SSC JE CONVENTIONAL 2016

GENERAL ENGINEERING (MECHANICAL)

1. (a) **Draw and explain the p – T (Pressure – Temperature) diagram for a pure substance.** **[15 Marks]**

Solution :

Pure substance is a substance of constant chemical composition throughout its mass. It is a one component system. It may be exist in one or more phase. Now let us consider water as the representative of a pure substance.

p - T diagram :

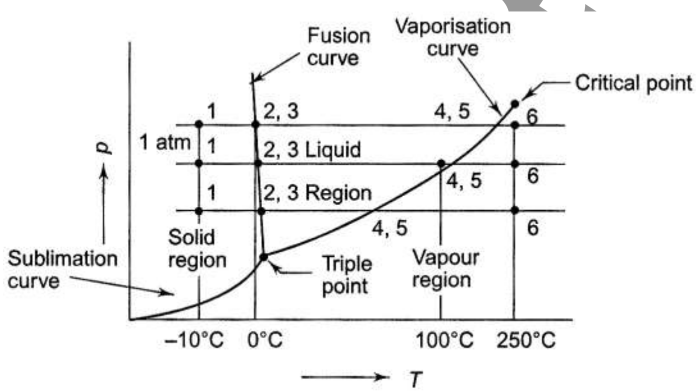


Fig. : *Phase equilibrium diagram on p – T coordinates*

When a pure substance are heated slowly at different pressure, then substance changes their. If there state changes are plotted on p - T coordinate, the diagram as shown in figure above will be obtained.

Let us assume, if the heating of ice at –10°C to steam at 250°C at constant pressure of 1 atm is considered,

Process 1 → 2 : Solid (ice) heating
Process 2 → 3 : Melting of ice at 0°C
Process 3 → 4 : Liquid heating
Process 4 → 5 : Vaporisation of water at 100°C
& Process 5 → 6 : Heating in the vapour phase.

So, The process will be reversed from state 6 to state 1 upon cooling.

Fusion curve : The curve passing through the 2, 3 point is called the fusion curve.

Vaporisation curve : The curve passing through the 4, 5 points which indicate the vaporisation (or con densation) at different temperature and pressure is called the vaporisation curve.

Sublimation curve : The vapour pressure of a solid is measured at different temperature and these are plotted is know as the sublimation curve.

The fusion curve, the vaporistaion curve and the sublimation curve meet at the triple point. For all substance the slope of the sublimation and vaporization curve are positive. The slope of the fusion curve for most substance is positve, but for water it is negative. The temperature at which a liquid boils is very sensitive to pressure, as indicated by the vaporisation curve which gives the saturation temperature at different pressure.

But the temperate at which a solid melts is not such a strong function of pressure. As indicated by the small slope of the fusion curve. The triple point of water is at 4.58 mm Hg & 273.16 K and CO_2 is at 3885 mm Hg (5 atm) and 216.55 K.

(b) With the assumptions, derive the Steady Flow Energy Equation (SFEE). [15 Marks]

Solution :

Assumption :

(i) The mass flow through the system remains constant.
(ii) Fluid uniform in composition.
(iii) The only interaction between the system and surrounding are work and heat.
(iv) Flow should be steady.
(v) In the analysis only potential, kinetic and flow energies are considered.

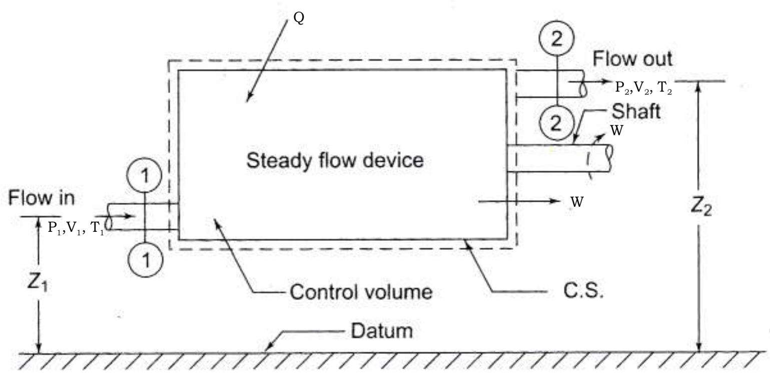


Figure shows a schematic flow process for an open system. An open system is one in which both mass and energy may cross the boundaries a wide interchange of energy may take places within an open system. These would be an interchange of chemical energy in the fuel, kinetic energy of moving particles, internal energy of gas and heat transferred and shaft work within the system. So, the mass entering the system equal the mass leaving, Also energy entering the system equal energy leaving.

Let us assume :

q = Heat supplied per kg of fluid
w = Work done per kg of fluid
V = Velocity of fluid
z = Datum head
p = Pressure of the fluid
v_1 = specific volume
u = Internal energy per kg of fluid

The total rate of flow of all energy stream entering the control volume must equal to the total rate of flow of all energy streams leaving the control volume.

$$(e_{flow})_1 + u_1 + (e_k)_1 + (e_p)_1 + q = (e_{flow})_2 + u_2 + (e_k)_2 + (e_p)_2 + w$$

$$p_1v_1 + u_1 + \frac{V_1^2}{2} + gz_1 + q = p_2v_2 + u_2 + \frac{V_2^2}{2} + gz_2 + w$$

$$(u_1 + p_1v_1) + \frac{V_1^2}{2} + gz_1 + q = (u_2 + p_2v_2) + \frac{V_2^2}{2} + gz_2 + w$$

where $h = u + pv$

$$h_1 + \frac{V_1^2}{2} + gz_1 + q = h_2 + \frac{V_2^2}{2} + gz_2 + w$$

if z_1 and z_2 are neglected , we get

$$h_1 + \frac{V_1^2}{2} + q = h_2 + \frac{V_2^2}{2} + w$$

The equation is known as steady flow energy equation. This equation is applicable to any medium in any steady flow.

(c) A system receives 50 kJ of heat while expanding with volume change of 0.14 m³ against an atmosphere of 1.2 × 10⁵ N/m². A mass of 90 kg in the surroundings is also lifted through a distance of 5.5 m.

