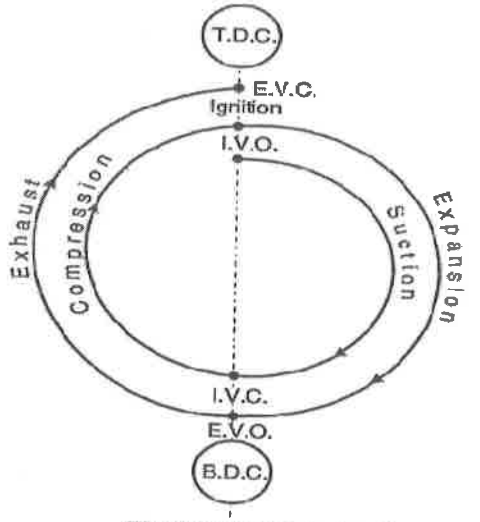
4. B.Tech -II Sem Regular exam June/July 2025

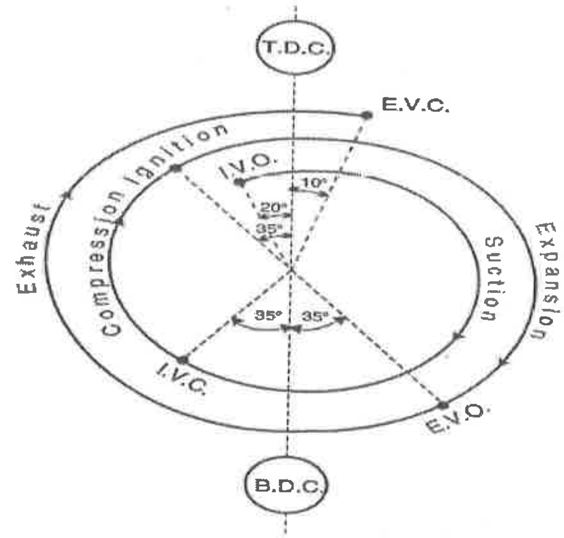
Thermal & Hydro Prime movers

1a) what is meant by valve timing diagram? mention the differences of actual four stroke single cylinder valve timing diag to the ideal valve timing diagram.

A) valve timing diagram is a graphical representation that shows the opening & closing position of inlet & exhaust valves of I.C engine w.r.to position of piston (crank angle) during four stroke.



. Theoretical valve timing diagram (four-stroke Otto cycle engine).



. Actual valve timing diagram (four-stroke Otto cycle engines).

→ In actual practise it is difficult to open & close the valve instant so to get better performance of engine valve timing diag are modified

→ The inlet valve opens 10-30° before TDC to enable fresh charge into the cylinder & helps to sent burnt gases at same time

→ The inlet valve closes 30-40 after BDC in order to allow additional time for air fuel mixture to flow into cylinder. It inc volumetric efficiency

→ spark plug produce spark 30-40 before TDC thus fuel get more time to burn

→ exhaust valve open 30-60 before BDC & close 10° after TDC in order to give more time to start leaving the cylinder.

1b) why boiler accessories are installed. explain the operation of economizer with the help of simple diagram.

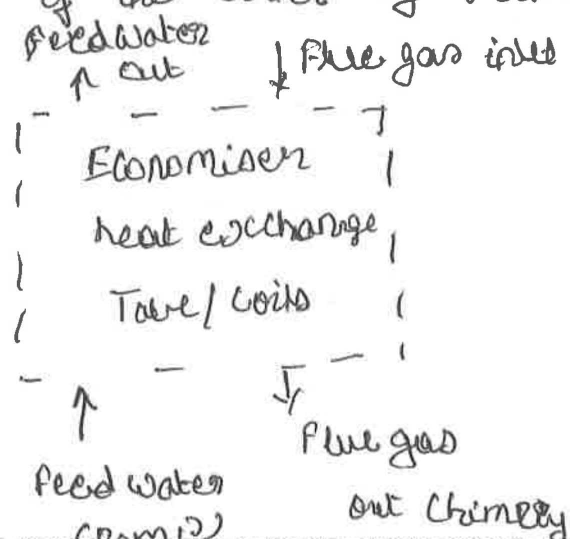
A) Boiler Accessories

These are auxillary parts required for steam boiler for their proper operation & for increase of their efficiency

Economiser.

Economiser is one of the boiler accessories which is used to increase the overall efficiency of the boiler.

The combustion gases coming out of the boiler contains a large quantity of heat. Therefore the maximum amount of heat from the gases should be recovery of heat in flue gases. The economiser is placed in the path of the gases. They improves the overall efficiency of the boiler by reducing fuel consumption



2a) A four cylinder 4 stroke S I engine develops a max brake torque of 160 Nm at 3000 rpm. calc the engine displacement, bore & stroke. The break mean effective pressure at the max engine torque point is 960 kpa Assume bore is equal to stroke.

