Fluid

↓

Dynamics of fluid

Energy Equation

F/M

Energy of fluid

1st

$$P + \frac{1}{2}\rho V^2 + \rho g z \Big]$$ energy per unit volume

2nd

$$\frac{P}{\rho g} + \frac{v^2}{2g} + z \Big]$$ energy per unit weight or load form.

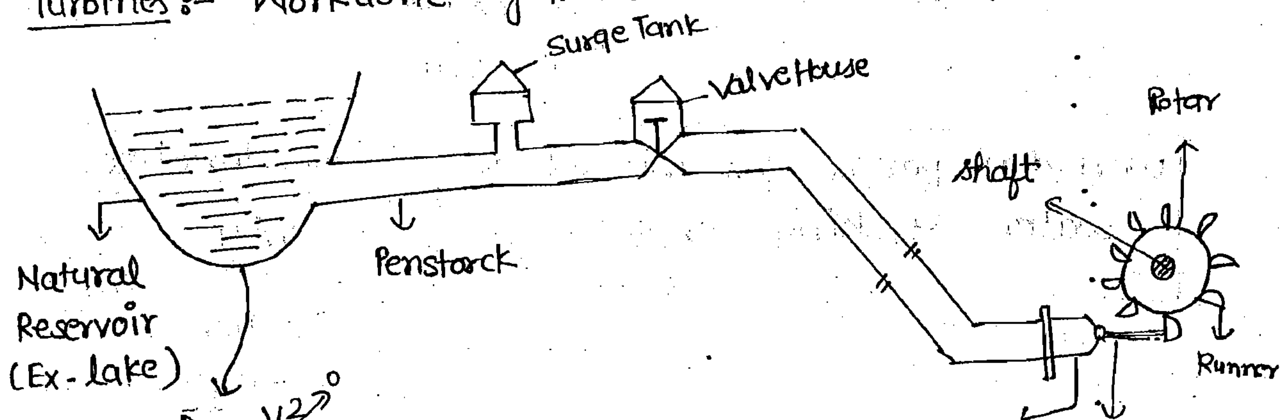
H/M

Water → Workdone by the water.
Ex.- Hydro electric Power Plants

Water → Workdone on the water.
Ex. Pump.

Classification of Hydraulic Machines :-

Turbines :- Workdone by the water.

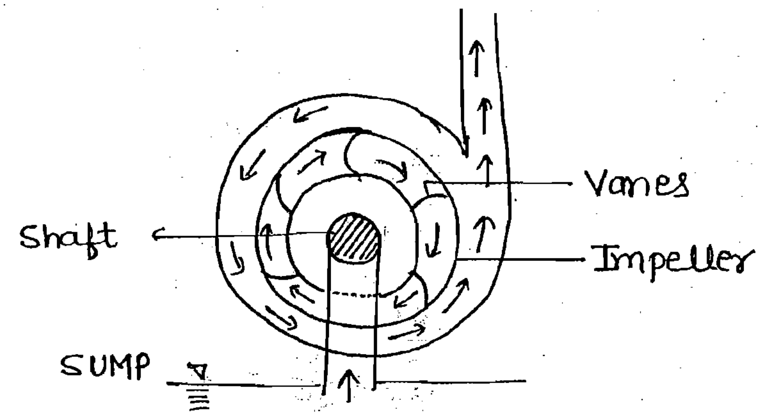


$$\frac{P}{\rho g} + \cancel{\frac{V^2}{2g}}^{0} + z$$

Hydraulic Energy ⟹ Mechanical shaft Power ⟹ electricity (electric Power)

Runner : Rotal having a series of vanes.

PUMP: Workdone on the water.



Electrical Energy $\Rightarrow$ Mechanical shaft work $\Rightarrow$ Hydraulic Energy.

Work done (Joule)	Workdone/sec (watt) or (Power)
$= \frac{1}{2} m v^2$	$= \frac{1}{2} \dot{m} v^2$
$= mgh$	$= \dot{m} g h$
$= F_x \cdot x$	$= F_x \cdot u$
	$\boxed{P = T \cdot \omega}$

$\frac{1}{2} m v^2 = wd$
mgh
$F_x \cdot x$

$\frac{1}{2} \dot{m} v^2$
$\dot{m} g h$
$F_x \cdot u$
$P = T \cdot \omega$

$$\boxed{\text{work done per sec. per unit wt. of water striking per sec. } (\dot{m}) = \frac{\text{workdone/sec}}{\dot{m} g}}$$

when $H = 30$
$\dot{m} g H$ = watt.