(i) Calculate the change in energy of the system.

(ii) The system is returned to its initial volume by an adiabatic process which requires 110 kJ of work. Find the change in energy of the system.

(iii) For the combined processes of (i) and (ii), calculate the change in energy of the system. [15 Marks]

Solution :

Q= 50 kJ $\Delta V = 0.14\ m^3$ m = 90 kg $P = 1.2\times10^5\ N/m^2$

h = 5.5

(i)
$$Q = (dU_1+W) + E_p$$
$$= (dU_1+p.dV) + mgh$$
$$dU_1 = Q - PdV - mgh$$
$$= 50 \times 10^3 - 1.2 \times 10^5 \times 0.14 - 90 \times 9.8 \times 5.5$$
$$= 50 \times 10^3 - 16.8 \times 10^3 - 4.85 \times 10^3$$
$$dU1 = 28.34 \times 10^3 J = 28.31 kJ$$

(ii)
$$dQ = dU2 - dW - E_p$$

Where work done is negative because work is giving to system.

dQ = 0, adiabatic process

Then,
$$0 = dU_2 - dW - E_p$$
$$dU_2 = -dW - E_p = -(dW+mgh)$$
$$= +(110 \times 10^3 + 90 \times 9.81 \times 5.5) kJ$$
$$dU = 114.86\ kJ$$

(iii)
$$\Delta U = dU_2 - dU_1$$
$$= 114.86 - 28.34$$
$$\Delta U = 86.52\ kJ$$

(d) (i) Define the second law of thermodynamics using Clausius and Kelvin-Planck statements.

(ii) Describe the working of the Carnot cycle.

(iii) What do you mean by the term "Entropy" ? [15 Marks]

Solution :

(i) Kelvin-Planck statement

The Kelvin-Planck statement of the second law of thermodynamics states that it is impossible for a heat engine to produce net work in a complete cycle if it exchanges heat only with bodies at a single fixed temperature.

The Kelvin Planck statement is used for heat engines. If $Q_2 = 0$ (i.e, $W_{net} = Q_1$, or $\eta = 1.00$), the heat engine will produce net work in a complete cycle by exchanging heat with only one reservoir, thus violating the Kelvin- Planck statement.

A heat engine has, therefore, to exchange heat with two thermal energy reservoirs at two different temperatures to produce net work in a complete cycle.

Clausius statement

Heat always flows from a body at a higher temperature to a body at a lower temperature. The reverse process never occurs spontaneously.

Clausius' statement of the second law gives: It is impossible to construct a device which, operating in a cycle, will produce no effect other than the transfer of heat from a cooler to a hotter body.

Heat cannot flow of it self from a body at a lower temperature to a body at a higher temperature. Some work must be expended to achieve this.

(ii) A Reversible cycle is an ideal hypothetical cycle in which all the processes constituting the cycle are reversible. Carnot cycle is a reversible cycle. For a stationary system, the cycle consists of the following four successive processes.

A reversible cycle is an ideal hypothetical cycle in which all the processes consti-tuting the cycle are reversible. Carnot cycle is a reversible cycle. For a stationary system, as in a piston and cylinder machine, the cycle consists of the following four successive processes

1. A reversible isothermal process in which heat Q_1 enters the system at t_1 reversibly from a constant temperature source at t_1 when the cylinder cover is in contact with the diathermic cover A. The internal energy of the system increases.

From first law,

$$Q_1 = U_2 - U_1 + W_{1-2} \quad \text{.....................(i)}$$

(for an ideal gas only, $U_1 = U_2$)

2. A reversible adiabatic process in which the diathermic cover A is replaced by the adiabatic cover B, and work W_E is done by the system adiabatically and reversibly at the expense of its internal energy, and the temperature of the system decreases from t_1 to t_2.

$$0 = U_3 - U_2 + W_{2-3.} \quad \text{.....................(ii)}$$

3. A reversible isothermal process in which B is replaced by A and heat Q_2 leaves the system at t_2 to a constant temperature sink at t_2 rreversibly, and the internal energy of the system further decreases.

From the first law,

$$-Q_2 = U_4 - U_3 + W_{3-4} \quad \text{.....................(iii)}$$

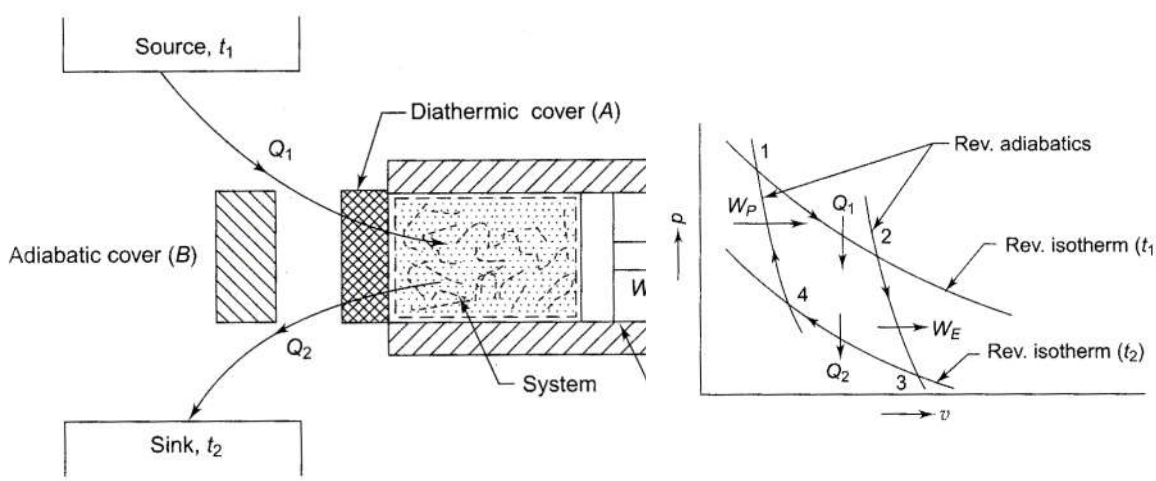
only for an ideal gas, $U_3 = U_4$

4. A reversible adiabatic process in which B again replaces A, and work Wp is done upon the system reversibly and adiabatically,a nd the internal energy of the system increases and the temperature rises from t_2 to t_1.

