QP Code: 25734 (TFPE Sem VI) (1)

Solution.

Ans 2) a) Given:- $p = 20 bar$, $t_{sup} = 260°C$,
$m_s = 37500 kg/h$, $t_1 = 15°C$, $t_2 = 90°C$,
$m_f = 4400 kg/h$, $C = 33000 kJ/kg$.

1. Equivalent evaporation per kg of fuel.

$$m_e = \frac{m_s}{m_f} = \frac{37500}{4400} = 8.52 \text{ kg/kg of fuel}$$

From steam tables, corresponding to feed water temperature of 15°C.

$h_{f1} = 62.9$ kJ/kg.

Corresponding to 20 bar steam pressure,

$h_g = 2797.2$ kJ/kg, $t = 212.4°C$

Enthalpy or Total heat of 1kg supersaturated steam

$$h_{sup} = h_g + c_p(t_{sup} - t)$$
$$= 2797.2 + 2.1(260 - 212.4)$$

$\boxed{h_{sup} = 2897 \text{ kJ/kg}}$ Take $c_p = 2.1$ kJ/kgK

Equivalent evaporation

$$E = \frac{m_e(h_{sup} - h_{f1})}{2257} = \frac{8.52(2897 - 62.9)}{2257}$$

$E = 10.7$ kg/kg of fuel

Thermal efficiency of plant

$$\eta = \frac{m_e(h_{sup} - h_{f1})}{C} = \frac{8.52(2897 - 62.9)}{33000}$$

$$\eta = 0.7317 = 73.17\%$$

% of Heat energy of fuel energy utilised by economiser.

From steam tables, corresponding to temp of 90°C. $h_{f2} = 376.9$ kJ/kg.

Heat utilised by economiser per kg of fuel.

$= m_e(h_{f2} - h_{f1})$

$= 8.52(376.9 - 62.9)$

$= 2675$ kJ

% of Heat utilised by economiser

$$= \frac{2675}{33000} = 0.081$$

$= 8.1\%$

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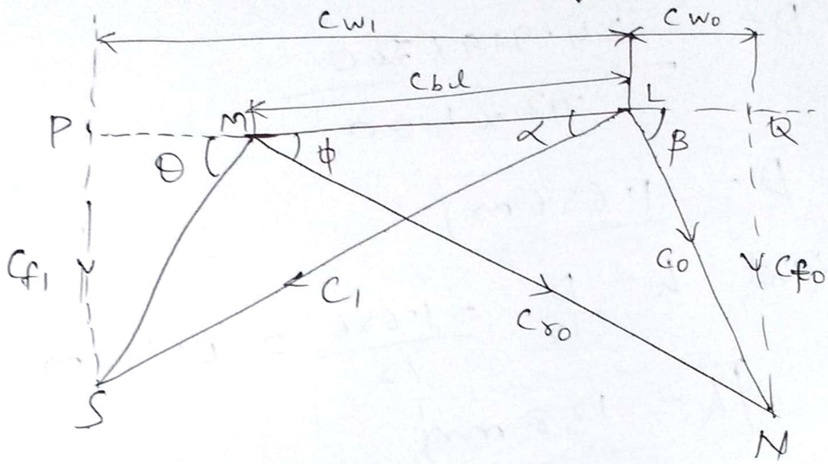
Ans 3) a)

$N = 400 rpm, \alpha = 20°$

$C_{ro} = C_1 = 1.35\ C_{bl}$

$\dot{m}_s = 8.33\ kg/s$

$v = 1.381\ m^3/kg$; $D = 12h$



Axial flow velocity.

$C_{f1} = C_{fo} = C_f = C_1 \sin\alpha$

$= 1.35\ C_{bl} \sin 20°$

$= 0.4617\ C_{bl}$

Area of flow, $A = \pi Dh$

$$A = \pi D \times \frac{D}{12} = \frac{\pi D^2}{12}$$

Mass flow rate, $\dot{m} = \frac{A C_f}{v}$

$8.33 = (A \times 0.4617\ C_{bl}) / 1.381$

(4)

$$\frac{8.33 \times 1.381}{0.4917} = A \times C_{bl} = \frac{\pi D^2}{12} \times \frac{\pi D N}{60}$$

$$24.916 = \frac{\pi^2 D^3 \times 400}{720}$$

$$D^3 = \frac{24.919 \times 720}{\pi^2 \times 400}$$

$$\boxed{D = 1.656 m}$$

Blade height $h = \frac{D}{12} = \frac{1.656}{12} = 0.138 m$

$$\boxed{h = 138 mm}$$

Diagram work $= \dot{m} \times C_{bl} (C_{w_1} + C_{w_0})$.

$$= \dot{m} \times C_{bl} (2 C_1 \cos\alpha - C_{bl})$$

$$= 8.33 \times C_{bl} (2 \times 1.35 C_{bl} \cos 20^\circ - C_{bl})$$

$$= 8.33 \times C_{bl}^2 \cdot (2 \times 1.35 \cos 20^\circ - 1)$$

$$= 8.33 \times \left(\frac{\pi D N}{60}\right)^2 \times 1.537$$

$$= 15401.2 W$$

Diagram work $= \underline{15.4 KW}$.

