_{r1}$

$\Rightarrow V_{r1} = V_1 - u_1$

$V_{r2} = K(V_1 - u_1)$

In this right Angle traingle,

$\cos\beta = \frac{b}{h} = \frac{u_2 + V_{w2}}{V_{r2}}$

$\Rightarrow V_{r2}\cos\beta = u_2 + V_{w2}$

$\Rightarrow V_{w2} = V_{r2}\cos\beta - u_2$

$\therefore$ Put it in Power or Maximum Power in the ~~Nozzle~~ Blad

$$P = \frac{2(V_1 + V_{r2}\cos\beta_2 - u)u}{V_1^2}$$

$$= \frac{2u}{V_1^2}(V_1 + V_{r2}\cos\beta_2 - u)$$

$$= \frac{2u}{V_1^2}\{(V_1 - u) + K(V_1 - u)\cos\beta_2\}$$

$$= \frac{2u}{V_1^2}(V_1 - u)\{1 + K\cos\beta_2\}$$

$$= \frac{2uV_1}{V_1^2} - \frac{2u^2}{V_1^2}(1 + K\cos\beta_2)$$

$$= \frac{2u}{V_1} - \frac{2u^2}{V_1^2}(1 + K\cos\beta_2)$$

$$= 2\rho - 2\rho^2(1 + K\cos\beta_2)$$

$$= 2(\rho - \rho^2)(1 + K\cos\beta_2)$$

$\therefore$ Blad Speed ratio $= (\rho) = \frac{u}{V_1}$

It is the ratio of bucket Speed or Nozzle Velocity

$\therefore$ Derivetive max or minimum

$$\frac{d\eta_b}{d\rho} = 0$$

$$\Rightarrow 2(1+K\cos\beta_2)\frac{d(\rho-\rho^2)}{d\rho} = 0$$

$$\Rightarrow 2(1+K\cos\beta_2)(1-2\rho) = 0$$

$$\Rightarrow 1-2\rho = 0 \Rightarrow 2\rho = 1 \Rightarrow \rho = 1/2$$

$\therefore$ Put the value of $\rho$ in equation i

$$2\left(\frac{1}{2}-\frac{1}{4}\right)(1+K\cos\beta_2)$$

$$= 2\left(\frac{2-1}{4}\right)(1+K\cos\beta_2)$$

$$= \frac{2}{4}(1+K\cos\beta_2)$$

$$= \frac{1+K\cos\beta_2}{2}$$

$\boxed{K = \text{Smooth surface}}$

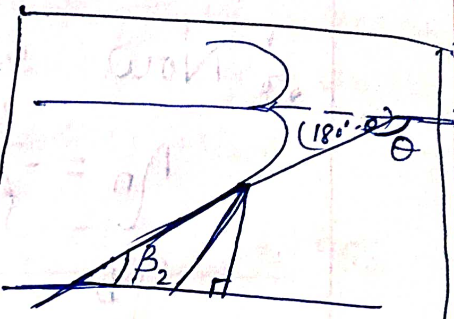
$$\therefore \eta_b = \frac{1+K\cos\beta_2}{2}$$

$\therefore$ If $K=1$, then $\eta_b = \dfrac{1+K\cos\beta_2}{2} = \dfrac{1+\cos\beta_2}{2}$

## Hydraulic Effiencic ($\eta_h$)

$$\eta_h = \frac{O.P}{I.P} = \frac{\text{Runner Power}}{\text{Water Power}}$$

$$= \frac{\dot{m}(V_{w1}u_1 \pm V_{w2}u_2)}{\rho g Q H}$$




$\theta$ = Angle of diflection

Generally $\beta_2 = 15°$ we consider

If we consider,

$$\eta_n \times \eta_b = \frac{K.E}{W.P} \times \frac{P_{runner}}{K.E}$$

$$= \frac{P_{runner}}{W.P} = \eta_h$$

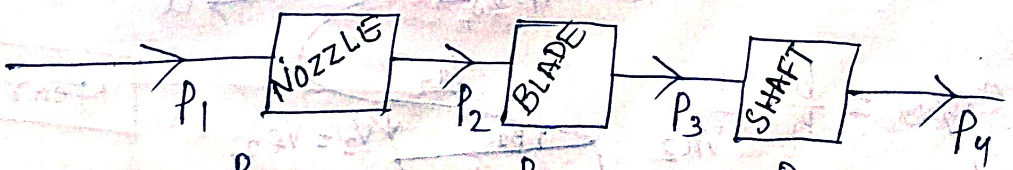
If we neglating $\eta_n$ or $\eta_n = 1$ → Frictionless

then, $\eta_b = \eta_h$

## Mechanical Effiency ($\eta_m$)

$$\eta_m = \frac{O/P}{I/P} = \frac{\text{Shaft Power}}{\text{Runner Power}}$$

## Calculating overall Effiency of a Body:-




$$\eta_N = \frac{P_2}{P_1}, \quad \eta_B = \frac{P_3}{P_2}, \quad \eta_S = \frac{P_4}{P_3}$$

$$\therefore \eta_{N.B} = \frac{P_2}{P_1} \times \frac{P_3}{P_2} = \frac{P_3}{P_1}$$