sol $n=4$ $\quad K=\frac{1}{2}$ $\quad T_b=160\,Nm$ $\quad N=3000\,rpm$

$P_{mb}=960\,Kpa=960\times10^3\,N/m^2=9.6\,bar$ $\quad D=L$

$$\text{Power}=\frac{2\pi NT}{60\times1000}$$

$$=\frac{2\pi\times3000\times160}{60\times1000}=50.265 \rightarrow (1)$$

$$BP=\frac{P_{mb}LANK\times10}{6}$$

$$=\frac{9.6\times D\times\frac{\pi}{4}D^2\times3000\times\frac{1}{2}\times10}{6}$$

$$=18849.6\,D^3 \rightarrow (2)$$

$1=2$

$D=0.1387\,m$

$L=D=0.1387\,m$

$$\text{Displacement}=A\times L$$

$$=\frac{\pi}{4}D^2\times L$$

$$=\frac{\pi}{4}\times0.1387^2\times0.1387$$

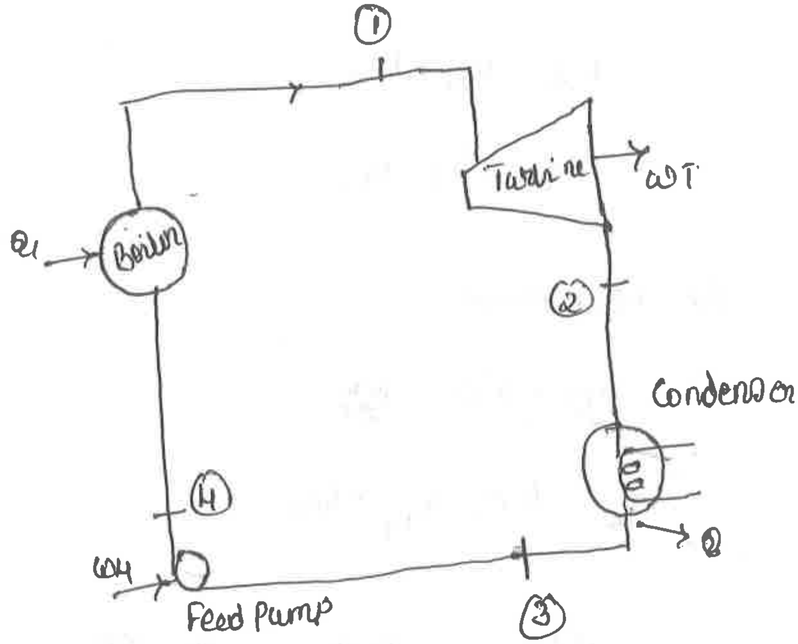
$$=0.002095\,m^3$$

2b. Compare & contrast fire tube boiler & water tube boilers

Fire tube boiler	Water tube boiler
1. Hot gases inside the tube & water out the tubes.	1. water inside the tubes & hot gases outside the tube.
2. Rate of steam generation is lower	2. Higher rate of steam generation
3. less chances of explosion due to low pressure	3. more chances of explosion due to high pressure
4 operating pressure is limited to 25 bar	4. operating pressure is limited to 125 bar
5. floor space requirement is less.	5. floor space requirement is more.
6. There is no water tubes. So there will be no problem of scale deposition. & less problem of overheating & bursting.	6. small deposition of scale will cause overheating & bursting of tube
7. Lancashire boiler, Cochran boiler	7. Babcock & Wilcox boiler
8. less skill workers are sufficient	8. more skilled worker & careful attention efficient & economic working.

3(a) Explain the working of simple Rankine cycle & derive the expression for its thermal efficiency.

A) Rankine cycle is the idealized cycle for steam power plant. In this cycle heat energy is converted into mechanical work while undoing the phase change.



Its consist of following Process.

Process 4-1: water is converted into steam at const pressure by the addition of heat in boiler

Process 1-2: Rev adiabatic expansion of steam in steam turbine

Process 2-3: const Pressure heat rejection in condenser to convert condensate into water

Process 3-4: water from condenser at low pressure is pumped into boiler at high pressure. This process is reversible adiabatic compression.

Applying steady flow Energy equation

(i) For boiler

$$h_{f_4} + Q_1 = h_1$$

$$Q_1 = h_1 - h_{f_4}$$

For turbine

$$h_1 = W_T + h_2$$

$$W_T = h_1 - h_2$$

For Condenser

$$h_2 = Q_2 + h_{f3}$$

$$Q_2 = h_2 - h_{f3}$$

For feed pump

$$h_{f3} + W_P = h_{f4}$$

$$W_P = h_{f4} - h_{f3}$$

$$\eta_{Rank} = \frac{W_{net}}{Q} = \frac{W_T - W_P}{Q_1}$$

$$= \frac{(h_1 - h_2) - (h_{f4} - h_3)}{h_1 - h_{f4}}$$

b) A Quantity of steam at 10 bar & 0.85 dryness occupies 0.15 m^3. The steam is heated at const pressure to raise its temp upto 300°C. Determine 1) The workdone 2) The change in internal energy 3) heat supplied

Sol Given

Initial steam state

Pressure = 10 bar $x = 0.85$ $V = 0.15 m^3$

Mass of Steam $= \frac{V_1}{x v_g} = \frac{0.15}{0.85 \times 0.194} = 0.909$

From steam tables heat,

$v_g = 0.194$ $T_{sat} = 179.9$ $h_f = 762.6$ $h_{fg} = 2013.6$

$h_g = 2776.2$,

Final state

Superheated steam at 10 bar, 300°C.

$h_2 = 3053$ KJ/kg $v_g = 0.2579$ m^3/kg

$V = m \times v_g = 0.909 \times 0.2579 = 0.2341 m^3$

heat supplied $Q = m \times (h_2 - h_1) = \underline{528.6}$.

