Q#9

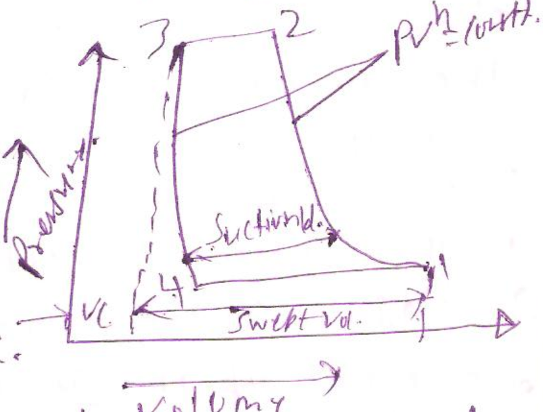
Ans! The volumetric efficiency of a single stage reciprocating compressor is defined as the volume of gas entering the compressor or per min. divide by the piston displacement of the compressor per minute. Therefor a single stage compressor.

$$\text{Volumetric efficiency} = \frac{\text{Vol. of gas entring compressor per minute}}{\text{Piston displacement per minute.}}$$

The volumetric eff. of multistage compressor or is defined in the same way except that the piston displacement taken that of the low pre. cylinder only. therefor for a single stage compressor.

$$\text{Volumetric compressor} = \frac{\text{Vol. of gas entering compressor per minute}}{\text{Piston disp. of the low pre. cylinder per minute}}$$

As by the fig.




$$\text{volumetric } \eta = \frac{V_1 - V_4}{V_1 - V_3}$$

from the Process 3-4

$$\left(\frac{P_3}{P_4}\right)^{1/n} = \frac{V_4}{V_3} = \left(\frac{P_2}{P_1}\right)^{1/n} \text{ or } V_4 = V_3 \times \left(\frac{P_2}{P_1}\right)^{1/n}$$

Since $P_3 = P_2$ & $P_4 = P_1$

$$\text{let the clearance ratio} = \frac{\text{clearance vol.}}{\text{Swept vol.}} = \frac{V_3}{V_1 - V_3} = K.$$

$$\text{then volumetric efficiency} = \frac{V_1 - V_4}{V_1 - V_3} = \frac{V_1 - V_3\left(\frac{P_2}{P_1}\right)^{1/n}}{V_1 - V_3} = \frac{V_1 - V_3\left(\frac{P_2}{P_1}\right)^{1/n}}{V_3/K}.$$

$$= \frac{KV_1}{V_3} - K\cdot\left(\frac{P_2}{P_1}\right)^{1/n}$$

$$\text{Since } K = \frac{V_3}{V_1 - V_3} \quad \text{So} \quad V_1 = \frac{V_3}{K} + V_3 = V_3\left(\frac{1}{K} + 1\right)$$

$$\therefore \text{ Volumetric efficiency} = K\,\frac{V_3\left(1/K + 1\right)}{V_3} - K\left(\frac{P_2}{P_1}\right)^{1/n}$$

$$= 1 + K - K\left(\frac{P_2}{P_1}\right)^{1/n} = 1 + K - K\left(\frac{V_1}{V_2}\right)$$

hence if $P_2 = P_1$ the volumetric eff. will be 100% whereas if $V_1 = V_4$ the volumetric $\eta$ will be zero.

$$= 1 + K - K\left(\frac{P_2}{P_1}\right)^{1/n} \times \frac{P_i T_a}{P_a T_i}$$

$$= 1 + K - K\left(\frac{V_1}{V_2}\right) \times \frac{P_i T_a}{P_a T_i}$$

Where suffix 'i' & 'a' stand for inside & atm. conditions.

Q#10

Ans! As we know mass of steam (Kg) discharged through the nozzle per second.

$$m = \frac{A}{V_1} \times \sqrt{\left[2\left(\frac{n}{n-1}\right)P_1 V_1 \left\{\left(\frac{P_2}{P_1}\right)^{2/n} - \left(\frac{P_2}{P}\right)^{\frac{n+1}{n}}\right\}\right]}$$

where $n = 1.135$ for dry saturated steam (B)

$P_1$ = Pre. of steam at entry in $N/m^2$ absolute.

