

# Fluid Machinery & Steam Generator

## Francis turbine

- Area of flow  $A_{f1} = K \pi d_1 b_1$
- Discharge through the runner  $Q = A_{f1} V_{f1}$
- Hydraulic power  $[HP = \rho g Q H]_{\text{wh}}$
- Runner power when  $v_{w1}$  is in direction of  $u_1$   
 $R.P = \frac{\rho g Q}{\rho} [v_{w1} u_1 - v_{w2} u_2]$
- Runner power when  $v_{w1}$  is in opposite direction of  $u_2$   
 $R.P = \frac{\rho g Q}{\rho} [v_{w1} u_1 + v_{w2} u_2]$
- Hydraulic efficiency  $\eta_h = \frac{R.P}{HP} = \frac{v_{w1} u_1}{gH}$  L-R-L-R
- Mechanical efficiency  $\eta_{mech} = \frac{S.P}{R.P}$  M-S-P
- Overall efficiency  $\eta_o = \eta_h \times \eta_{mech}$  O-S-L-R
- Volumetric efficiency  $\eta_{vol} = \frac{Q}{Q + \Delta Q}$   
 where  $\Delta Q$  = leakage loss  
 $Q$  = discharge entering the turbine
- Degree of reaction (R) :  $R = 1 - \frac{v_2^2 - v_1^2}{2 v_{w1} u_1}$
- Efficiency of draft tube  $\eta_d = \frac{\frac{v_1^2 - v_2^2}{2g}}{\frac{v_1^2 - v_2^2}{2g} + h_f}$
- Pelton wheel**
- Power available at inlet of vanes =  $\frac{\rho Q v^2}{2}$
- Runner power  $R.P = \frac{\rho g Q}{\rho} [v_{w1} - v_{w2}] u$
- $(\eta_h)_{max} = \frac{1 - k \cos \alpha}{2}$
- Blade efficiency  $\eta_{b, max} = \frac{v_1^2 - v_2^2}{v_1^2}$
- Specific speed of Turbine  $N_s = \frac{N \sqrt{P}}{H^{5/4}}$

## Model relationships for turbine / Cp

Capacity or flow  $Q$  constant, speed  $N$  constant

$$\left[ \frac{Q}{ND^3} \right]_1 = \left[ \frac{Q}{ND^3} \right]_2 \quad \left[ \frac{gH}{N^2 D^5} \right]_1 = \left[ \frac{gH}{N^2 D^5} \right]_2$$

Power  $P$  constant

$$\left[ \frac{P}{N^3 D^5} \right]_1 = \left[ \frac{P}{N^3 D^5} \right]_2$$

## Brayton cycle or Joule cycle:- [G.M.P.P]

$$\eta = 1 - \frac{1}{(r_p)^{\gamma}}$$

$$T_2 = T_4 = \sqrt{T_{max} \cdot T_{min}}$$

$$(r_p)_{optimum} = \left( \frac{T_{max}}{T_{min}} \right)^{\frac{1}{\gamma-1}}$$

$$(r_p)_{optimum} = \sqrt{(r_p)_{max}}$$

$$(r_p)_{max} = \left( \frac{T_{max}}{T_{min}} \right)^{\frac{1}{\gamma-1}}$$

$$\text{Back work Ratio} = \frac{W_c}{W_T}$$

$$\text{Work Ratio} = \frac{W_{net}}{W_T} = \frac{W_T - W_c}{W_T} = 1 - \frac{W_c}{W_T}$$

## Rankine vapour power cycle (or) steam power cycle

$$\text{Specific steam consumption } SSC = \frac{3600}{W_{net}} \frac{\text{kg}}{\text{kwhr}}$$

$$\eta_{Rankine} = 1 - \frac{Q_{out}}{Q_{in}} = 1 - \frac{T_c}{T_h} = \frac{W_{net}}{Q_c} = \frac{Q_2 - Q_1}{Q_1} = 1 - \frac{Q_2}{Q_1}$$

## For regeneration in Rankine cycle

$$W_1 = (1-x)(h_1 - h_2) + (1-y)(h_1 - h_2)$$

$$W_2 = (1-x)(h_1 - h_2) + (1-y)(h_1 - h_2)$$

$$W_{net} = W_1 - W_2$$

$$Q_2 = (1-x)(h_2 - h_3)$$

## Applying conservation of energy

# Mechanical Engineering Formula

**Charles MacCaughey Sames**



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