work done $= P(V_2 - V_1)$

$= 10 \times 10^5 (0.2341 - 0.15) = 84{,}100 J = \underline{84.1 KJ}$

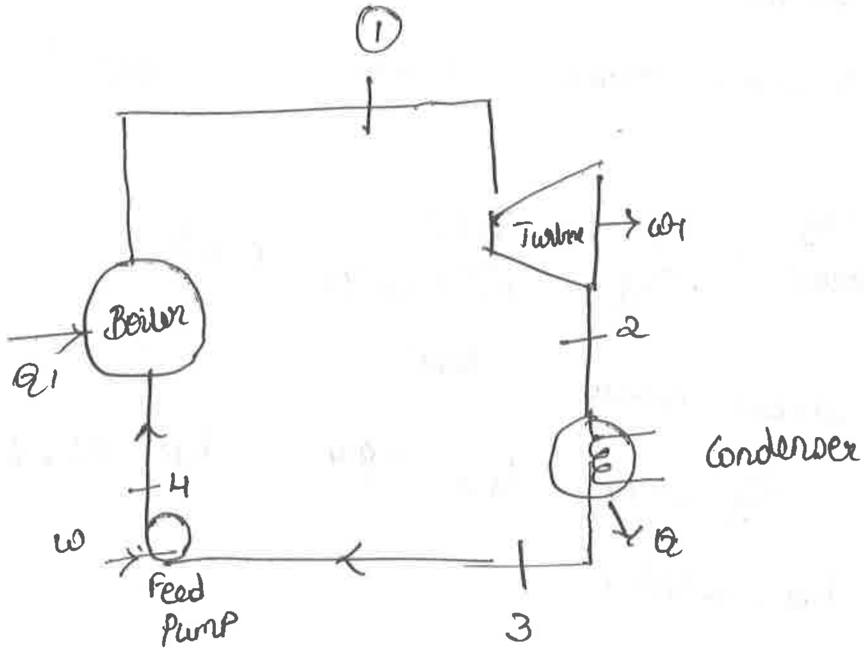
change in internal energy

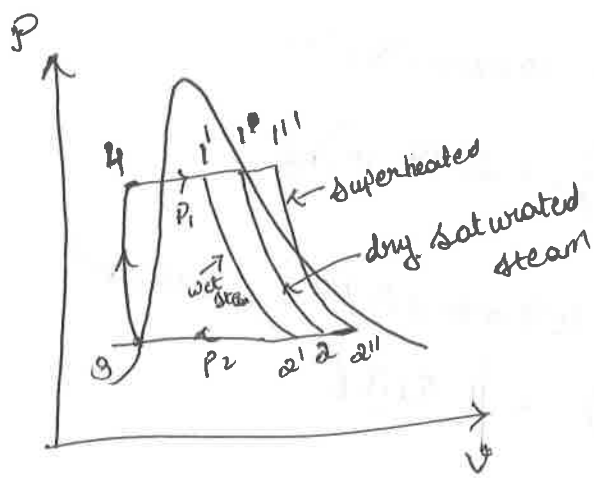
$Q = \Delta U + W$

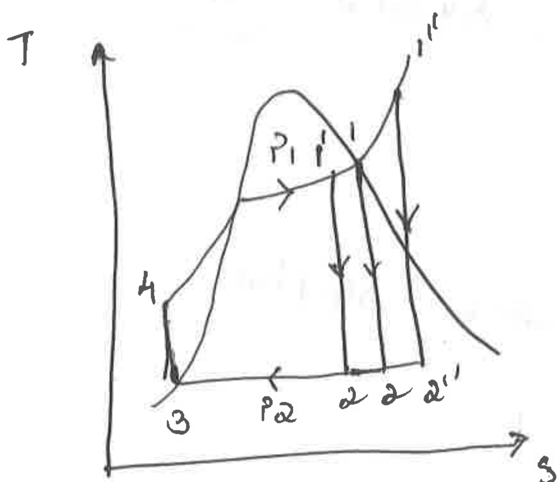
$\Delta U = Q - W = 528.6 - 84.1 KJ$

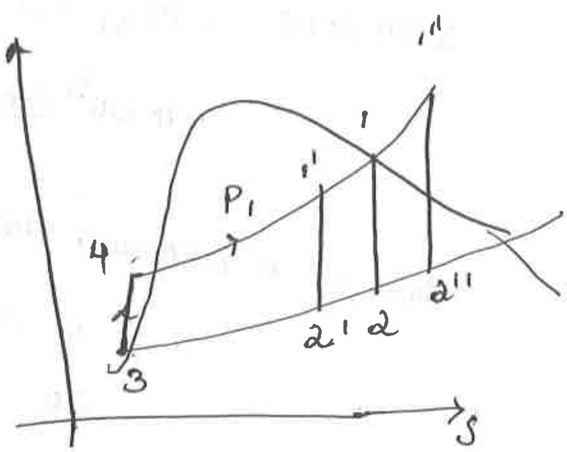
$\underline{\Delta U = 444.5 KJ.}$

4(a) Draw the schematic for an ideal Rankine cycle. Draw PV & h-S diagram for this cycle.









4(b) Discuss the thermodynamic variables that affects the efficiency & output of Rankine cycle.

A) The Rankine cycle efficiency can be improved by

(i) Increasing the average temperature at which heat is supplied

1) Increasing boiler pressure

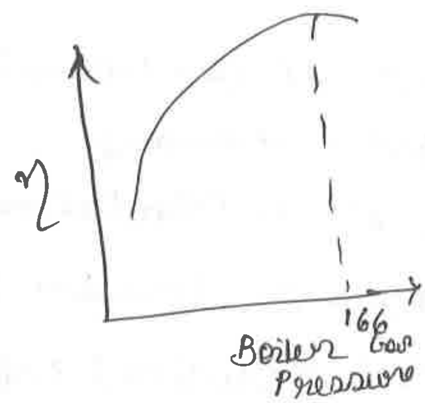
2) Superheating

2) Decreasing the temp at which heat is rejected from working fluid in condenser

i.e Reducing condenser pressure

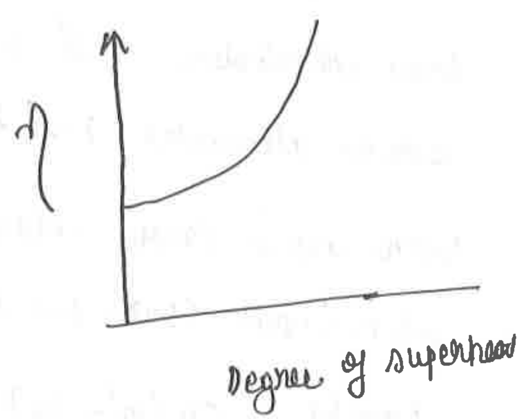
1. Increasing boiler pressure:

It has been observed that by increasing the boiler pressure the efficiency of the cycle tends to raise & reaches a max value at a boiler pressure at about 166 bar



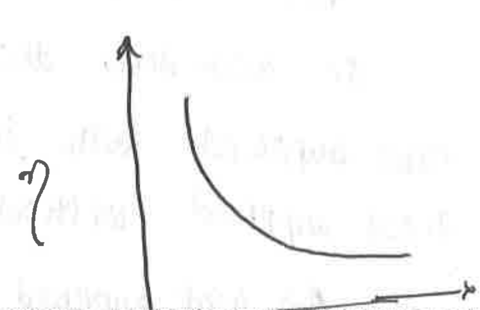
2. Superheating:

All other factor remaing the same If the steam is superheated before allowing it to expand. the Rankine cycle efficiency is increased. It ensure a longer blade life



3. Reducing Condenser pressure:

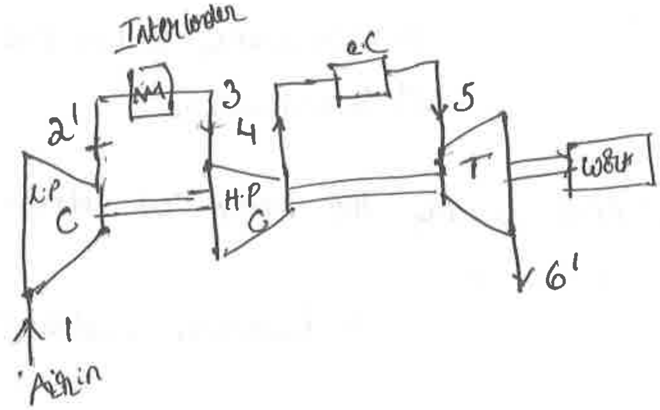
Thermal efficiency can be improved by reducing condenser pressure. But the inc in efficiency is obtained at increased cost



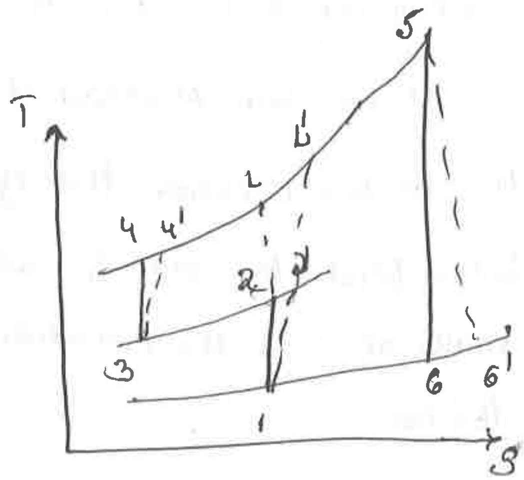
5a) Discuss the effect of intercooling on the thermal efficiency of a gas turbine.

A) Intercooling:

A compressor in gas turbine cycle utilises the major percentage of Power developed by the gas turbine. The work required by the compressor can be reduced by compressing air in two stages & incorporating an intercooler b/w the compressor



1-2' - LP (Low Pressure) Compression
2'-3 - Intercooling
3-4' - HP (High Pressure) Compression
4'-5 - C.C Combustion Chamber
5-6' - T (Turbine) expansion.



Ideal cycle 1-2-3-4-5-6

with intercooler: 1-2'-3-4'-5-6.

with out intercooler - 1-2'-L'-5-6.

Work input (with intercooling) $= c_p(T_{2'}-T_1)+c_p(T_{4'}-T_3)$

Work input (with out intercooling) $= c_p(T_{L'}-T_1) = c_p(T_{2'}-T_1)+c_p(T_{L'}-T_{2'})$

From fig $c_p(T_{4'}-T_3) < c_p(T_{L'}-T_{2'})$

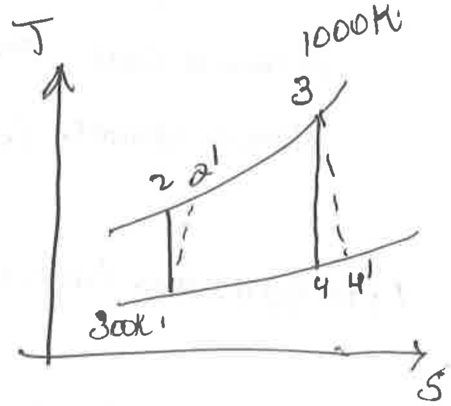
so work done decreases

Heat supplied with intercooler - $c_p(T_5-T_{4'})$

Heat supplied without intercooling $= c_p(T_5-T_{L'})$

As heat supplied inc. → Thermal efficiency decreases

5b) A gas turbine consists of single stage compressor & turbine. If the plant works b/w the temp limits of 300K & 1000K 1bar & 16 bar. Find the net power of the plant per kg of air $C_p = 1 KJ/Kg$