∴ Overal Effiency ($\eta_{N.B.S}$ or $N_O$) =

$$\frac{P_2}{P_1} \times \frac{P_3}{P_2} \times \frac{P_4}{P_3} = \frac{P_4}{P_1}$$

∴ Now we put Pelton wheel turbine,

$$\eta_n = \frac{\frac{1}{2}mv^2}{\rho g Q H}$$

$$\eta_b = \frac{\text{Runner Power}}{\frac{1}{2}mv^2} = \frac{\dot{m}u(V_{w_1} - V_{w_2})}{\frac{1}{2}mv^2}$$

$$\eta_m = \frac{\text{Shaft Power}}{\text{Runner Power}} = \frac{\text{Shaft Power}}{\dot{m}(V_{w_1} - V_{w_2})u}$$

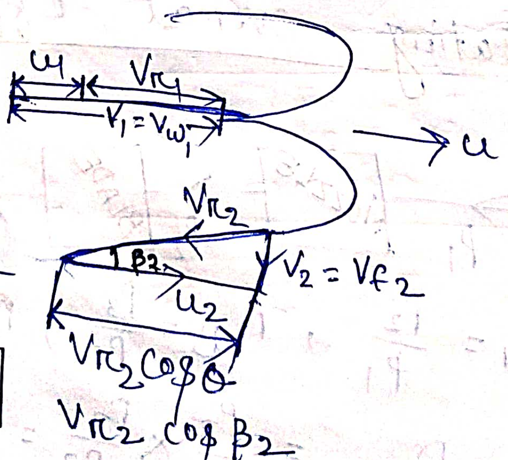
∴ overal Effieny ($\eta_o$) =

$$\frac{K.E}{W.P} \times \frac{\text{Runner Power}}{K.E} \times \frac{\text{Shaft Power}}{\text{Runner Power}}$$

$$\eta_o = \frac{\text{Shaft Power}}{\text{Water Power}}$$

If I Consider $\beta_2$ in 3 possibility traingle

In case 1-



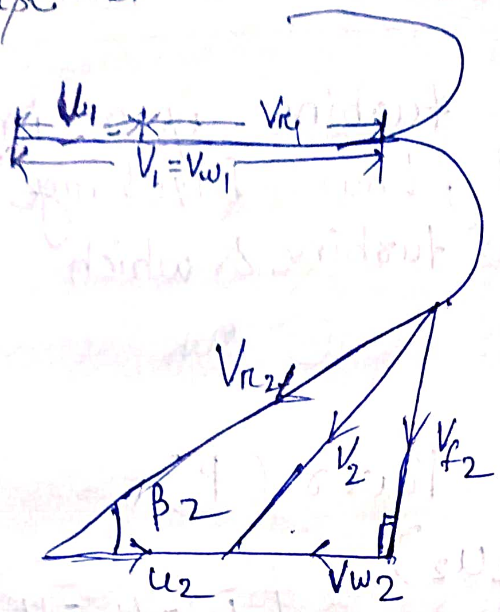

∴ $\cos\theta = \frac{b}{h} = \frac{u_2}{V_{r_2}}$

$\Rightarrow V_{r_2}\cos\theta = u_2$

$\Rightarrow \boxed{V_{r_2}\cos\beta_2 = u_2}$

$\boxed{\text{Hear } u_2 = u}$

In Case - 2



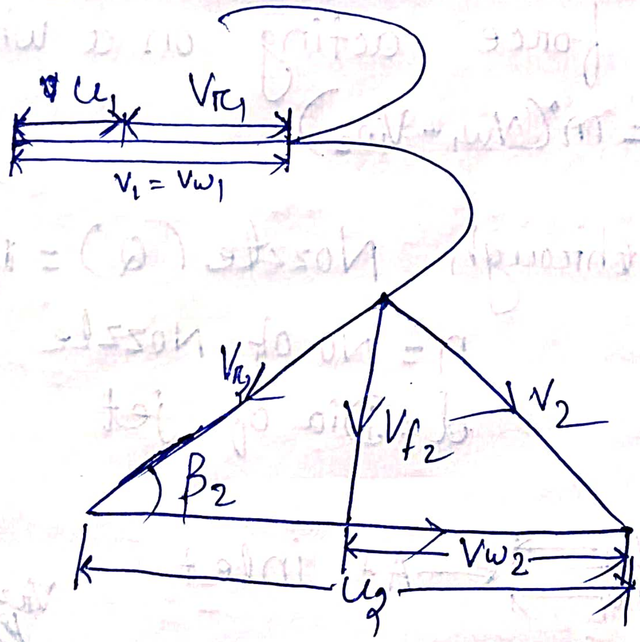

$\because \cos\theta = \frac{b}{h} = \frac{u_2 + V_{w_2}}{V_{r_2}}$

$\Rightarrow V_{r_2}\cos\theta = u_2 + V_{w_2}$

$\Rightarrow V_{r_2}\cos\beta_2 = u_2 + V_{w_2}$

$\boxed{\therefore V_{r_2}\cos\beta_2 > u_2}$

In case - 3




$\because \cos\beta_2 = \frac{b}{h} = \frac{u_2 - V_{w_2}}{V_{r_2}}$

$\Rightarrow V_{r_2}\cos\beta_2 = u_2 - V_{w_2}$

$\Rightarrow \boxed{u_2 > V_{r_2}\cos\beta_2}$

## Overview in Pelton wheel turbine :-

→ A Pelton wheel turbine is a "impulse turbine It is a high head, Low Discharge, Low spefic speed flow turbine & which has K·E at In let.

