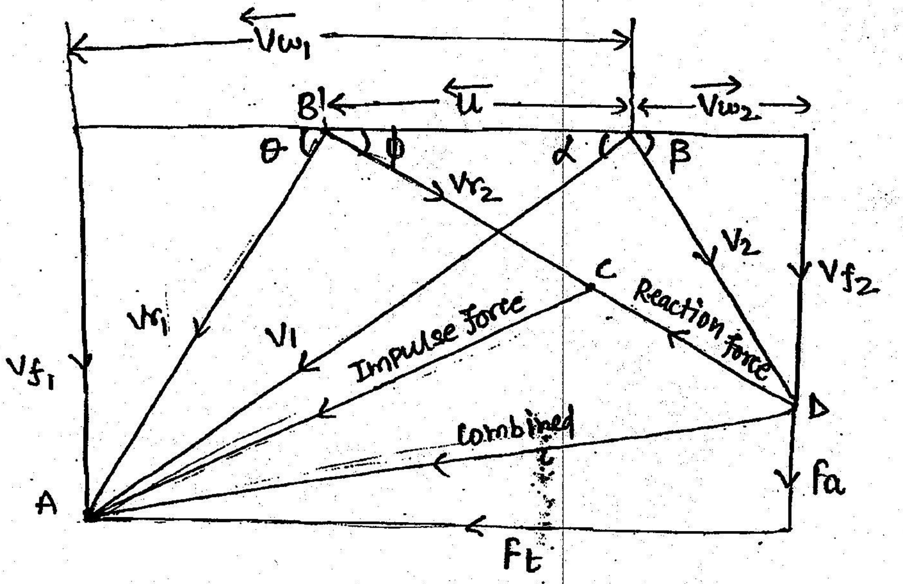
REACTION TURBINE :-



$(\theta > \phi) \rightarrow$ unsymmetrical blade are used for reaction thrusts.

AB = BC

Impulse Force — AC

Reaction Force — CD

combined — AD

(*) Reaction turbine works on the principle of impulse and reaction. Each stage consist of a set of fixed and moving moving blade and the blade passage is made converging type both for fixed and moving blade. In the fixed blade there is drop in pressure due to which absolute velocity increases. There is further drop of pressure in the moving blade due to which relative velocity increases. The total work is obtained in the moving blade ue to imulse $\left(\frac{V_1^2 - V_2^2}{2}\right)$ and reaction $\left(\frac{V_{r_2}^2 - V_{r_1}^2}{2}\right)$ and so these turbines should be call impulse reaction turbine. The energy at the inlet of moving blade consist of both kinetic energy and pressure energy.

$$\boxed{\text{Inlet energy} = \frac{V_1^2}{2} + \frac{V_{r_2}^2 - V_{r_1}^2}{2}}$$

$$\boxed{\eta_b = \frac{2u(V_{w_1} + V_{w_2})}{V_1^2 + V_{r_2}^2 - V_{r_1}^2}}$$

$$\eta_b = \frac{\dot{m}(V_{w_1} + V_{w_2})u}{\dot{m}\left(\frac{V_1^2}{2} + \frac{V_{r_2}^2 - V_{r_1}^2}{2}\right)}$$

(Rest of the Formula are Same as impulse turbine)

50% Reaction stage or Parsons Turbine :

In practical thermal power plant 50% Reaction stage i.e parson's turbine is used because the axial thrust get neutralised, blade manufacturing and design become simple and efficiency obtained is near optimum.

$(\theta > \phi) \rightarrow$ unsymmetrical blade

$$\boxed{\begin{array}{l} V_1 = V_{r_2}, \; V_2 = V_{r_1} \\ \alpha = \phi, \; \beta = \theta \end{array}}$$ for 50% Reaction stage

Maximum Blade efficiency for parson's turbine :-

$$\boxed{\rho_{opt} = \frac{u}{V_1} = \cos\alpha}$$

$$\boxed{(\eta_b)_{max} = \frac{2\cos^2\alpha}{1+\cos^2\alpha}}$$

	IMPULSE	REACTION
Blade	Symmetrical $(\theta = \phi)$	unsymmetrical $(\theta > \phi)$
Pressure & V_r	$P_1 = P_2$ (M.B), $V_{r_1} = V_{r_2}$	$P_1 > P_2$ (M.B), $V_{r_1} < V_{r_2}$
Inlet Energy	$\frac{V_1^2}{2}$ (K.E)	$\frac{V_1^2}{2} + \frac{V_{r_2}^2 - V_{r_1}^2}{2}$ (K.E + P.E)
$\rho_{opt} = \frac{u}{V_1}$	$\frac{\cos\alpha}{2}$	$\cos\alpha$
$(\eta_b)_{max}$	$\cos^2\alpha$	$\frac{2\cos^2\alpha}{1+\cos^2\alpha}$

... speed of steam at the exit of fixed blade is 150 m/s with the Flow ratio at Inlet $(V_{f_1}/u) = 0.75$ and $V_{f_2}/u = 0.78$. If $\dot{m} = 2.8\,kg/s$ and discharge blade angle both for rotor and stator is $20°$ then calculate —

1) the inlet rotor blade angle
2) The power developed in kW
3) Degree of Reaction.