Sol Given $T_1 = 300K$ $T_3 = 1000K$

$P_1 = 1 bar$ $P_2 = 16 bar$

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

$$\frac{T_2}{T_1} = \left(\frac{16}{1}\right)^{\frac{1.4-1}{1.4}} = 2.208$$

$$T_2 = 662.45K$$

$$\frac{T_3}{T_4} = \left(\frac{16}{1}\right)^{\frac{\gamma-1}{\gamma}}$$

$$\frac{1000}{T_4} = (16)^{\frac{1.4-1}{1.4}}$$

$$T_4 = \frac{1000}{(16)^{0.4/1.4}} = 452.86$$

work done of turbine

$$W_T = m c_p (T_3 - T_4)$$

$$= 1 \times 1 \times (1000 - 452.86)$$

$$= 547.14 \text{ KJ}$$

work done by compressor $= m c_p (T_2 - T_1)$

$$= 1 \times 1 \times (662.45 - 300)$$

$$= 362.45$$

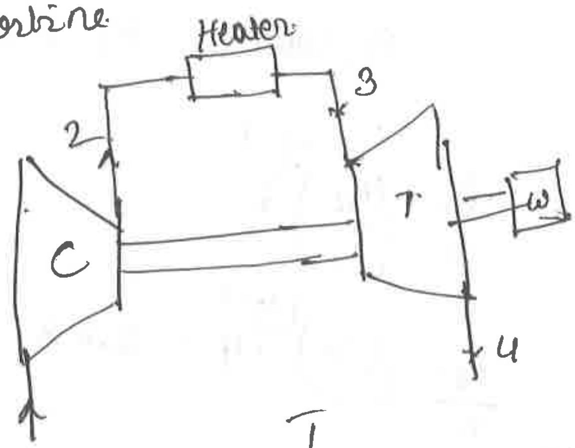
Net work done $= W_T - W_C = 547.14 - 362.45 = 184.69 \text{ KJ}$

6a) How gas turbines are classified ? Explain with suitable sketches

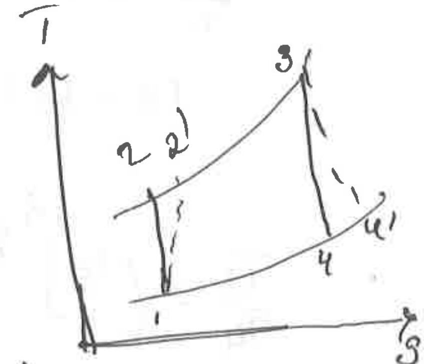
A) Gas turbine may be classified into

1) open cycle constant pressure gas turbine
2) closed cycle constant pressure gas turbine
3) const volume combustion gas turbine

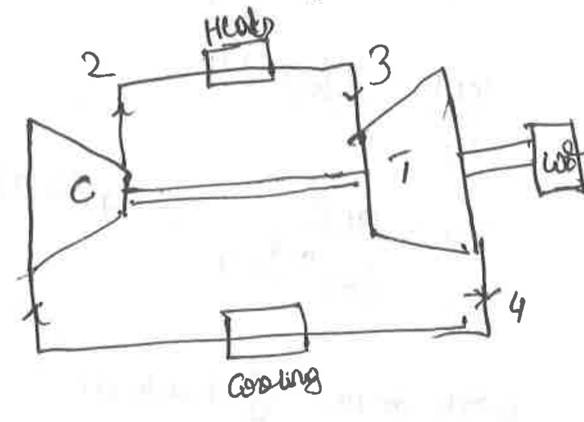
Open cycle gas turbine :



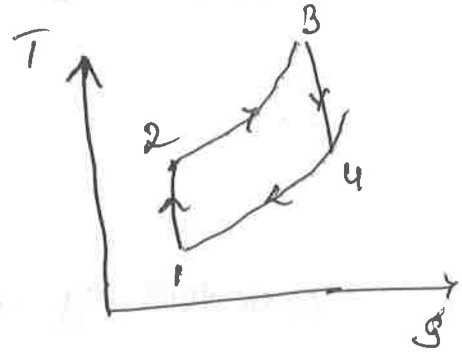
1-2 - Ideal Isentropic compression
2-3 - Const pressure heat supply
3-4 - Isentropic expansion
1-2' - Irreversable adiabatic comp
3-4' - Irreversable adiabatic expansion



Closed cycle gas turbine:



1-2 - Isentropic compression
2-3 - const pressure heat addition
3-4 - Isenthropic expansion
4-1 - Const pressure heat rejection



Constant volume combustion

In this almost all the combustion of fuel takes place at constant volume.

6b) In a gas turbine plant, operating on Brayton cycle, air enters the compressor at 1bar & 27°c. The pressure ratio in the cycle is 6. calc the max temp in the cycle & the Power developed. Assume turbine work as 2.5 times compressor work.

sol $P_1 = 1bar$ $T_1 = 27+273 = 300K$ Pressure ratio $r_p = 6$

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = (6)^{\frac{1.4-1}{1.4}} = 1.668$$

$$T_2 = 1.668 \times 300 = 500.4K$$

$$\frac{T_3}{T_4} = (r_p)^{\frac{\gamma-1}{\gamma}} = (6)^{\frac{1.4-1}{1.4}} = 1.668$$