→ Runner Power or Power (P)

$= \dot{m}(V_{w_1}u_1 - V_{w_2}u_2)$

$= \dot{m}(V_{w_1} - V_{w_2})u$ $\quad \left[u_1 = u_2 = u = \frac{\pi D N}{60}\right]$

D = wheel Dia

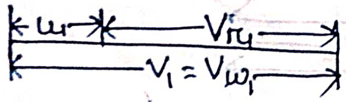
→ Tangential force acting on a wheel

$F_t = \dot{m}(V_{w_1} - V_{w_2})$

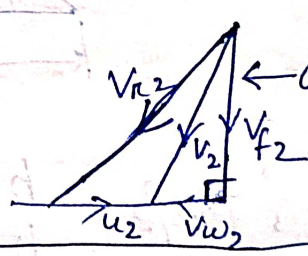
→ Discharge through Nozzle $(Q) = n \times \frac{\pi}{4} \times d^2 \times V_1$

n = No of Nozzle

d = Dia of jet

→ 

← At inlet



← out let

$V_{r_1} > V_{r_2} \Rightarrow \frac{V_{r_2}}{V_{r_1}} < 1$

$\frac{V_{r_2}}{V_{r_1}} = K$

$\boxed{K = \text{Blade Co-efficient of friction}}$

$\therefore V_{r_2} = K V_{r_1}$

∴ when "K" Smooth surfac then

$\boxed{K = 1}$

→ Blade Speed Ratio ($\rho$) = $\frac{u}{V_1}$

$V_1$ = Velocity at inlet

$u$ = water jet

Why we calculate Effiency?

→A:- Because we know the machine performence

## In Pelton Wheel turbine some Problems :-

Problem No-1

The bucket speed of pelton wheel turbine 15 N/s the rate of flow of water under a Head of 42 m is $1 m^3/s$, If the jet is deflected by 165°, Find the power and hydraulic efficiency of turbine. Take,

$C_V = 0.985$

Given Data:-

Bucket Speed ($u$) = 15 N/s

Head (H) = 42m

Discharge (Q) = $1 \; m^3/s$

Angle ($\beta_2$) = 180° - 160° = 15°

$\therefore \beta_2 = 15°$

$C_V = 0.985$

Power (P) = ??

$\eta_h$ = ??

$V_1 = C_V \sqrt{2gH} = (0.985)\sqrt{2 \times 9.81 \times 42}$ m/s

$= 28.27$ m/s , $\therefore$ We know that $\boxed{V_1 = V_{w_1}}$

mass flow rate ($\dot{m}$) = $\rho a v$ [$av = Q$]

$= \rho Q$ [Hear Water Density = 1000]

~~= 0.53 ×~~

$= 1000 \times 1 = 1000$ kg/s

$\therefore V_{r_1} = V_1 - u_1 = 28.27 - 15 = 13.27$ m/s

$V_{r_1} = V_{r_2}$ [Inlet velocity = out let Velocity]

$\therefore V_{r_2} \cos\beta_2 = 13.27 \times \cos(15°) = 12.81$ m/s

Hear $u > V_{r_2}\cos\beta_2$

$u_2 - V_{w_2} = V_{r_2}\cos\beta_2$

$\Rightarrow V_{w_2} = u_2 - V_{r_2}\cos\beta_2$

$= 15 - 12.81 = 2.19$ m/s

$\therefore$ Power $= \dot{m}(V_{w_1} - V_{w_2})u$

$= 1000(28.27 - 2.19)15$ [$V_1 = V_{w_1}$]

$= 391200$ W/s

$= 391200/1000 = 391.2$ kW

Hydrolic Effiency ($\eta_h$)

$= \dfrac{\text{R.Power}}{\text{Water Power}} = \dfrac{391200}{1000 \times 9.81 \times 1 \times 42} = 0.94 = 94\%$

$\therefore$ The Power is 391.2 kW and the hydrolic effiency is ($\eta_h$) 94% !

## Problem NO-02

A Pelton wheel turbine is to be desine for the following spepicification:-

Shaft power (S.P) = 11772 kW

Head (H) = 380 m

Speed (N) = 750 r.p.m

and overal effieney ~~exceed~~ 86% and jet diameter is not to exceed 1/6 of the wheel diameter. Determine wheel diameter, Dia of the jet and number number of Nozzle required.