Applying the first law,

$$0 = U_1 - U_4 - W_{4-1} \quad \text{.....................(iv)}$$

Two reversible isotherms and two reversible adiabatic constitute a constitute a Carnot cycle, which is represented in p-v coordinates in figure.



Summing up Eqs (i) to (iv)

$$Q_1 - Q_2 = (W_{1-2} + W_{2-3}) - (W_{3-4} + W_{4-1})$$

or

$$\sum_{cycle} Q_{net} = \sum_{cycle} W_{net}$$

(iii) Entropy can be viewed as a measure of molecular disorder, or molecular randomness. As a system becomes more disordered, the position of the molecules becomes less predictable and entropy increase

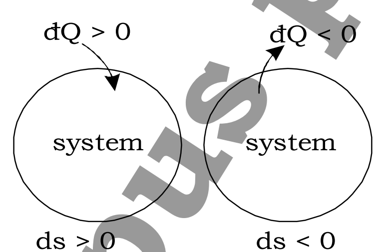
So,

$$\frac{\text{Solid} \longrightarrow \text{liquid} \longrightarrow \text{gas}}{\text{Entropy increase}\longrightarrow}$$

In solid phase the molecules of the substance continually oscillate about their equilibrium position but they cannot move relative to each other, and there position at any instant can be predicted with good certainty.

In the gas phase molecules move about random collide with each other and change direction make it extremely difficult to predict to predict accurately the microscopic state of a system at any instant. Associated with this molecular chaos a high value of entropy entropy of system can changes with heat interaction and dissipative effect of work.

$$ds = \frac{dQ}{T}$$



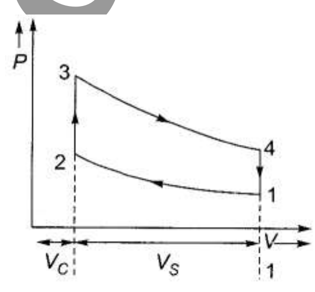
With dissipative effect entropy generated in the system.

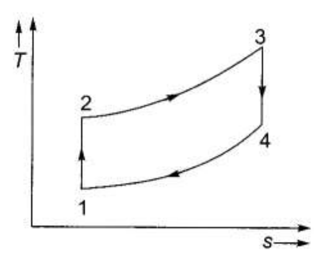
$$ds = \frac{dQ}{T} + ds_{gen}$$

2. (a) With the help of P – V and T – s diagrams derive the thermal efficiency expression for air-standard Otto cycle. [15 Marks]

Solution :

Otto cycle :





Process 1 – 2 : Reversible adiabatic compression
Process 2 – 3 : Constant volume heat addition
Process 3 – 4 : Reversible adiabatic expansion
Process 4 – 1 : Constant volume heat rejection

Compression ratio, $r = \frac{V_1}{V_2} = \frac{V_C + V_S}{V_C} = 1 + \frac{V_S}{V_C}$

Heat Supplied, $Q_S = mC_V(T_3 - T_2)$

Heat rejection, $Q_R = mC_V(T_4 - T_1)$

Efficiency, $\eta_{Otto} = 1 - \dfrac{Q_R}{Q_S}$

$$\eta_{Otto} = 1 - \frac{mC_V(T_4 - T_1)}{mC_V(T_3 - T_2)} = 1 - \frac{(T_4 - T_1)}{(T_3 - T_2)} \qquad .....(1)$$

Considering isentropic process 1 – 2 and 3 – 4, we have

$$\frac{T_3}{T_4} = \left(\frac{V_4}{V_3}\right)^{\gamma-1} \qquad .....(2)$$

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1} \qquad .....(3)$$

But, $$\frac{V_1}{V_2} = \frac{V_4}{V_3} = r \qquad .....(4)$$

$\therefore$ $$\frac{T_2}{T_1} = \frac{T_3}{T_4} \qquad .....(5)$$

From equation (5),

$$\frac{T_4}{T_3} = \frac{T_1}{T_2} = \frac{T_4 - T_1}{T_3 - T_2} = \left(\frac{1}{r}\right)^{\gamma-1}$$

From equation (1)

$$\eta_{Otto} = 1 - \left(\frac{1}{r}\right)^{\gamma-1} \qquad \eta_{Otto} = 1 - \frac{1}{(r)^{\gamma-1}}$$

Note that the thermal efficiency of Otto cycle is a function of compression ratio r and the ratio of specific heats, g. As g is assumed to be a constant for any working fluid, the efficiency is increased by increasing the compression ratio. Further, the efficiency is independent of heat supplied and pressure ratio. The use of gases with higher g values would increase efficiency of Otto cycle.

(b) An air-standard Diesel cycle has a compression ratio of 14. The air conditions before compression are 1 bar and 27ºC. The maximum temperature of the cycle is 2500ºC. Determine the

(i) temperature and pressure at salient points of the cycle.

(ii) network output per unit mass of air.

(iii) thermal efficiency. **[15 Marks]**

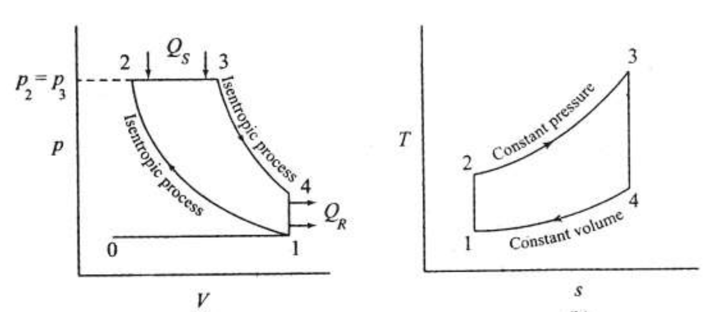
Solution :

(i) $\dfrac{V_1}{V_2} = r = 14$

P = 1 bar

$T_1 = 218 + 273 = 300$ K

$T_3 = 2500°C + 273 = 2773$ K



(a) (b)