$$T_4 = \frac{T_3}{1.668}$$

Given $W_T = 2.5 W_C$

$$mc_p(T_3 - T_4) = 2.5\, mc_p(T_2 - T_1)$$

$$T_3 - \frac{T_3}{1.668} = 2.5(500.4 - 300)$$

$$= 501$$

$$T_3 = 1251K$$

$$T_4 = 750K$$

Max Temp = 1251K

$$W_{net} = W_T - W_C$$

$$= 2.5W_C - W_C$$

$$= 1.5W_C = 1.5(1 \times 1 \times (500.4 - 300)) = 300.6\ KJ/s$$

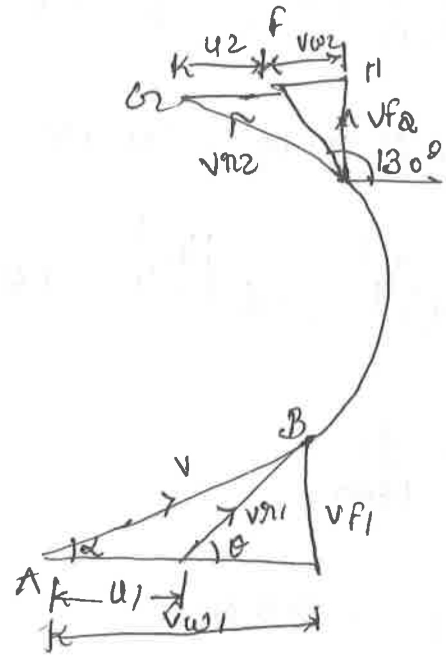
Power developed = 300.6 KW

700) A Jet of water having a velocity of 20 m/s strikes a curved vane, which is moving with a velocity of 10 m/s. The Jet makes an angle of 20° with the direction of vane at inlet and leaves at an angle of 130° to the direction of motion of vane at outlet. Determine

1) The angles of curved vane tips

2) The work done per N of water entering the vane

sol



velocity of jet $V_1 = 20\,m/s$

Velocity of vane $u_1 = 10\,m/s$

$\alpha = 20^0$

$\beta = 180 - 130 = 50$

$u_1 = u_2 = 10\,m/s$

$V_{r1} = V_{r2}$

From Inlet velocity Δle

ABD

$\tan\theta = \dfrac{V_{f1}}{V_{w1} - u_1}$

$V_{f1} = V_1 \sin\alpha = 20 \sin 20 = 6.84\,m/s$

$V_{w1} = V_1 \cos\alpha = 20 \cos 20 = 18.79\,m/s$

$\tan\theta = \dfrac{6.84}{18.794 - 10} \Rightarrow \theta = 37^{\circ}52$

$\sin\theta = \dfrac{V_{f1}}{V_{r1}} \Rightarrow V_{r1} = 11.14$

$V_{r1} = V_{r2} = 11.14$

From ΔEFG applying Sine rule

$$\frac{V_{r2}}{\sin(180-\beta)} = \frac{u_2}{\sin(\beta-\phi)}$$

$$\frac{11.14}{\sin 50} = \frac{10}{\sin(50-\phi)}$$

$$\phi = 6.56^0$$

work done per unit weight of water

$$= \frac{1}{g}\left[V_{w_1} + V_{w_2}\right] \times u$$

$$V_{w_2} = V_{r_2}\cos\phi - u_2 = 11.14 \cos 6.56 - 10 = 1.067 \text{ m/s}$$

$$= \frac{1}{9.81}\left[18.794 + 1.067\right] \times 10 = 20.24 \text{ Nm/N}$$

7b) Give the classification of hydraulic pumps & write the advantages of centrifugal pump over reciprocating pump

A)

Pumps
- Rotodynamic Pumps
  - Centrifugal
  - Axial flow
  - Mixed flow
  - Turbine
- Positive displacement Pumps
  - Rotary
    - Gear
    - Lobe
    - Sliding Vane
    - Screw
  - Reciprocating
    - Piston
    - Diaphragm
    - Plunger

Advantages of centrifugal Pumps

→ It is used for high discharge

→ It is used for low head

→ Viscosity of liquid is less than 1000 centipoise

→ Lower vibrations & Noise

→ High speed operation

8a) A Jet of water 50mm in diameter issues with a velocity of 10m/sec & impinges normally on stationary flat plate which moves in forward motion. Determine the force exerted by Jet on the plate & workdone consider the same data & calc the force exerted by Jet on the plate & workdone when the plate is moving with velocity of 3 m/s in same direction

sol Dia of Jet $d = 50mm = 50 \times 10^{-3} m = 0.05m$

$Area(a) = \frac{\pi}{4} d^2 = \frac{\pi}{4} (50 \times 10^{-3})^2 = 0.0019635 \ m^2$

Force exerted by Jet on stationary flat plate

$F = \rho a V^2 = 1000 \times 0.0019635 \times (10)^2 N$

$= 196.35 \quad N$

Force exerted by Jet when vane is moving

$F_x = \rho a (V-u)^2 = 1000 \times 0.0019635 \times (10-3)^2$

$= 96.2115 N$

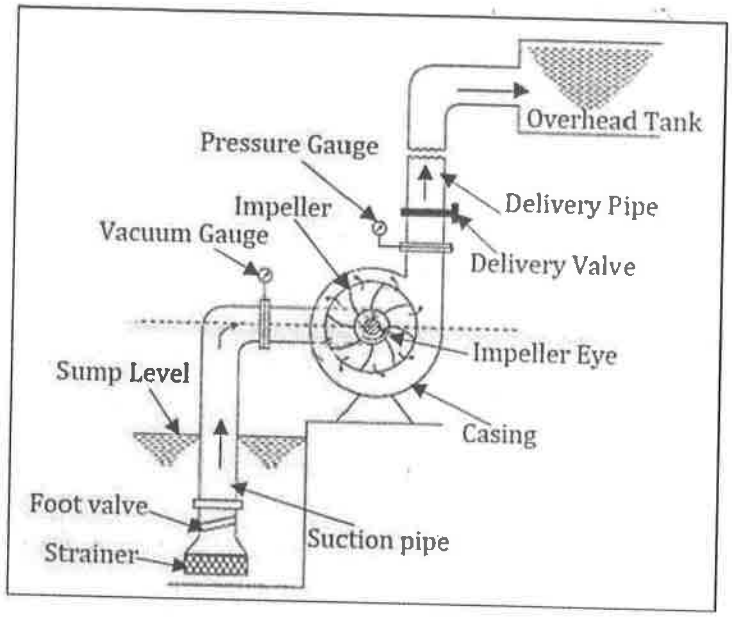
workdone $= F_x \times u = 1000 \times 0.0019635 \times (10-3)^2 \times 3$