**Given Data:-**

$S.P = 11772\ kW$

$H = 380\ m$

$N = 750\ r.p.m$

$\eta_0 = 86\%$

$d = \frac{1}{6} D$, $C_v = 0.985$

$D = ??$

$d = ??$

$n = ??$

$$V_1 = C_v\sqrt{2gH} = 0.985\sqrt{2 \times 9.81 \times 380} = 85.05\ m/s$$

$$\therefore \rho = \frac{u}{V_1}$$

$$\Rightarrow 0.45 = \frac{u}{85.05} \Rightarrow u = 85.05 \times 0.45 = 38.27$$

$\therefore$ We know, $u = \frac{\pi D N}{60}$

$$\Rightarrow 38.27 = \frac{\pi \times D \times 750}{60}$$

$$\Rightarrow \frac{38.27 \times 60}{\pi \times 750} = D \Rightarrow D = 0.97\ m$$

In question, $d = \frac{1}{6} D$

$= \frac{1}{6} \times 0.97 = 0.164\,m$

$\therefore$ We know that

$$\eta_o = \frac{\text{Shaft Power}}{\text{Water Power}}$$

$$\Rightarrow \frac{86}{100} = \frac{11772 \text{ k.W}}{1000 \times 9.81 \times 380 \times Q \text{ W}} \Rightarrow \frac{86}{100} = \frac{11772 \times 1000}{1000 \times 9.81 \times 380 \times Q}$$

$$\Rightarrow 86 \times 9.81 \times 36 \times Q = 11772 \times 100$$

$$\Rightarrow Q = \frac{11772 \times 100}{86 \times 9.81 \times 36} = 3.67 \text{ m}^3/\text{s}$$

$\therefore$ Discharge $(Q) = n \times \frac{\pi}{4} d^2 v_1$

$$\Rightarrow 3.67 = n \times \frac{\pi}{4} \times (0.164)^2 \times 85.05$$

$$\Rightarrow 3.67 = n \times \frac{\pi}{4} \times 0.0256 \times 85.05$$

$$\Rightarrow n = \frac{3.67}{1.710031713}$$

$$\Rightarrow n = 2.14 = 2$$

$\therefore$ Wheel Dia $(D) = 0.97$

Jet Dia $(d) = 0.164$

And Number of Number Required $= 2$

All unit of the water Discharge

$\frac{Kg}{m^3} \times \frac{m}{s^2} \times \frac{m^3}{s} \times m$

$\rho \times g \times Q \times H$

$$\frac{kg \cdot m^2}{s^3} = \frac{kg \cdot m}{s^2} \times \frac{m}{s} = N \times \frac{m}{s} = J/s$$

$$\boxed{\therefore J = \frac{kg \cdot m^2}{s^2}} \quad \boxed{N = \frac{kg \cdot m}{s^2}}$$

$= \frac{Joule}{Sec} = Watt$

$\therefore 1\ watt = \frac{Joule}{Sec}$

Problem No- 03

Two jets strike the buckets of pelton wheel which is having a shaft Power of 15450 KW. The diameter of each jet is 200mm if the Head on turbine is 400m. Find the overall Efficiency. Take $C_v = 1$

Solution:- Given Data:-

$n = 2$

$S.P = 15450\ KW$

$d = 200\ mm = \frac{200}{1000} = 0.2m$

$H = 400m$

$C_v = 1$

$\therefore V_1 = C_v\sqrt{2gH} = 1\sqrt{2 \times 9.81 \times 400} = 88.58\ m/s$

$$Q = n \times \frac{\pi}{4} \times d^2 \times V_1$$

$$= 2 \times \frac{\pi}{4} \times 0.2 \times 88.58$$

$$= 5.565 \ m^3/s$$

$\therefore$ overal Effiency ($\eta_o$) = $\frac{S.P}{W.P}$

$$= \frac{S.P}{\rho g Q H} = \frac{15450 \times 1000}{1000 \times 9.81 \times 5.565 \times 400} = 0.70 = 70.75\%$$

Problem No-04

A Pelton wheel turbine is recieving water from a penstroke with a gross head of 510m 1/3 of gross head is lossed in friction in the penstroke. The rate of flow through the nozzle fitted at the end of penstraoke is $2.2 m^3/s$. The angle of deflection of jet is $165^0$. And $\rho = 0.45 \ kg/m^3$ Determine

(i) The Power Given by the water of the runner.

(ii) Hydrolic Effiencicy ($\eta_h$).