Process 1 →2

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1}$$

$$T_2 = 300 \times (14)^{g-1}$$
$$= 300 \times 2.87 = 862.1 \text{ K}$$

$$P_1V_1^{\gamma} = P_2V_2^{\gamma} = 1\times(14)^{1.4}$$
$$P_2 = 40.23 \text{ bar}$$

Process 2→3

$$\frac{V_2}{T_2} = \frac{V_3}{T_3} \text{ or } \frac{V_3}{V_2} = \frac{T_3}{T_2} = 3.2165$$

Process 3→4

$$\frac{T_4}{T_3} = \left(\frac{V_3}{V_4}\right)^{\gamma-1}$$

$$T_4 = T_3 \times \left(\frac{V_3}{V_2}.\frac{V_2}{V_4}\right)^{\gamma-1}$$

$$T_4 = T_3 \times \left(\frac{V_3}{V_2}.\frac{V_2}{V_1}\right)^{\gamma-1} \quad ....(i) \qquad [\therefore v_1 = v_4]$$

From equation (i)

$$T_4 = T_3 \times \left(\frac{V_3}{V_2}.\frac{1}{r}\right)^{\gamma-1}$$

$$= 2773\times\left(3.2165\times\frac{1}{14}\right)^{\gamma-1}$$

$$T_4 = 1539.768 \text{ K}$$

or $T_4 = 1266\ ^\circ\text{C}$

for Process 4 → 1
(Isochoric Process)

$$\frac{P_4}{T_4} = \frac{P_1}{T_1}$$

$$P_4 = \left(\frac{T_4}{T_1}\right).P_1 = \left(\frac{1539.7}{300}\right).1$$

$$P_4 = 5.13 \text{ bar}$$

(ii)
$$W = Q_1 - Q_2$$
$$W = C_p(T_3-T_2) - C_v(T_4-T_1)$$
$$= C_p[(T_3-T_2) - \frac{1}{\gamma}(T_4-T_1)]$$

$$= 1.005\ [(2773-862.1) - \frac{1}{1.4}(1539.7-300)]$$

$$W = 1.0305 \text{ kJ/ kg}$$

(iii)
$$\eta = \left(\frac{W}{Q_1}\right)\times 100\%$$

$$\eta = \left(\frac{1.0305}{1.920}\right)\times 100$$

$$\eta = 53.67\%$$

(c) Derive the network output and thermal efficiency expressions for a simple Rankine cycle with schematic and T – s diagrams. [15 Marks]

Solution :

Rankine Cycle :

For the steam boiler, this would be a reversible constant pressure heating process of water to form steam, for the turbine the ideal process would be a reversible adiabatic expansion of steam, for the condenser it would be a reversible constant pressure heat rejection as the steam condenses till it becomes saturated liquid, and for the pump, the ideal process would be the reversible adiabatic compression of this liquid ending at the intial pressure. When all these four processes are ideal, the cycle is an ideal cycle, called a *Rankine cycle*. This is a reversible cycle. Fig. 1 shows the flow diagram of the Rankine cycle, and in Fig. 2, the cycle has been plotted on the *p-v, T-s,* and *h-s* planes. The numbers on the plots correspond to the numbers on the flow diagram. For any given pressure, the steam approaching the turbine may be dry saturated (state 1) wet (state 1′), or superheated (state 1″), but the fluid approaching the pump is, in each case, saturated liquid (state 3). Steam expands reversibly and adiabatically in the turbine from state 1 to state 2 (or 1′ to 2′, or 1″ to 2″), the steam leaving the turbine condenses to water in the condenser reversibly at constant pressure from state 2 (or 2′, or 2″) to state 3, the water at state 3 is then pumped to the boiler at state 4 reversibly and adiabatically, and the water is heated in the boiler to form steam reversibly at constant pressure from state 4 to state 1 (or 1′ or 1″).

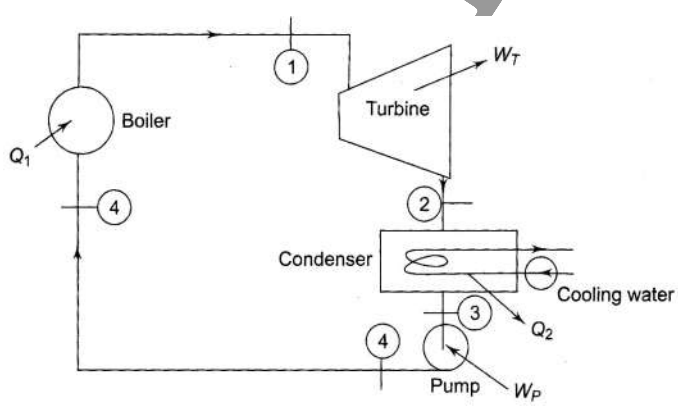


Fig. 1 : *A simple steam plant*

For purposes of analysis the Rankine cycle is assumed to be carried out in a steady flow operation. Applying the steady flow energy equation to each of the processes on the basis of unit mass of fluid, and neglecting changes in kinetic and potential energy, the work and heat quantities can be evaluated in terms of the properties of the fluid.

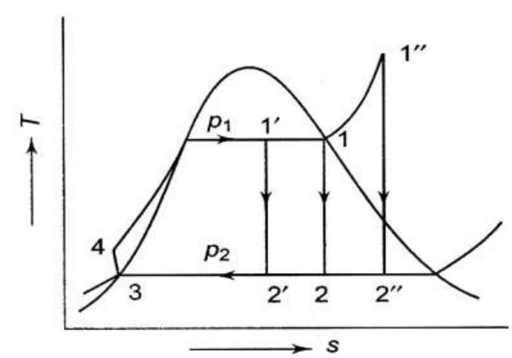


Fig. 2 : *Rankine cycle onT-s diagrams*

For 1 kg Fluid :

