Unacademy

Mechanical Engineering

Toppers Handwritten Notes

Power Plant Engineering

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Power Plant Engineering-1

Classroom Notes

[Handwritten]

For GATE | ESE | PSU's

Mechanical Engineering

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Vapour power cycles

SPP
Max·temp - 620°c
weight/power = 55kg/kW
η_{th} = 35-42%.
pressure ratio = 180 to 300

Reason's for using water as working fluid -
→ It is cheap.
→ It is chemically stable.
→ It is non toxic.

Selection of a power plant -

✓ Efforts to improve efficiency and thereby reducing the running cost or operating cost may be desirable ~~and~~ but this would lead to increase initial or capital ~~powe~~ cost. and hence efforts must be taken to optimise the total cost.

Specific steam Consumption (SSC):

$$SSC = \frac{\dot{m}_s}{P_{net}} = \frac{\dot{m}_s}{\dot{m}_s \times W_{net}}$$

$$SSC = \frac{1}{W_{net}} \frac{kg}{kJ} \quad \Big| \quad W_{net} \rightarrow kJ/kg$$

$$SSC = \frac{1}{W_{net}} \frac{kg}{\frac{kJ}{sec} \times sec} \Rightarrow \frac{1}{W_{net}} \frac{kg}{kW\text{-}sec}$$

1 hr = 3600 sec

1 sec = $\frac{1}{3600}$ hr

$$\boxed{SSC = \frac{3600}{W_{net}} \frac{kg}{kW\text{-}hr}} \quad \left\{ W_{net} \text{ is in } \frac{kJ}{kg} \right\}$$

Significance of SSC :-

SSC indicates size of the plant smaller the ssc larger is the net work and hence for developing given power mass flow rate of steam must be less that is smaller the ssc, ~~s~~ lessar is the size of the plant and hence such plants are preferable.

Work Ratio :-

It is the ratio of Net work to the +ve work.

$$\boxed{r_w = \frac{W_{net}}{+ve\ work}}$$

$$\Rightarrow \frac{W_{+ve} - W_{-ve}}{W_{+ve}}$$

$$\boxed{r_W = 1 - \frac{W_{-ve}}{W_{+ve}}}$$

$$\boxed{r_W = 1 - \frac{W_P}{W_T}}$$

$W = -vdP$

pump - liquid

compressor - gas

$v_g >> v_l$

$W_p = -v_l dP$

$W_c = -v_g dP$

$W_c >> W_p$

pump work is less

→ power plants with high work ratio's are preferable.

→ Work ratio is highest for rankine cycle, among all other cycles this is because in rankine cycle pump work is used. which consumes less work.

→ In case of gas turbine power plant the work ratio is about 0.4 to 0.6 i.e. in gas turbine power plant compressor about 40 - 60% of turbine work.

→ In rankine cycle the work ratio are about 0.96 - 0.98 (close to unity) i.e. in rankine cycle pump consumes 2-4% of turbine work.

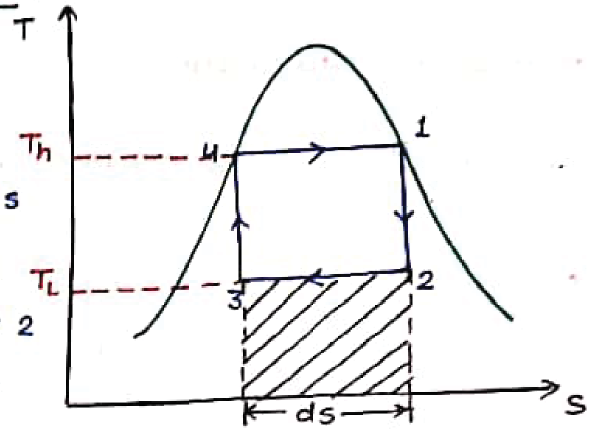
Back work Ratio (r_{bw}): It is the ratio of -ve work to the +ve work.

$$r_{bw} = \frac{W_{-ve}}{W_{+ve}}$$

$$r_W = \frac{W_{Net}}{W_{+ve}} = \frac{W_{+ve} - W_{-ve}}{W_{+ve}} \Rightarrow 1 - \frac{W_{-ve}}{W_{+ve}} = 1 - r_{bw}$$

$$\boxed{r_W = 1 - r_{bw}}$$

Carnot vapour power cycle:



Drawbacks:

(1) Saturated vapour which is entering the turbine at 1 leaves at 2 which is in wet region. The liquid which is present at state 2 may damage turbine blades due to high velocity.

(2) It is difficult to design a condenser which suddenly stops at point 3.

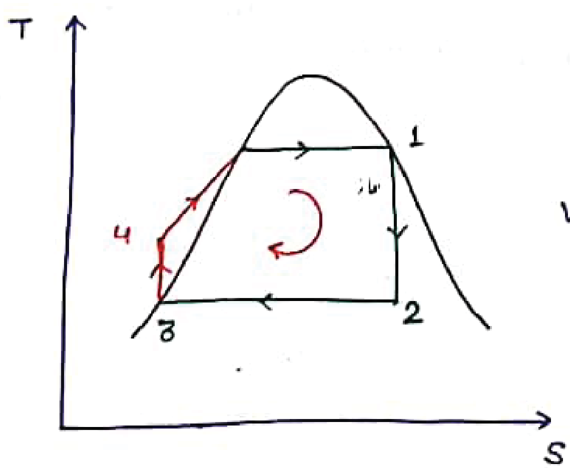
(3) It is difficult to design a compressor which handles both liquid and vapour.