Solution:-

Given Data:-

$H_g = 510 m$

$Q = 2.2 m^3/s$

$\phi = 180^0 - 165^0 = 15^0$

$B_2 = 15^0$

$\therefore$ Net head (H) = Gross Head ($H_g$) - ($H_f$) Friction Head

$$H = 510 - \frac{510}{3}$$
$$= 510 - 170$$
$$= 340\ m$$

$$\rho = 0.45\ kg/m^3$$

$$V_1 = C_V\sqrt{2gH}$$
$$= 1\sqrt{2\times9.81\times340} = 81.67\ m/s$$

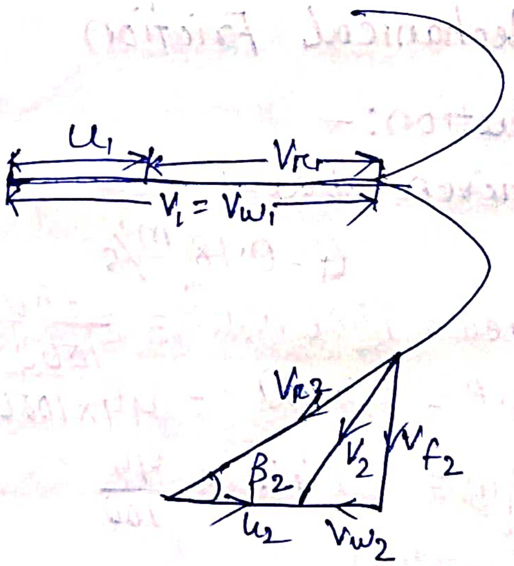
$$\therefore Q = n\times\frac{\pi}{4}\times d^2 V_1$$
$$= 2.2\ m^3/s$$

$$m' = \rho\times(a\times v) = \rho\times Q = \overset{1000}{\cancel{0.45}}\times 2.2 = \cancel{0.99}\ 2200\ kg/s$$

$\therefore$ We know bucket speed ratio($\rho$)

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

$$\Rightarrow 0.45 = \frac{u}{81.67}$$
$$\Rightarrow 0.45\times81.67 = u$$
$$\Rightarrow u = 36.75\ m/s$$




$\therefore$ In traeingle

$$u + V_{r_1} = V_1$$
$$\Rightarrow 81.67 = 36.75 + V_{r_1}$$
$$\Rightarrow V_{r_1} = 81.67 - 36.75$$
$$= 44.9\ m/s$$

$$\therefore V_{r_1} = V_{r_2}$$

$$\therefore V_{r_2}\cos\beta_2 = 44.9\times\cos(15^\circ) = 43.37$$

$$\therefore V_{r_2}\cos\beta_2 > u$$

$\therefore$ Power $(P) = \dot{m}(V_{w_1} - (-V_{w_2}))$

$= \dot{m}(V_{w_1} + V_{w_2})u$

$= 2200(36.73)88.27$

$= 7132745.62$

Problem No-05

The following data where obtain from a based on pelton wheel head at the base of Nozzle $= 32\,m$, Discharge of Nozzle $= 0.18\,m^3/s$ and area of jet $7500\,mm^2$, shaft power 44 kW, Mechanical efficiency 94% | Calculate the power lost-

(i) In the Nozzle

(ii) Runner ~~Power~~

(iii) Mechanical Friction

Solution:-

Given Data:-

$Q = 0.18\,m^3/s$

$\text{Area} = 7500\,mm^2 = \frac{7500}{1000} = 7.5\,m^2 = 7.5 \times 10^{-3}\,m$

$S.P = 44\,kW = 44 \times 1000\,W$

$\eta_m = 94\% = \frac{94}{100}$

$H = 32\,m$

($V_1 = C_v\sqrt{2gH}$) = This formula is not aplicabule in this process.

So,

We know $Q = aV$

$\Rightarrow 0.18 = 7.5 \times 10^{-3} \times V$

$\Rightarrow \quad V = \dfrac{0.18}{7.5 \times 10^{-3}} = 24 \text{ m/s}$

$\therefore \; Q = 0.18,$

(i) Power inlet of the Nozzle

$W.P = \rho g Q H$

$= 1000 \times 9.81 \times 0.18 \times 32$

$= 56505.6 \text{ W}$

$= 56505.6 \div 1000 = 56.50 \text{ kW}$

$\therefore$ Power outlet of the Nozzle

$K.E = \frac{1}{2} m v^2$

$= \frac{1}{2} \times 180 \times (24)^2$

$= 51840 \text{ W} = 51.84 \text{ kW}$

$\therefore \dot{m} = \rho Q$

$= 1000 \times 0.18$

$= 180 \text{ kg/s}$

$\therefore$ Power lost in the Nozzle

$= W.P - K.E$

$= 56.50 - 51.84 = 4.66 \text{ k.W}$

(ii) Runner at inlet is K.E = 51.84 K.W

at out-let

We know that, $\eta_m = \frac{S.P}{P_R}$

$\Rightarrow \frac{94}{100} = \frac{44 \times 1000}{P_R}$

$\Rightarrow P_R = \frac{44 \times 1000 \times 100}{94} = 46808.510 W$

$= 46.805 KW$

$\therefore$ Power lost in Runner

$= K.W - P_R = 51.84 - 46.805 = 5.035 KW$

(iii). Power lost in mechanical friction

$(P_R - P_{shft})$

$= 46.805 - 44 = 2.805 K.W$

$\therefore$ Power lost in Mechanical friction $= 2.805 KW$.

$\therefore$ Power lost in Runner $= 5.035 KW$

$\therefore$ Power lost in Nozzle $= 4.66 KW$

(Ans).