$V_1 = 150\,m/s$

$\frac{V_{f_1}}{u} = 0.75$

$\frac{V_{f_2}}{u} = 0.78$

$\alpha = \phi = 20°$

$\sin\theta = \frac{V_{f_1}}{V_{r_1}}$

$V_{r_1} = 88.86\,m/s$

$V_{w_1} = V_1 \cos\alpha = 140.95\,m/s$

$V_{f_1} = V_1 \sin\alpha = 51.30\,m/s$

$u = \frac{V_{f_1}}{0.75} = 68.4\,m/s$

$V_{f_2} = 53.35\,m/s$

$\sin\phi = \frac{V_{f_2}}{V_{r_2}}$

$V_{r_2} = 156\,m/s$

$V_{w_2} = V_{r_2}\cos\phi - u = 78.19\,m/s$

1) $\tan\theta = \frac{V_{f_1}}{V_{w_1} - u}$ $\boxed{\theta = 35.26°}$

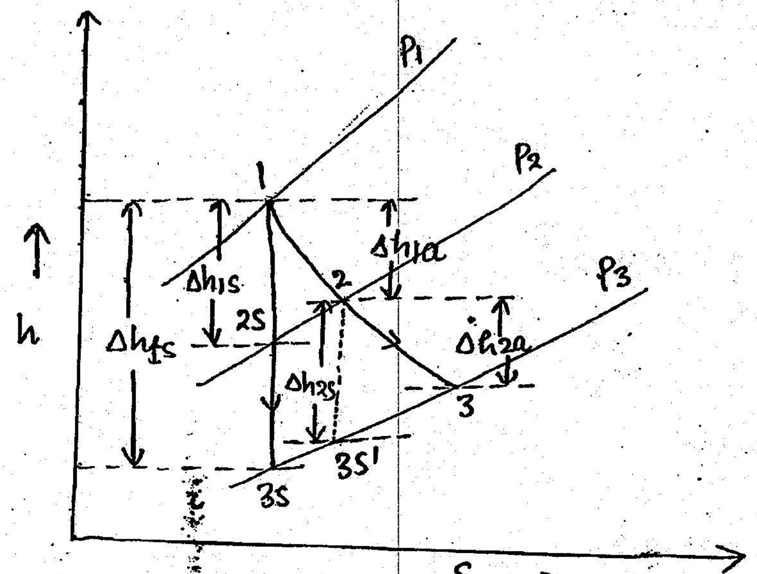
2) $P = \dot{m}(V_{w_1} + V_{w_2})u$

$\boxed{P = 41.96\,kW}$

3) $R = \frac{\left(\frac{V_{r_2}^2 - V_{r_1}^2}{2}\right)}{(V_{w_1} + V_{w_2})u}$

$\boxed{R = 54.8\%}$

Reheat Factor:



It is the term used to represent extent of irreversibility. It is the ratio of cummalative isentropic enthalpy drop for each stage to the total isentropic enthalpy drop from the initial to final stage.

$$RF = \frac{\text{Cumulative Isentropic enthalpy drop}}{\text{Total Isentropic enthalpy drop}}$$

$$\boxed{RF = \frac{\Delta h_{1s} + \Delta h_{2s}}{\Delta h_{ts}}} \qquad \boxed{RF \geq 1} \qquad RF \text{ is } 1.03 \text{ to } 1.05$$

Stage efficiency :-

$$\eta_s = \frac{\text{Actual enthalpy drop}}{\text{Isentropic enthalpy drop}}$$

$$\eta_{s1} = \frac{\Delta h_{1a}}{\Delta h_{1s}}$$

$$\boxed{\Delta h_{1a} = \eta_{s1} \cdot \Delta h_{1s}} \quad \text{— (a)}$$

$$\eta_{s2} = \frac{\Delta h_{2a}}{\Delta h_{2s}}$$

$$\Delta h_{2a} = \eta_{s2} \cdot \Delta h_{2s} \quad \text{— (b)}$$

On adding ⓐ & ⓑ if

$$\eta_{s1} = \eta_{s2} = \eta_s$$

$$\Delta h_{1a} + \Delta h_{2a} = \eta_s(\Delta h_{1s} + \Delta h_{2s})$$

Dividing both sides by Δh_{ts}

$$\frac{\Delta h_{1a} + \Delta h_{2a}}{\Delta h_{ts}} = \eta_s \left(\frac{\Delta h_{1s} + \Delta h_{2s}}{\Delta h_{ts}} \right)$$

$$\boxed{\eta_0 = \eta_s \times RF}$$

$$\boxed{\eta_0 \geq \eta_s}$$

(1) Simple impulse or Rateau :-
(Delaval)

$$\boxed{V_1 \propto \sqrt{\Delta h}}$$

$$\rho = \frac{u}{V_1} = \frac{\cos\alpha}{2}$$

$$V_1 = \frac{2u}{\cos\alpha} = \sqrt{\Delta h_s}$$

$$\boxed{\Delta h_s = \frac{4u^2}{\cos^2\alpha}} \leftarrow \text{Simple impulse (Delaval) or Rateau}$$