Torque is Rate of change of angular Momentum.
where angular Momentum is moment of linear Momentum.

Cause of Workdone ⇒ Force

Newton's 2^{nd} Law –

$$\vec{F}_{ext.} = \frac{d}{dt}(m.\vec{v})$$

↓ system (water)

Force exerted on the water

$$\vec{F}_{water} = \dot{m}(\vec{v}_2 - \vec{v}_1) \quad \text{In pumps}$$

Force exerted by the water

$$\vec{F} = -\vec{F}_{water} \quad (\text{Newton's } 3^{rd} \text{ law})$$

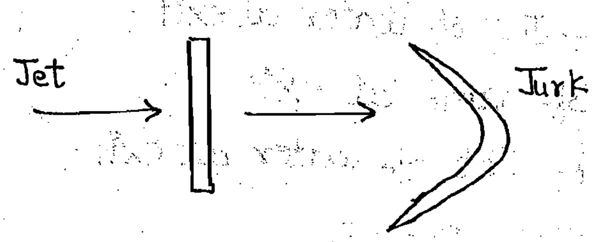
$$\vec{F} = \dot{m}(\vec{v}_1 - \vec{v}_2) \quad \text{In turbines}$$

$\vec{v}_2$ = Absolute Velocity of water at exit. v_2 = Ab – exit

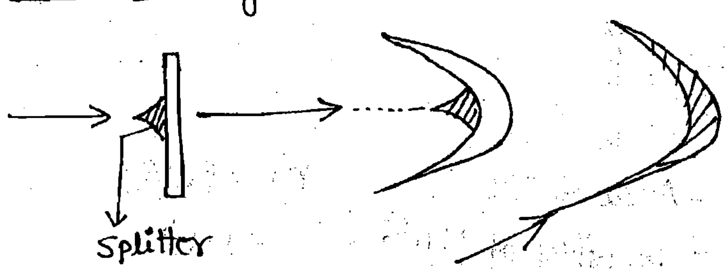
$\vec{v}_1$ = absolute velocity of water at inlet. v_1 – Ab – inl.

Our Requirement :-

(1)

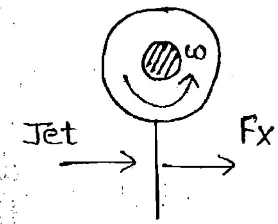


Smooth Entry →



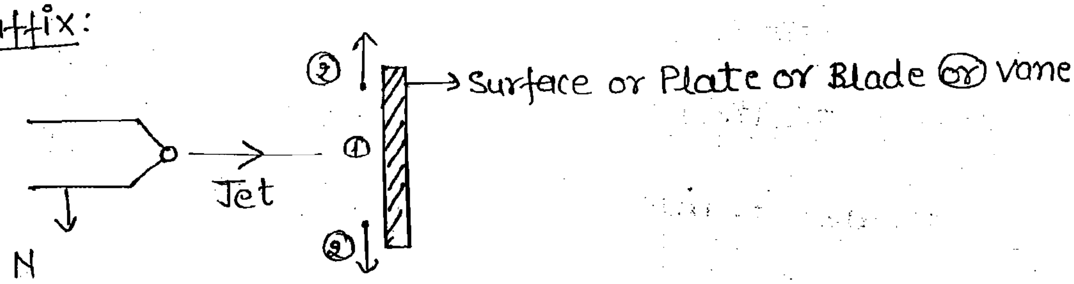
(2) Force in $-x$-dir^n & not in y-dir^n

otherwise misalignment of Rotar.



Impact of Jet :-

Suffix:



Entry at vane $\Rightarrow$ ①

Exit from Vane $\Rightarrow$ ②

At inlet:-

$V_1 \Rightarrow$ Absolute Velocity of Jet of water at inlet.

$u_1 \Rightarrow$ Absolute velocity of Vane at inlet.

$V_{r_1} \Rightarrow$ Relative Velocity of Jet of water.

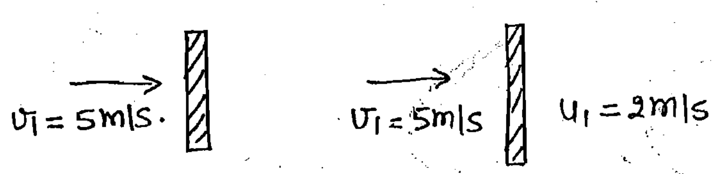
At exit:

V_2 = Absolute Velocity of Jet of water at exit.

u_2 = Absolute Velocity of vane at exit

V_{r_2} = Relative velocity of Jet of water at exit.