$V_1$ = Vol. of one kg. of steam at pre. $P_1$ in $m^3$

$P_2$ = Pre. of steam $N/m^2$ abs.

$A$ = Area of crossection ($m^2$) of nozzle at the throat.

$V_2$ = Vol. of one kg. of steam at absolute pre. $P_2$.

Now there is only one value of the ratio $\left(\frac{P_2}{P_1}\right)$ to which the discharge of steam through the nozzle is maxm. The value $\left(\frac{P_2}{P_1}\right)$ is called critical pre. ratio. Therefor we differentiate only that portion which is inside the square backets & equate it is zero.

i.e $\frac{2}{n}\left(\frac{P_2}{P_1}\right)^{2/n-1} - \frac{n+1}{n}\left(\frac{P_2}{P_1}\right)^{\frac{n+1}{n}-1} = 0$ or $\frac{2}{n}\left(\frac{P_2}{P_1}\right)^{\frac{2-n}{n}} = \frac{n+1}{n}\left(\frac{P_2}{P_1}\right)^{1/n}$

$$= \left(\frac{P_2}{P_1}\right)^{\frac{2-n}{n}-\frac{1}{n}} = \frac{n+1}{n} \times \frac{n}{2} = \frac{n+1}{2}$$

$$\Rightarrow \left(\frac{P_2}{P_1}\right)^{\frac{1-n}{n}} = \frac{n+1}{2} = \left(\frac{2}{n+1}\right)^{-1} \text{ or } \frac{P_2}{P_1} = \left(\frac{2}{n+1}\right)^{\frac{-n}{1-n}}$$

$$\Rightarrow \left(\frac{P_2}{P_1}\right) = \left(\frac{2}{n+1}\right)^{\frac{n}{n-1}} \Rightarrow \frac{P_2}{P_1} = \left(\frac{2}{n+1}\right)^{\frac{n}{n-1}}$$

on for dry saturated is 1.135 & critical pre. ratio is 0.518.

Ans 12

It may be defined as the ratio of isentropic head drop in the moving blades to isentropic head drop in the reaction turbine.

Thus degree of Reaction (R) = $\frac{\text{Enthalply drop in moving blades}}{\text{Enthalpy drop in stage}} = \frac{h_2-h_3}{h_1-h_3}$

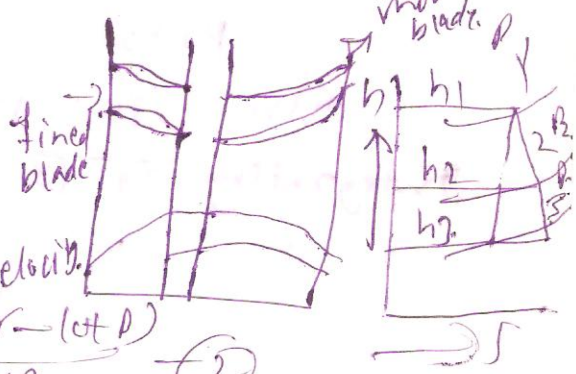
$= \frac{\text{Increase in the relative K.E in moving blade}}{\text{Stage work output}}$

$$\frac{V_{r0}^2 - V_{r1}^2}{V_b(V_{w1}-V_{w0})} = \frac{V_{r0}^2 - V_{r1}^2}{2V_b(V_{w1}-V_{w0})} \quad \text{--- (1)}$$

$V_{r0} = V_f \operatorname{cosec} r$ & $V_{r1} = V_f \operatorname{cosec} \beta$.

$V_{w1} + V_{w0} = V_f(\cot\beta + \cot r)$

$V_f$ = vel. of flow which remains constt. through the stage




$$\therefore R = \frac{V_f^2 \operatorname{cosec}^2 r - V_f^2 \operatorname{cosec}^2\beta}{2V_f(\cot\beta + \cot r)V_b} = \frac{V_f(\cot r - \cot\beta)}{2V_B} \quad \text{--- (2)}$$

for 50% degree of reaction $V_b = V_f(\cot r - \cot\beta)$ --- (3)

from the vel. triangle $V_b$ can also be expressed as under

$V_b = V_f(\cot r - \cot\theta) = V_f(\cot\alpha - \cot\beta)$ --- (4)