Problem NO-06 :- A Single jet in pelton wheel turbine is requir. to devlope a S.P of 10 MW the head at the Nozzle is 760m and Mechanical effiencicy = 0.95, $\eta_h$ = '87, $\beta_2 = 15^0$, $C_v = 0.97$, $V_{r2} = 0.85 V_{r1}$, $u = 0.46 V_1$ Calculate

(i) Discharge (ii) Jet dia (iii) Force Exted on the jet

(iv) Beast Shrinkonus Speed for the generator at 50Hz, Coressponding mean dia of whil to jet dia $D/d = 10$,

Solution:—

Given Data:—

S.P = 10 MW = $10 \times 10^6$ W

$C_v = 0.97$

H = 760m

$V_{r2} = 0.85 V_{r1}$

$\eta_m = 0.95$

n = 1

$\eta_h = .87$

$\beta_2 = 15^0$

$$V_1 = C_v\sqrt{2gH} = 0.97\sqrt{2 \times 9.81 \times 760} = 118.4 \text{ m/s}$$

$\therefore u = 0.46 \times 118.4 = 54.46$ m/s

$V_{r1} = V_1 - u = 118.4 - 54.46 = 63.94$ m/s

$\therefore V_{r2} = 0.85 V_1 \Rightarrow V_{r2} = 0.85 \times 63.95 = 54.349$ m/s

$\therefore V_{r2} \cos\beta_2$

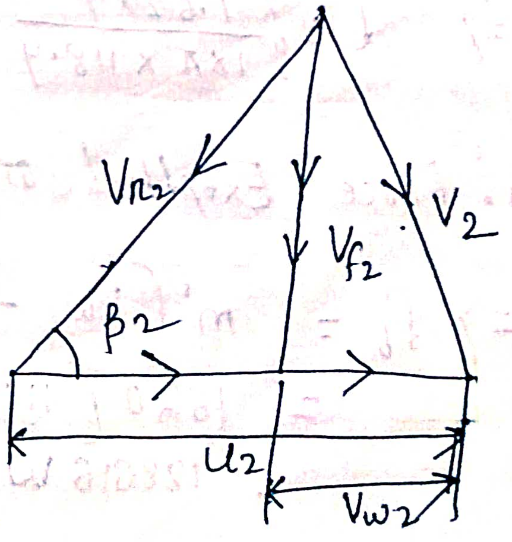
$\Rightarrow 54.349 \cos 15^\circ = 52.49$

$\therefore U > V_{r2} \cos\beta_2$

$\therefore \cos\theta = \dfrac{u_2 - V_{w2}}{V_{r2}}$

$\Rightarrow V_{r2} \cos\theta = u_2 - V_{w2}$

$\Rightarrow u_2 = V_{r2} \cos\beta_2 + V_{w2}$



$\Rightarrow V_{w_2} = u_2 - V_{r_2}\cos\beta_2$

$= 54.46 - 52.49 = 1.97$

$\therefore$ We know that

$\eta_h = \dfrac{\text{Runner Power}}{\text{Water Power}}$ & $\eta_m = \dfrac{\text{Shaft Power}}{\text{Runner Power}}$

So, $\eta_h \times \eta_m = \dfrac{S.P}{W.P}$

$\therefore \dfrac{0.95 \times 0.87}{\cancel{100 \times 100}} = \dfrac{10 \times 10^6}{1000 \times 9.81 \times Q \times 760}$

$\Rightarrow Q \times 0.95 \times 0.85 \times 1000 \times 9.81 \times 760 = \cancel{100 \times 100} \times 10 \times 10^6$

$\Rightarrow Q = \dfrac{\cancel{100 \times 100} \times 10 \times 10^6}{0.95 \times 0.87 \times 1000 \times 9.81 \times 760} = 1.622 \ m^3/s$

$\therefore Q = n \times \frac{\pi}{4} d^2 V_1 \Rightarrow Q = 1 \times \frac{\pi}{4} \times d^2 \times 118.4$

$\Rightarrow 1.62 = \dfrac{1 \times \pi \times 118.4 \times d^2}{4}$

$\Rightarrow \dfrac{1.62 \times 4}{1 \times \pi \times 118.4} = d^2$

$\Rightarrow d = \sqrt{\dfrac{1.62 \times 4}{1 \times \pi \times 118.4}} = 0.13 m$

$\therefore m^\circ = \rho Q$

$= 1000 \times 1.62$

$= 1620 \ kg/s$

$\therefore$ Force Exerted on the jet ($f_t$)

$\Rightarrow f_t = m^\circ (V_{w_1} - V_{w_2})$

$= 1620 [118.4 - 1.97]$

$= 188616 \ W = 188.616 \ kW$

$\because \frac{D}{d} = 10 \Rightarrow \frac{D}{0.13} = 10 \Rightarrow D = 10 \times 0.13 = 1.3m$

$u = \frac{\pi D N}{60}$

$\Rightarrow 54.46 = \frac{\pi \times 1.3 \times N}{60}$

$\Rightarrow 54.46 \times 60 = \pi \times 1.3 \times N$

$\Rightarrow N = \frac{54.46 \times 60}{\pi \times 1.3} = 802.72 \, r.p.m$

Form Electrical Engineer

$N = \frac{120F}{P}$ $\quad \because$ Firquency$(F) = 50Hz$

$\Rightarrow 802.72 = \frac{120 \times 50}{P}$

$\Rightarrow P = \frac{120 \times 50}{802.72} = 7.47$

$\therefore$ Maximum Speed $(N) = \frac{120 \times 50}{\cancel{802.72} \; 7.47} = 803 \, r.p.m$ (Ans)

# REACTION TURBINE

→ Reaction Turbines are Francis, Kaplan Turbine.