The SFEE for the boiler (control volume) gives

$$h_4 + Q_1 = h_1$$

$\therefore$ $$Q_1 = h_1 - h_4$$

The SFEE for the turbine (control volume) gives

$$h_1 = W_T + h_2$$

$\therefore$ $$W_T = h_1 - h_2$$

Similarly, the SFEE for the condenser is

$$h_2 = Q_2 + h_3$$

$\therefore$ $$Q_2 = h_2 - h_3$$

and the SFEE for the pump gives

$$h_3 + W_p = h_4$$

$\therefore$ $$W_p = h_4 - h_3$$

Net output:

$W_{net} = W_T - W_P = (h_1 - h_2) - (h_1 - h_2)$

Thermal Efficiency of Rankine Cycle :

$$\text{Thermal efficiency, } \eta_{th} = \frac{\text{Net work}}{\text{Heat supplied}}$$

$$\eta = \frac{W_{net}}{Q_1} = \frac{W_T - W_p}{Q_1} = \frac{(h_1 - h_2) - (h_4 - h_3)}{h_1 - h_4}$$

Usually, the pump work is quite small compared to the turbine work and is sometimes neglected. Then $h_4 = h_3$,

Therefore, $$\eta = \frac{h_1 - h_2}{h_1 - h_4}$$

d

(d) Give the differences between fire tube and water tube boilers with examples.

[15 Marks]

Solution :

Comparison of Fire tube boiler and Water tube boiler :

Fire tube Boiler :

1. Hot flue gases flow inside the tube and the water outside the tube.
2. These boilers are generally internally fired.
3. The boiler pressure is limited up to 20 bar.
4. Fire tube boilers have lower rate of steam production.
5. Not suitable for large power plants.
6. Involves lesser risk of explosion due to lower pressure.
7. For a given power it occupies large floor space.
8. This boiler is difficult to construct.
9. Difficult in transportation.
10. They require less skills to operate.
11. They are difficult to repair and cleaning as they are internally fired.
12. They require large shell diameter because the fire tube situated inside the shell.
13. The efficiency of FTB is less compare to WTB though it will increase using accessories.
14. The maintenance of this boiler is costly. It requires regular inspection.
15. The treatment of water is not necessary.
16. Ex: Cornish boiler Lancashire boiler scotch marine boiler.

Water tube Boiler

1. Water flows inside the tube and the hot flue gases outside the tube.
2. Generally externally fired.
3. The boiler pressure is limited upto 100 bar.

4. Higher rate of steam production.
5. Suitable for large power plants.
6. Risk of explosion is higher due to high boiler pressure.
7. For a given power it occupies less floor space.
8. Simple in construction.
9. Simple in transportation.
10. They require a skilled operator.
11. They are easy to repair and clean as they are externally fired.
12. They require small shell diameter.
13. WTB more efficient compared to FTB.
14. They are easy to maintain as they are externally fired.
15. The water flows through small diameter tube. So water is treated before entering into the tube otherwise it will jam the tube.
16. **Ex. :** Babcock and Wilcox boiler.

3. (a) Define the following : **[15 Marks]**

(i) Steady and Unsteady flows
(ii) Uniform and Non-uniform flows
(iii) Laminar and Turbulent flows
(iv) Compressible and Incompressible flows
(v) Rotational and Irrotational flows

Solution :

(i) Steady flow : Steady flow is defined as that type of flow in which the fluid characteristics like velocity, pressure, density, etc. at a point do not change with time. Thus for steady flow, mathematically, we have

$$\left(\frac{\partial V}{\partial t}\right)_{x_0, y_0, z_0} = 0, \left(\frac{\partial p}{\partial t}\right)_{x_0, y_0, z_0} = 0, \left(\frac{\partial \rho}{\partial t}\right)_{x_0, y_0, z_0} = 0$$

where (x_0, y_0, z_0) is a fixed point in fluid field.

Example : Flow of fluid through a pipe at constant rate.

Unsteady flow : Unsteady flow is that type of flow, in which the velocity, pressure of density at a point changes with respect to time. Thus, mathematically, for unsteady flow

$$\left(\frac{\partial V}{\partial t}\right)_{x_0, y_0, z_0} \neq 0, \left(\frac{\partial p}{\partial t}\right)_{x_0, y_0, z_0} \neq 0, \left(\frac{\partial \rho}{\partial t}\right)_{x_0, y_0, z_0} \neq 0$$

Example : Water flow through a tap which has just been opened.

(ii) Uniform flow : Uniform flow is defined as that type of flow in which the velocity at any given time does not change with respect to space (*i.e.*, length of direction of the flow). Mathematically, for uniform flow

$$\left(\frac{\partial V}{\partial s}\right)_{t\,=\,\text{constant}} = 0$$

where ∂V = Change of velocity

∂s = Length of flow in the direction *s*.

Example : Flow of water in a pipe of constant diameter at constant velocity.

Non-uniform flow : Uniform flow is defined as that type of flow in which the velocity at any given time does change with respect to space (*i.e.*, length of direction of the flow). Mathematically, for uniform flow

$$\left(\frac{\partial V}{\partial s}\right)_{t\,=\,\text{constant}} \neq 0$$

where ∂V = Change of velocity

∂s = Length of flow in the direction s.

(iii) **Laminar flow :** Laminar flow is defined as that type of flow in which the fluid particles move along well-defined paths or stream line and all the streamlines are straight acid parallel. Thus the particles move in laminar or layers sliding smoothly over the adjacent layer. This type of flow is also called streamline flow or viscous flow.

Example : Smooth flow of a viscous liquid through a tube or pipe.

(ii) Turbulent flow : Turbulent flow is that type of flow in which the fluid panicles move in a zig-zag way. Due to the movement of fluid panicles in a zig-zag way, the eddies formation takes place which arc responsible for high energy loss. For a pipe flow, the type of flow is determined by a non-dimensional number $\frac{VD}{\nu}$ called the Reynold number.

Where, D = Diameter of pipe

V = Mean velocity of flow in pipe

ν = Kinematic viscosity of fluid

If the Reynold number is less than 2000. the flow is called laminar. If the Reynold number is more than 4000, it is called turbulent flow. If the Reynold number lies between 2000 and 4000, the flow may be laminar or turbulent.

Example : The flow through pumps and turbines.