$= 288.63 \ Nm/s$

8b)
Q) Explain the working of single stage centrifugal pump

A) The main Components of centrifugal Pump are

1. Suction pipe
2. Impeller
3. Casing
4. Delivery Pipe



Suction pipe:
It is a pipe whose upper end is connected to inlet of pump ie at the center of the impeller eye & the lower end is dipped into liquid in suction tank

Impeller:- The rotating part of a centrifugal pump is called impeller Provides a series of backward vanes. It is connected to electric motor which imparts the energy.

Casing: casing is an air tight passage surrounding impeller & it is designed in such a way that K.E is converted to pressure energy

Delivery pipe: It is pipe whose end is connected to the outlet of the pump & other end delivers the liquid at a required pipe

working:
Centrifugal pump works on the principle of forced vortex flow
The flow in the centrifugal pump is radial outward direction
As the liquid enters the pump impeller eye, the blade accelerate

the liquid along the surface of impeller. the liquid gains K.E.

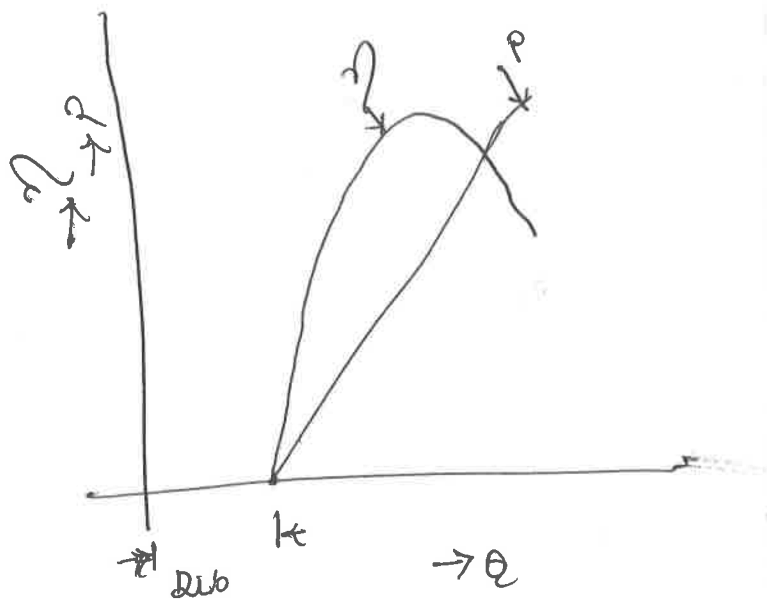
The gained K.E is converted into pressure energy in the casing.

When the delivery valve is opened the liquid is made to flow in outward radial direction there by leaving the vanes of the impeller.

9a) Draw a neat diagram of the operating characteristic curve of Pelton, Francis & Kaplan turbine. Discuss the importance of these curves

A) operating characteristic curves are Plotted when the speed on the turbine is constant

For operating characteristic N & H are constant. hence the variation of Power & η w.r.to Q are Plotted.



The Power curve of the turbine shall not pass through the origin because certain amount of discharge is needed to produce Power to over come the friction

Hence the power & efficiency curves will be slightly away from origin on x-axis as to overcome the initial friction certain amount of discharge is required.

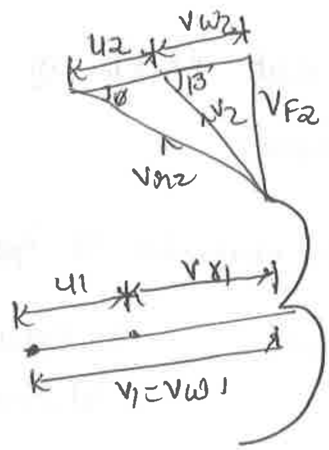
6) The Jet of water coming out of nozzle strikes the bucket of Pelton wheel which when stationary would deflect the jet through 165°. The velocity of water at exit 0.9 times at inlet the bucket speed is 0.45 times the Jet speed. If the speed of the pelton wheel is 300 rpm & effective head is 150 m. determine 1) Hydraulic efficiency 2) dia of wheel. Take $C_v = 0.98$

Sol Velocity of Jet

$V_1 = C_v\sqrt{2gH}$

$V_1 = 0.98 \times \sqrt{2 \times 9.81 \times 150}$

$V_1 = 53.19$ m/s.



Velocity of bucket

$u = 0.45 \times V_1$

$u_1 = 0.45 \times 53.19$

$u_1 = 23.94$ m/s

From fig

$V_{r1} = V_1 - u_1 = 53.19 - 23.94 = 29.25$

$V_1 = V_{w1} = 53.19$ m/s

From outlet velocity Δle

$V_{r2} = 0.9 V_{r1} = 26.325$

$V_{w2} = V_{r2}\cos\phi - u_2$

$= 0.9 V_{r1}\cos 15° - 23.94 = 1.4879$

$$\eta_h = \frac{2[V_{w1} + V_{w2}] \times u}{V_1^2} = \frac{2[53.19 + 1.4879] \times 23.94}{53.19^2}$$