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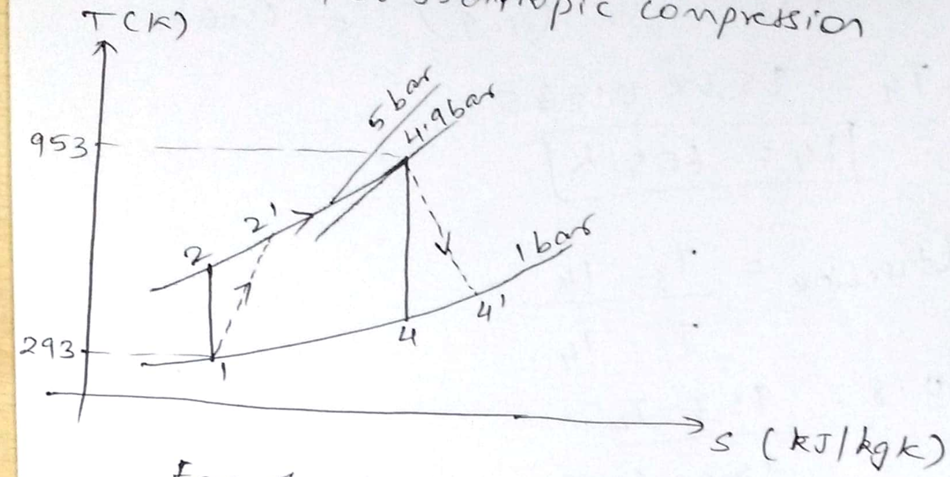
Ans 6) a) Quantity of air circulation :-
For Isentropic compression



For Isentropic compression 1-2,

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\gamma-1/\gamma}$$

$$\frac{T_2}{T_1} = \left(\frac{5}{1}\right)^{\frac{1.4-1}{1.4}} = 1.584.$$

$$T_2 = 293 \times 1.584 = 464\ k.$$

$$\boxed{T_2 = 464\ k}$$

$$\eta_{Compressor} = \frac{T_2 - T_1}{T_2' - T_1} \Rightarrow$$

$$0.85 = \frac{464 - 293}{T_2' - 293}$$

$$T_2' = \frac{464 - 293}{0.85} + 293 \quad \therefore \boxed{T_2' = 494\ k}$$

For isentropic expansion process 3-4,

$$\frac{T_4}{T_3} = \left(\frac{P_4}{P_3}\right)^{\frac{\gamma-1}{\gamma}} = \left(\frac{1}{4.9}\right)^{\frac{1.4-1}{1.4}} = 0.635$$

$$T_4 = 953 \times 0.635$$

$$\boxed{T_4 = 605\ k}$$

$$\eta_{turbine} = \frac{T_3 - T_4'}{T_3 - T_4}$$

$$0.8 = \frac{953 - T_4'}{953 - 605}$$

$$T_4' = 953 - 0.8(953 - 605)$$

$$T_4' = 674.6\ k$$

$$W_{compressor} = c_p(T_2' - T_1)$$

$$= 1.024(494 - 293)$$

$$= \underline{205.8\ kJ/kg}$$

$$W_{turbine} = c_p(T_3 - T_4')$$

$$= 1.024(953 - 674.6)$$

$$= 285.1\ kJ/kg$$

$$W_{net} = W_{turbine} - W_{compressor}$$

$$= 285.1 - 205.8$$

$$\boxed{W_{net} = 79.3\ kJ/kg \text{ of air}}$$

6)a) (Continue)

If mass of air flowing is ma kg/sec

$$P = m_a \times W_{net} \text{ kW}$$

$$1065 = m_a \times 79.3$$

$$\boxed{m_a = 13.43 \text{ kg}}$$

Quantity of air circulation = 13.43 kg

Heat supplied per kg of air circulation:-

Actual heat supplied per kg of air circulation:-

$$= \frac{c_p (T_3 - T_2')}{\eta_{combustion}} = \frac{1.024(953-494)}{0.85}$$

$$= 552.9 \text{ kJ/kg}$$

Thermal efficiency of cycle $\eta_{thermal}$:

$$\eta_{thermal} = \frac{\text{Work output}}{\text{Heat supplied}}$$

$$= \frac{79.3}{552.9}$$

$$= 0.1434$$

$$\boxed{\eta_{thermal} = 14.34\%}$$