(iv) **Compressible and Incompressible Flows :** Compressible flow is that type of flow in which the density of the fluid changes from point to point or in other words The density (ρ) is not constant for the fluid. Thus, mathematically, for compressible flow

$$\rho \neq \text{Constant}$$

Incompressible flow is that type of flow in which the density is constant for the fluid flow. Liquids are generally incompressible while gases are compressible. Mathematically, for incompressible flow

$$\rho = \text{Constant}$$

(v) Rotational and Irrotational Flows : Rotational flow is that type of flow in which he fluid particles while flowing along stream lines, also rotate about their own axis. Axis of the fluid particles while flowing along stream-lines, do not rotate about their own axis then that type of flow is called irrotational flow.

(b) A U-tube manometer is used to measure the pressure of water in a pipeline, which is in excess of atmospheric pressure. The right limb of the manometer contains mercury and is open to the atmosphere. The contact of water and mercury is in the left limb. Calculate the pressure of water in the main line, if the difference in the level of mercury in the limbs of the U-tube is 10 cm and the free surface of mercury is in level with the centre of the pipe.

[15 Marks]

Method - 1

(Jumping fluid technique)

$$P_A + \rho_w gh - \rho_m gh = P_{atm}$$
$$P_A + P_{atm} = \rho_m gh - \rho_w gh$$
$$P_A - P_{atm} = (\rho_m - \rho_{w)}\, g.h$$

$$(P_A)_{gauge} = (13600 - 1000)\, 9.81 \times \frac{10}{100}$$

$$= 12600 \times 9.81 \times \frac{10}{100}$$

$$(P_A)_{gauge} = 12360.6 \text{ Pa}$$

Gauge pressure of water in pipline is 12360.6 Pa.

Mthod - 2

(Changing fluid head technique)

Head of mercury changes into Head of water

let head of mercury = x

head of water = h

both Head are equivalent

$$h = x[S_m - 1]$$

$$h = \frac{10}{100}[13.6-1]$$

$$h = 0.1 \times 12.6 = 1.26 \text{ m}$$

so pressure in pipe is given as

$$P_A - \rho_w gh = P_{atm}$$

$$P_A - P_{atm} = 1000 \times 9.81 \times 1.26$$

$$(P_A)_{gauge} = 12360.6 \text{ Pa}$$

(c) What is Euler's equation of motion ? How will you obtain Bernoulli's equation from it ? **[15 Marks]**

Solution:

Assumption :

(a) The fluid is ideal
(b) The flow is steady
(c) The flow is incompressible
(d) The flow is irrotational

In this equation, we have taken forces due to gravity and pressure. Consider a cylindrical element of cross section *dA* and length *dl*. Some forces acting on the cylindrical element.

1. Pressure force in the direction of flow = pdA
2. Pressure force in the opposite direction of flow = $\left(p + \frac{\partial p}{\partial l} dl\right) dA$
3. Weight of cylindrical element = $\rho g dA dl$

Force acting on fluid element in l direction = mass of element × acceleration in l direction

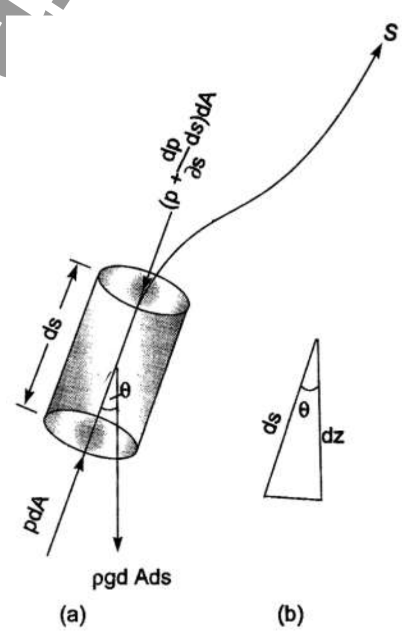


Fig. : *Forces on a fluid element.*

$$p.dA - \left(p + \frac{\partial p}{\partial l}.dl\right)dA - \rho g dA dl \cos\theta = \rho dA dl \times a_l \quad \text{..........(i)}$$

$\because$
$$a_l = \frac{dv}{dt} = \frac{\partial v}{dl}.\frac{dl}{dt} + \frac{\partial v}{\partial t}$$

$$a_l = v\frac{\partial v}{\partial l} \qquad \left[\frac{\partial v}{\partial t} = 0, \text{flow is steady}\right] \quad \text{..........(ii)}$$

Substitute the value of a_l in equation (i),

$$p.dA - pdA - \frac{\partial p}{\partial l}.dl.dA - \rho g dA dl \cos\theta = \rho dA dl.v\frac{\partial v}{\partial l}$$

$$\Rightarrow \qquad -\frac{\partial p}{\partial l}.dl.dA - \rho g dA dl \cos\theta = \rho dA dl \times v\frac{\partial v}{\partial s}$$

Dividing by $\rho dl dA$,

$$-\frac{\partial p\, dl dA}{\partial l\, .\, \rho dl dA} - \frac{\rho g dA dl \cos\theta}{\rho dl dA} = \frac{\rho dA dl}{\rho dl dA} \times v\frac{\partial v}{\partial l}$$

$$\frac{\partial p}{\rho \partial l} + g\cos\theta + v\frac{\partial v}{\partial l} = 0$$

$$\frac{1}{\rho}.\frac{\partial p}{\partial l} + g\frac{dz}{dl} + v\frac{\partial v}{\partial l} = 0 \qquad \left[\because \cos\theta = \frac{dz}{dl}\right]$$

$$\frac{\partial p}{\rho} + g\, dz + v dv = 0$$

Above equation known as Euler's equation of motion. And integrating the Euler's equation of motion. We get

$$\int \frac{dp}{\rho} + \int g\, dz + \int v dv = 0$$

$$\frac{p}{\rho} + gz + \frac{v^2}{2} = \text{Constant}$$

Above equation known as Bernoulli's Equation. If flow is incompressible, ρ is constant.