## Francis Turbine

→ Construction of Francis Turbine :-

Definition :-

(1) Francis turbine is a radially inward and Axially outlet flow turbine.

(2) This turbine opperates under medium heads (60-250)m and Medium specific speed (60-400).

(3) In inlet only kinetic energy and Pressure energy present in the turbine.

(4) It is a medium discharge.

The main parts of the Francis Turbine :-

1. Penstock :- The penstock is also known as the input pipe. The diameter lies between 1 to 10 meters.

2. Spiral Casing :- It is the inlet of water to the turbine. The water flowing from the reservoir or dam is made to pass through this pipe with high pressure.

→ Which the area of cross-section of the casing is gradually decreasing, The casing completely surrounded runner of the turbine.

3. <u>Guide Vane</u> :- The main function of the guide vane are to guide the water to ward the runner.

→ It converts pressure energy of the fluid into kinetic Energy.

<u>Runner Blades</u> :-

→ In runner the energy from the water it converts to rotational motion of the main shaft.

→ The runner blades design how effectively a turbine is going to perform.

→ The runner blades are devided into two parts :- The lower half is made in the shape of a small bucket so that it uses the impulse action of water to rotate the turbine.

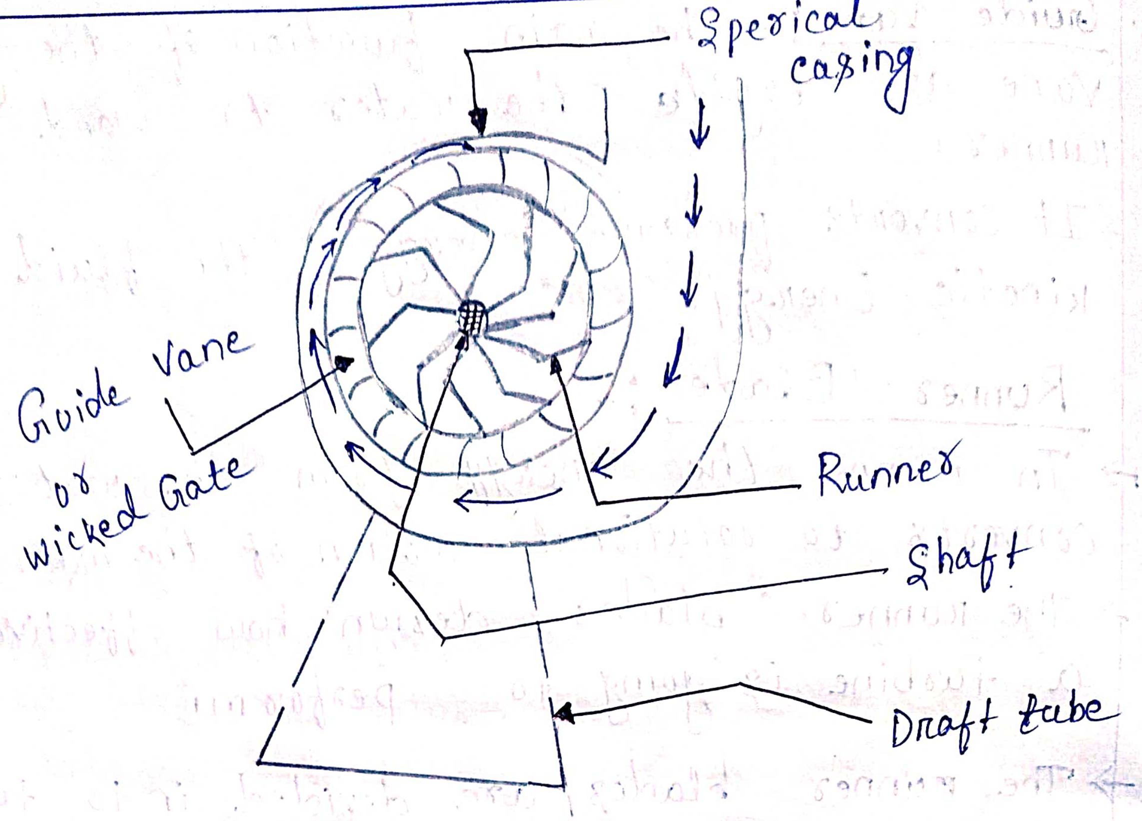
→ The upper parts of the blades uses the reaction force of water flowing through it.

<u>Draft Tube</u> :-

→ The draft tube is an expanding tube is used to discharge the water through the runner and next to the tail race.

→ The main function of the draft tube is to reduce the water velocity at the time of discharge.

→ It's cross-Sectional area increases along it's Length. As the water coming out of the runner blades.