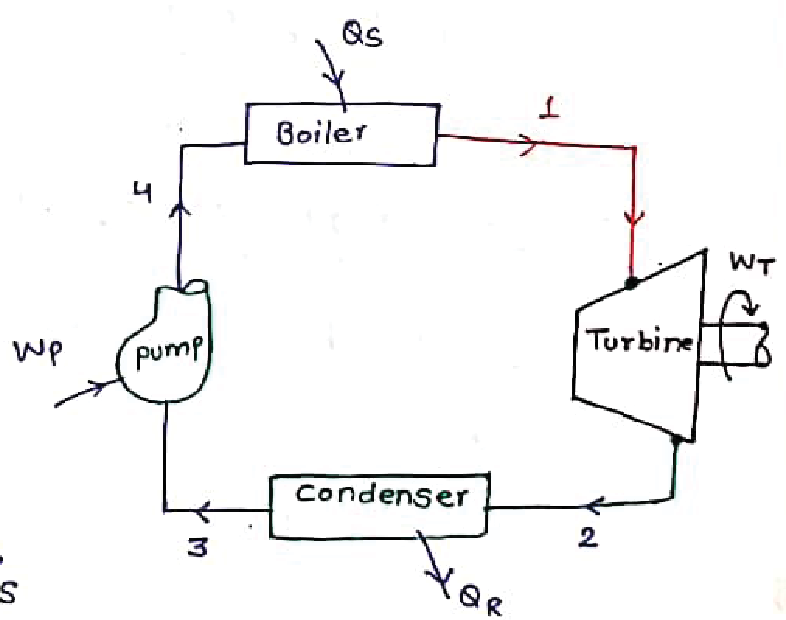
(4) As carnot vapour power cycle usages compressor, the compressor work is large and hence Net work is less. [$W_{net} = W_T - W_c$]

$$\eta = 1 - \frac{Q_R}{Q_S} \Rightarrow 1 - \frac{T_L\, ds}{T_H \cdot ds}$$

$$\boxed{\eta = 1 - \frac{T_L}{T_h}}$$

Rankine Cycle:-





$$\eta = \frac{W_{net}}{Q_S}$$

$$\boxed{\eta = \frac{W_T - W_P}{Q_S}}$$

1-2 → Reversible adiabatic Expansion (Turbine)

2-3 → constant pressure heat Rejection (condenser)

3-4 → Rev. adiabatic compression (pump)

4-1 → constant pressure heat addition (boiler)

Analysis of the cycle :-

Assumptions:

(1) Each device is ~~fitted~~ treated as steady flow device.

(2) K.E & P.E. changes are Neglected.

Turbine (1-2) [Reversible adiabatic]

$$h_1 + \frac{C_1^2}{2} + z_1 g + q = h_2 + \frac{C_2^2}{2} + z_2 g + W$$

$$h_1 = h_2 + W$$

$$\boxed{W_{Turbine} = h_1 - h_2}$$

Condenser (2-3) (No work)

$$h_2 + \frac{C_2^2}{2} + z_2 g + q = h_3 + \frac{C_3^2}{2} + z_3 g + W$$

$$\Rightarrow h_2 + q = h_3 \quad \text{(heat rejected)}$$

$$-q = h_2 - h_3.$$

$$\Rightarrow \boxed{q_{rejection} = h_2 - h_3}$$

{ $h_2 - h_3 = C_p(T_2 - T_3)$ Only for gas/air but here we used water So we can't write it for water. }

Pump (3-4):

$$h_3 + \frac{C_3^2}{2} + z_3 g + q = h_4 + \frac{C_4^2}{2} + z_4 g + \omega$$

$$\boxed{W = h_3 - h_4}$$

$$\Rightarrow -W = h_4 - h_3 \Rightarrow \boxed{W_{pump} = h_4 - h_3}$$

-ve represent work done on the System.

~~Boiler (4-1)~~

~~$h_4 + C_4$~~

Note:- We know that open system work $W = -vdp$ this equation is applicable when the flow is steady, KE & PE changes are Neglected and when the process is reversible.

SFEE can be applied for rev. as well as irreversible process if the pumping process is reversible then work obtained for SFEE and $W = -vdp$ can be equated.

$$h_3 - h_4 = -vdp$$

$$\boxed{h_4 - h_3 = vdp}$$

⇒ We know that $W_P = h_4 - h_3$, if the pump work is very small then it can be neglected therefore

$h_4 \simeq h_3$ when pump work is Negligible.

Boiler:- [4-1]

$$h_4 + \cancel{\frac{C_4^2}{2}} + \cancel{z_4 g} + q = h_1 + \cancel{\frac{C_1^2}{2}} + \cancel{z_1 g} + \cancel{W} \quad \text{[No work]}$$

$$h_4 + q = h_1$$

$$q = h_1 - h_4 \quad ; \quad \boxed{q_s = h_1 - h_4}$$

$$\eta = \frac{W_T - W_P}{Q_S}$$

$W_T = h_1 - h_2$

$q_R = h_2 - h_3$

$W_P = h_4 - h_3$

$q_s = h_1 - h_4$

$$\eta = \frac{(h_1 - h_2) - (h_4 - h_3)}{(h_1 - h_4)}$$

when pump work is Negligible

$$h_4 = h_3$$

$$\eta = \frac{h_1 - h_2}{h_1 - h_4} \Rightarrow \boxed{\eta = \frac{h_1 - h_2}{h_1 - h_3}}$$