2) Curtis (Velocity compounded) :-

$$\rho_{opt} = \frac{u}{V_1} = \frac{\cos\alpha}{2 \cdot n} \leftarrow \text{Row of M.B}$$

2 Row Curtis

$$\rho = \frac{u}{V_1} = \frac{\cos\alpha}{4}$$

$$V_1 = \frac{4u}{\cos\alpha} = \sqrt{\Delta h_s}$$

$$\boxed{\Delta h_s = \frac{16u^2}{\cos^2\alpha}} \leftarrow \text{Curtis}$$

3) Parson's (50% stage) :-

$$\rho = \frac{u}{V_1} = \cos\alpha$$

$$V_1 = \frac{u}{\cos\alpha} = \sqrt{\frac{\Delta h_s}{2}}$$

$$\boxed{\Delta h_s = \frac{2u^2}{\cos^2\alpha}} \leftarrow \text{50\% Reaction stage (Parson's)}$$

NOTE :- A two row curtis stage is equivalent to 4 simple impulse stages and 8 reaction stages.

$$\boxed{(\Delta h_s)_{Parson} : (\Delta h_s)_{\substack{Delaval \\ or \\ Rateau}} : (\Delta h_s)_{Curtis} = 1 : 2 : 8}$$

(1) Deleval or Rateau $V_1 = \frac{u}{\cos\alpha}$

(2) Curtis $V_1 = \frac{4u}{\cos\alpha}$

(3) Parson's $V_1 = \frac{u}{\cos\alpha}$

$\boxed{\text{Losses} \propto V_1^2}$

$\therefore$ $\boxed{\eta_{50\%\ \text{Stage}} > \eta_{\text{Deleval or Rateau}} > \eta_{\text{2-Row Curtis}}}$

Curtis :-

2- Row $\boxed{WD_1 : WD_2 = 3 : 1}$

3- Row $\boxed{WD_1 : WD_2 : WD_3 = 5 : 3 : 1}$

4- Row $\boxed{WD_1 : WD_2 : WD_3 : WD_4 = 7 : 5 : 3 : 1}$

Total WD = 6400 kW

for 3rd of 4-row -

$\frac{6400 \times 3}{16}$ = Contribution

Rateau :-

If n stages of Rateau are used in place of Deleval turbine.

$$\boxed{V_{Rateau} = \frac{V_{Deleval}}{\sqrt{n}}}$$

PB: Cooling water enters at 32°c and leave at 38°c in a surface condenser and it recieves steam at 40°c at 250 Ton/hr. Heat rejected in the condenser is at the rate of 2100 KJ/kg of steam. $U_0 = 2600\ W/m^2K$ and $V_w = 2\ m/s$ condenser tubes are of 25 mm of outer diameter and 1.25 mm thickness. Determine—

1) Rate of cooling water required
2) No. of tubes required
3) length of tube required.

$T_{c_1} = 305\ K \quad T_{c_2} = 38°C$

$\dot{m}_s(h_g - h_c) = \dot{m}_c C_{pw}(T_{c_2} - T_{c_1})$

$\frac{250 \times 10^3}{3600}(2100) = \dot{m}_c \times 4.18(38-32)$

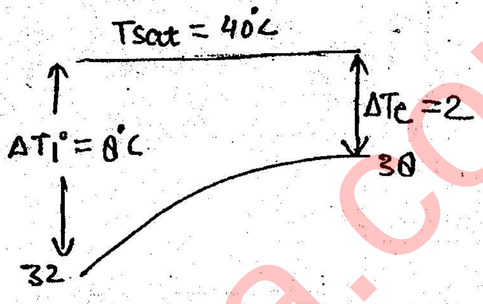
$\boxed{\dot{m}_c = 5814.7\ kg/s}$

2) $\dot{m}_c = n\left(\frac{\pi}{4}d_i^2\right)\rho_w V_w$

$5814.7 = n\left(\frac{\pi}{4} \times \left(\frac{25-2.5}{1000}\right)^2\right) \times 1000 \times 2$

$\boxed{n = 7312}$

(3)



$\Delta T_m = \frac{\Delta T_i - \Delta T_e}{\ln\left(\frac{\Delta T_i}{\Delta T_e}\right)}$

$\Delta T_m = 4.33°C$

$Q = \dot{m}_s(h_s - h_c) = U_0 A_0 \Delta T_m$

$\dot{m}_s(h_s - h_c) = U_0 \times n \pi d_0 l \cdot \Delta T_m$

$\boxed{l = 22.5\ m}$