Mass Flow Rate Responsible for Force :



$\dot{m} = \rho a V_1$
$= \rho a(5)$

a = Area of Jet
ρ = Density of fluid

$\dot{m} = \rho a V_{r_1}$
$= \rho a(5-2)$
$= \rho a(3)$.

The mass Flow rate responsible for the force will be calculated on the basis of relative Velocity.

Impact of Jet :

Aim :- Designing of the shape of Vanes.

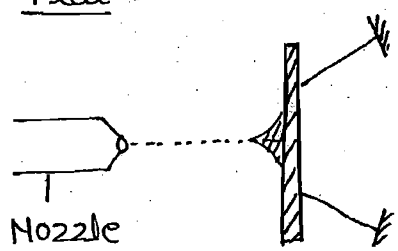
Requirement :

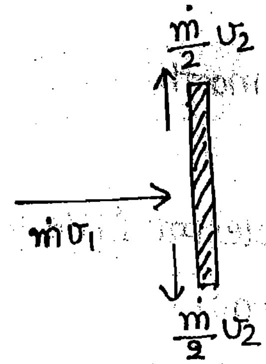
$F_x = \text{max}^m$

$F_y = 0$

Stationary Surface :

(1) Flat :-





Assume

Vane Surface is smooth.

$\boxed{v_2 - v_1}$

Mass flow Rate Responsible for force -

$$\boxed{\dot m = \rho a v_1}$$

F_x = Initial Momentum/sec in the x-dir^n. − Final Momentum/sec. in the x-dir^n.

$$F_x = \dot m v_1 - 0 = \dot m v_1 = (\rho a v_1) \cdot v_1$$

$$\boxed{F_x = \rho a v_1^2}$$

F_y = Initial Momentum/sec. in the y-dir^n − Final Momentum/sec. in y-dir^n.

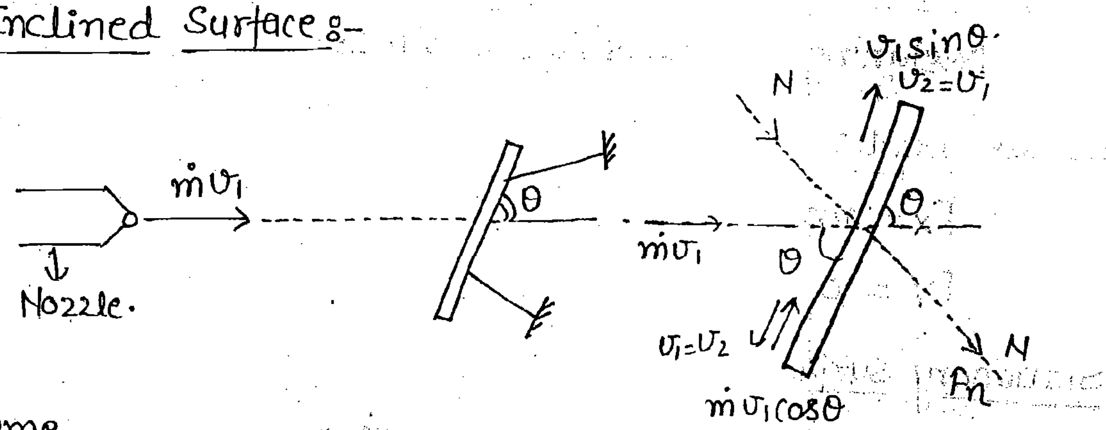
$$= 0 - \left[\frac{\dot m}{2} v_2 - \frac{\dot m v_2}{2}\right] \qquad \{v_2 = v_1\}$$

$\boxed{f_y = 0}$ as pipe is assumed smooth.

NOTE:

If a jet strikes at 90° then the forces will exist in the same dir^n.

(2) Inclined Surface:-



Assume

Vane surface is smooth

$$\boxed{v_2 = v_1}$$

mass flow Rate responsible for force

$$\boxed{\dot{m} = \rho a v_1}$$

Now,

Fn = Initial Momentum/sec at inlet in N-dir^n − Final Momentum/sec at exit in N-N dir^n.

$$= \dot{m}v_1 \sin\theta - 0$$

$$\boxed{F_n = \rho a v_1^2 \sin\theta}$$

$$F_x = F_n \cos(90^\circ - \theta)$$

$$\boxed{F_x = \rho a v_1^2 \sin^2\theta}$$

$$F_y = F_n \sin(90 - \theta)$$

$$\boxed{F_y = \rho a v_1^2 \sin\theta \cdot \cos\theta}$$