(d) Give the differences between impulse turbine and reaction turbine. [15 Marks]

Solution:

Impulse Turbine :

1. All hydraulic energy is converted into kinetic energy by a nozzle and it is the jet so produced which strikes the runner blades.
2. The velocity of jet changes, the pressure throughout remaining at atmospheric.
3. Water-tight casing is not necessary. Casing has no hydraulic function to perform, it only serves to prevent splashing and guide water to the tail race.
4. Water is admitted only in the form of jets. There may be one or more jets striking equal number of buckets simultaneously.
5. The turbine doesn't run full and air has a free access to the bucket.
6. The turbine is always installed above the tail race and there is no draft tube used.
7. Flow regulation is done by means of a needle valve fitted into the nozzle.
8. Example of impulse turbine is Pelton wheel.
9. Impulse turbines have more hydraulic efficiency.
10. Impulse turbine operates at high water heads.
11. Water flow is tangential direction to the turbine wheel.

12. Needs low discharge of water.
13. Degree of reaction is zero.
14. Need less maintenance.

Reaction Turbine :

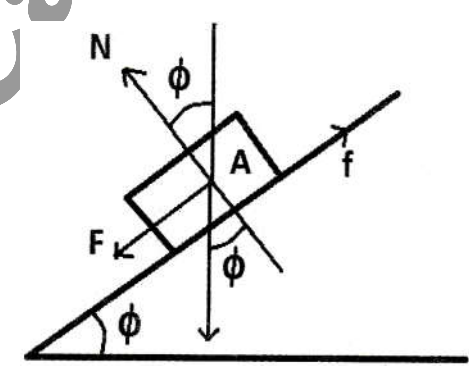
1. Only some amount of the available energy is converted into kinetic energy before the fluid enters the runner.
2. Both pressure and velocity changes as fluid passes through a runner. Pressure at inlet is much higher than at outlet.
3. The runner must be enclosed within a watertight casing.
4. Water is admitted over the entire circumference of the runner.
5. Water completely fills at the passages between the blades and while flowing between inlet and outlet sections does work on the blades.
6. Reaction turbine are generally connected to the tail race through a draft tube which is a gradually expanding passage. It may be installed below or above the tail race.
7. The flow regulation in reaction turbine is carried out by means of a guide-vane assembly. Other component parts are scroll casing, stay ring runner and the draft tub.
8. Examples of reaction turbine are Francis turbine, Kaplan and Propeller Turbine, Deriaz Turbine, Tubuler Turbine, etc.
9. Reaction turbines have relatively less efficiency.
10. Reaction turbines operate at low and medium heads.
11. Water flows in radial and axial direction to turbine wheel.
12. Needs medium and high discharge of water.
13. Degree of reaction is between '0' & '1'
14. More maintenance.

4. (a) Explain the following terms:
(i) Angle of repose
(ii) Angle of friction
(iii) Cone of friction

[15 Marks]

(i) Angle of repose :

The angle of repose is the maximum angle to which a surface can be tilted from the horizontal, such that an object on it is just able to stay on the surface without sliding on it.



Look at the diagram

When the block A is just about to move,

Friction force, $f = \mu N$

N is given as

$$N = W\cos\phi = mg\cos\phi$$

And force $F = mg\sin\phi$

At limiting condition

$$F = f = \mu N = mg \sin\phi$$

$$\mu mg \cos\phi = mg \sin\phi$$

$$\tan\phi = \mu$$

$$\phi = \tan^{-1} \mu$$

By the definition of angle of friction θ

$$\theta = \tan^{-1} \mu$$

$\Rightarrow$ $$\theta = \phi$$

$\therefore$ Angle of friction is equal to repose.

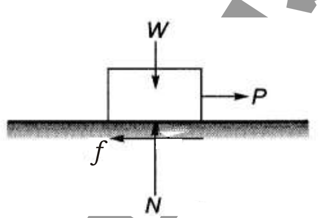
The angle of repose and of friction are essentially the same, given by the inverse tangent of the coefficient of the friction between the two surfaces;

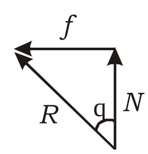
i.e. $$\phi = \theta = \tan^{-1} \mu$$

(ii) Angle of friction :

Angle of friction is defined as the angle made between the normal reaction force and the resultant force of normal reaction force and friction.

Consider the block shown in figure resting on a horizontal surface and subjected to horizontal pull *P*. Let *f* be the frictional force developed and *N* be the normal reaction. They can be combined graphically to get the reaction *R* which acts at angle θ to normal reaction. This angle θ, called the angle of friction.



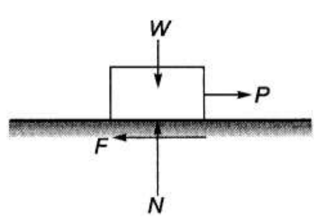


$$\tan\theta = \frac{F}{N}$$

Angle of friction, $\theta = \tan^{-1}\left(\frac{F}{N}\right)$

(iii) Coefficient of friction :

It shows relationship between the friction force between two surfaces and the normal force between two surfaces.



$$F = \mu N$$

Where F is the frictional force & N is the normal reaction

At limiting case

$$F = \mu N$$

Coefficient of friction, $\mu = \frac{F}{N}$

Coefficient of friction is of two types;

(a) Coefficient of static friction, μ_s : It is the coefficient of friction between two bodies when neither of the bodies are moving.

(b) Coefficient of kinetic friction, μ_k : It is the coefficient of friction between two bodies when, one body is moving or two bodies are moving against each other.