→ In Francis Turbine $u_1 \neq u_2$

$\therefore u_1 = \frac{\pi D_1 N}{60}$ and $u_2 = \frac{\pi D_2 N}{60}$

→ Runner Power $(P_R) = m^{\circ}(V_{w_1} u_1 \pm V_{w_2} u_2)$

→ In Francis case,


$\therefore$ Always $V_{r_2} > V_{r_1}$

$\therefore V_{r_2} > V_{r_1}$

→ Francis turbine blades or Bucket is 16-20 ।

→ Absolute velocity is the resultant of bucket speed and relative

→ kaplain turbine Blade or vane is always less then francis turbine ।

Efficiency :- $\frac{O/P}{I/P}$

$$\eta_h = \frac{R.P}{W.P} = \frac{P_R}{P_W} = \frac{\dot{m}(V_{w_1}u_1 \pm V_{w_2}u_2)}{\rho g Q H}$$ [$V_{w_2}$ = Because axialy out]

$V_{w_2}u_2 \rightarrow 0$

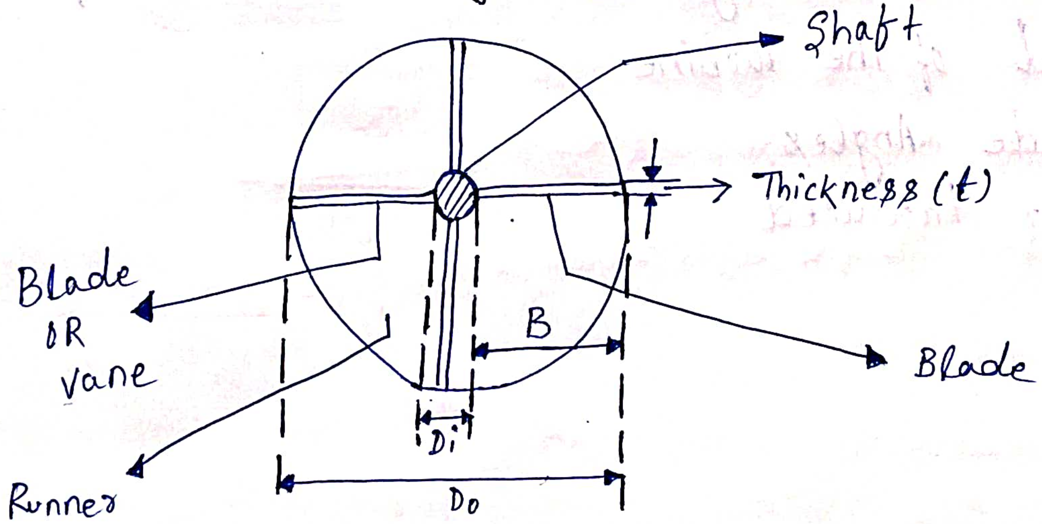
$$= \frac{\dot{m}(V_{w_1}u_1)}{\rho g Q H}$$ $\boxed{\dot{m} = \rho Q}$

$$= \frac{\rho Q (V_{w_1}u_1)}{\rho g Q H} = \frac{V_{w_1}u_1}{g H}$$

$$\eta_m = \frac{S.P}{R.P} = \frac{P_s}{P_R} = \frac{P_s \times gH}{V_{w_1}u_1}$$

$$\eta_o = \eta_m \times \eta_h = \frac{S.P}{W.P} = \frac{P_s}{P_W}$$

## Discharge (Q)




$$\text{Total Area} = (A) = \frac{\pi}{4}(D_o^2 - D_i^2)$$

Dm = Mean Diameter

B = Width Diameter

$$= \frac{\pi}{4}(D_o + D_i)(D_o - D_i)$$

$$= \pi \left(\frac{D_o + D_i}{2}\right)\left(\frac{D_o - D_i}{2}\right)$$

$$= \pi D_m B$$

$$\boxed{(\text{Discharge}) Q = \pi D B V_f}$$

$$Q = AV$$

$$D_1 \cancel{\pi} B_1 V_{f1} = D_2 B_2 V_{f2} \cancel{\pi}$$

$$\Rightarrow \boxed{\cancel{Q} = D_1 B_1 V_{f1} = D_2 B_2 V_{f2}}$$

$$\boxed{Q = \pi(\cancel{\pi} D - Zt) B V_f}$$

Z = No. of Blade
t = Thikness
D = Mean Dia

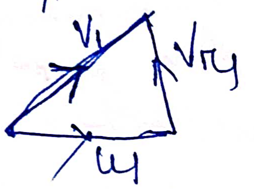
# VELOCITY TRAINGLE

→ Francis Turbine -

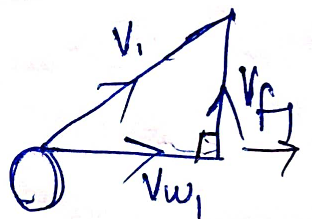
Always Remember

→ Absolute velocity (V) is the resultant of bucket speed (u) and Relative velocity ($V_r$).

Ex:-




or




→ Absolute velocity (V) is a resultant of flow velocity and bucket speed.