$= 92.5\%$

$$u = \frac{\pi D N}{60}$$

$$D = \frac{u \times 60}{\pi \times N} = \frac{u \times 60}{\pi \times 300} = \frac{23.94 \times 60}{\pi \times 300}$$

$$= 1.52 m$$

10) a) Make a neat sketch of hydro power plant & clearly explain the various elements

A) The various elements in hydro power plant

1) Reservoir
2) Dam
3) Penstock
4) Surge tank
5) Spillway
6) Power house
7) Hydro turbine
8) Draft tube

Reservoir:

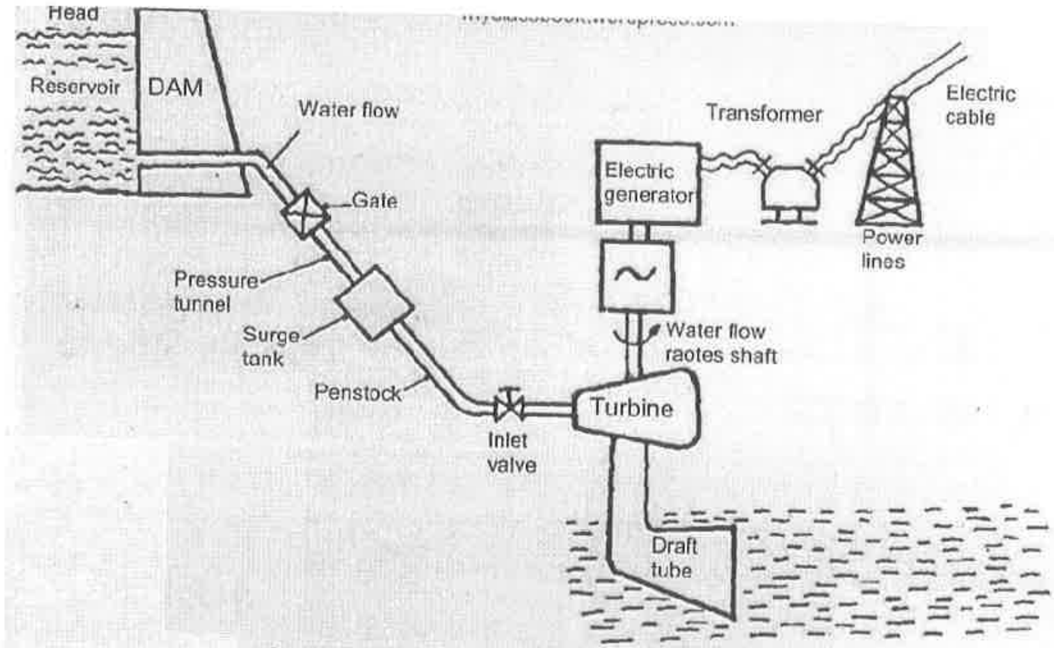
The function of reservoir is to store water during rainy season & supply the same during dry season.

Dam: The function of dam is to increase the height of water level increases the potential energy

Penstock: Large diameter tube through which water from dam come to turbine inlet. It is made from steel.

Surge tank: The main function of surge tank is reduce the water hammering effect. When load on generator decreases in order to keep the generator at const speed the water admitting into the turbine is reduced by closing the valve which increases the pressure in penstock. This may cause to the burst of penstock

Surge tank is a tank provided to absorb any water surge caused in penstock due to sudden loading & unloading of the generator.



Layout of hydro electric power plant

Spillway:

The function of spillway is to provide safety of dam. Spillway should have capacity to discharge more water during floods with damage to dam

Power house:

It consist of two parts a sub structure to support hydraulic & electric equipment & superstructure to house & Protect this equipment

Power movers & Hydro turbine:

Turbines are the devices which converts the K.E of water into mechanical energy to produce the electric power

10b) The following data pertain to Kaplan turbine. S.P = 13230 kW, Speed = 75 rpm, head = 8m, dia of boss of runner = 0.35 times the external dia Speed ratio = 2, flow ratio = 0.6. Find the efficiency of the turbine.

sol

$S.P = 13230\ kW$

$N = 75\ RPM$

$head = 8\ m$

Speed ratio = 2

$u_1 = 2 \times \sqrt{2 \times g \times H} = 2 \times \sqrt{2 \times 9.81 \times 8} = 25.056\ m/s$

$\frac{V_{f1}}{\sqrt{2gH}} = 0.6$

$V_{f1} = 0.6 \times \sqrt{2gH} = 0.6 \times \sqrt{2 \times 9.81 \times 8} = 7.517\ m/s$

Diameter of boss = 0.35 × Dia of runner

$D_b = 0.35 \times D_O$

$\eta_o = \frac{S.P}{W.P} = \frac{13230}{\frac{\rho \times g \times Q \times H}{1000}}$

$u_1 = \frac{\pi D_O N}{60}$

$2 \times \sqrt{2 \times 9.81 \times 8} = \pi \times \frac{D_b}{0.35} \times \frac{75}{60} \Rightarrow 25.056 = \frac{\pi \times D_b \times 75}{0.35 \times 60}$

$D_b = 2.233\ m$

$D_O = \frac{D_b}{0.35} = 6.3804\ m$

$$Q = \frac{\pi}{4}\left[D_0^2 - D_b^2\right] \times V_f$$

$$= \frac{\pi}{4}\left[D_0^2 - (0.35 D_0)^2\right] \times V_f$$

$$= \frac{\pi}{4}\left[0.8775 D_0^2\right] \times 7.517$$

$$= 11.433 D_0^2 = 5.18 \times 6.38^2 = 210.87$$

$$\eta_0 = \frac{S.P}{W.P} = \frac{13230}{\frac{1000 \times g \times Q \times H}{1000}} = 79.9$$

$$\simeq 80\%$$

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