(b) A specimen of steel 20 mm diameter with a gauge length of 200 mm is tested to destruction. It has an extension of 0-25 mm under a load of 80 kN and the load at elastic limit is 102 kN. The maximum load is 130 kN. The total extension at fracture is 56 mm and diameter at neck is 15 mm. Calculate :

(i) Stress at elastic limit

(ii) Young's modulus

(iii) Percentage reduction in area

(iv) Percentage elongation

(v) Ultimate tensile stress **[15 Marks]**

Solution :

(b) Given ,

$d_0 = 20$ mm

$L_0 = 200$ mm

$(\delta L)_1 = 0.25$ mm at

$P_1 = 80$ kN

Load at Elastic limit, $P_2 = 102$ kN

Maximum load, $P_3 = 130$ kN

$(\delta L)_{Total} = 56$ mm

$(d)_{neck} = 15$ mm

(i)
$$\sigma_{\text{Elastic limit}} = \frac{\text{Load at Elastic limit}}{\text{Cross - sectional Area}}$$

$$= \frac{102 \times 10^3}{\frac{\pi}{4} \times 20^2} = 324.67 \text{ MPa}$$

(ii)
$$E = \frac{\sigma}{\varepsilon} = \frac{P_1 / A_0}{(\delta L)_1 / L_0} = \frac{\frac{80 \times 10^3}{\frac{\pi}{4} \times 20^2}}{\frac{0.25}{200}}$$

$$= 203718 \text{ MPa} = 203.7 \text{ GPa}$$

(iii)
$$\% \text{ reduction in Area} = \frac{A_0 - A_{neck}}{A_0} \times 100$$

$$= \frac{\frac{\pi}{4}(20^2) - \frac{\pi}{4}(15^2)}{\frac{\pi}{4}(20^2)} \times 100 = 43.75\%$$

(iv)
$$\%\ \text{elongation} = \frac{L_{final} - L_{initial}}{L_{initial}} \times 100$$

$$= \frac{(L_0 - \delta L_{Total}) - L_0}{L_0} \times 100$$

$$= \frac{256 - 200}{200} \times 100 = 28\%$$

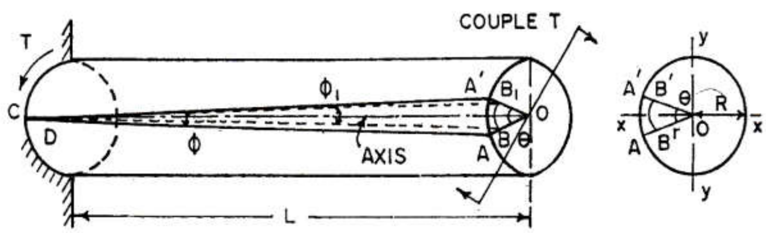
(v)
$$\sigma_u = \frac{\text{Maximum load}}{\text{Cross - section Area}} = \frac{130 \times 10^3}{\frac{\pi}{4} \times 20^2} = 413.8 \text{ MPa}$$

(c) Derive an expression for the shear stress produced in a circular shaft which is subjected to torsion. [15 Marks]

Solution:

Assumptions :

1. Shaft is loaded with twisting couples in planes that are perpendicular to the axis of the shaft.
2. Torsion is uniform along the length i.e. all normal cross-section which are at the same axial distance suffer equal relative rotations.
3. Circular sections remain circular. Thus radii remain straight after torsion.
4. Plane normal sections of shaft remain plane after twisting, i.e. no warping or distortion of parallel planes normal to the axis of the shaft takes place.
5. Stress is proportional to strain, i.e. stresses do not exceed proportional limit.
6. Material is homogeneous and isotropic.



Let, T = Torque transmitted by the shaft
t = Maximum shear stress
R = External radius of shaft
q = angle of twist
G = Modulus of rigidity
L = Length of the shaft

If t is maximum shear stress induced at the surface of the shaft, then strain f is given by

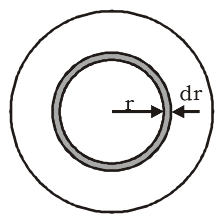
$$f = \frac{\tau}{G} \qquad \text{..........(i)}$$

Also,
$$f = \frac{AA'}{L} = \frac{OA.\theta}{L} = \frac{R\theta}{L} \qquad \text{..........(ii)}$$

From equation (i) and (ii), we get

$$\frac{\tau}{R} = \frac{G\theta}{L} \qquad \text{..........(iii)}$$

Consider an elemental ring at r distance from the distance as shown in fig.



Let shear stress at this strip is t_r.

The turning force on the ring = $\tau_r \times 2pr \times dr$

So, Turning moment, dT = turning force × radius

$= t_r \times 2pr \times dr \times r$

$= 2\,p\,r^2\,dr.T_r = 2\pi r^2 dr.\frac{r}{R}\tau$

$= 2\pi r^3 dr.\frac{\tau}{R}$

Hence, turning moment T set up by the whole section of the shaft is

$$T = 2\pi\frac{\tau}{R}\int_o^R r^3 dr$$

$$T = 2\pi\frac{\tau}{R}\left[\frac{r^4}{4}\right]_o^R$$

$$T = 2\pi\frac{\tau}{R}.\frac{R^4}{4} = \frac{\pi R^3}{2}.\tau$$

$$= \frac{\pi D^3}{16}.\tau$$

$$= \frac{\pi D^4}{32}.\frac{\tau}{(D/2)}$$

$$= J.\frac{\tau}{(D/2)} = J.\frac{\tau}{R} \qquad \text{..........(iv)}$$

Here, J or I_p is the polar moment of inertia of the shaft cross-section

$$J = \frac{\pi D^4}{32}$$

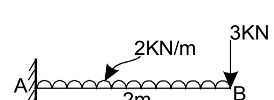
From equation (iii) & (iv),

So, $$\frac{T}{J} = \frac{\tau}{R} = \frac{G\theta}{L}$$

(d) A cantilever of length 2 m carries a uniformly distributed load of 2 kN/m length over the whole length and a point load of 3 kN at the free end. Draw the shear force and bending moment diagrams. [15 Marks]

Solution:

Reaction at A :



$$R_A = 3 + 2 \times 2 = 7 \text{ kN}$$

shear force:

$$F_A = 7 \text{ kN}$$

$$F_{B^-} = 7 - 2\times2 = 3 \text{ kN}$$

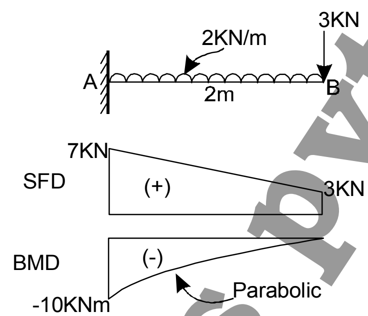
$$F_{B^+} = 3 - 3 = 0$$

Bending Moment :

$$M_B = 0$$

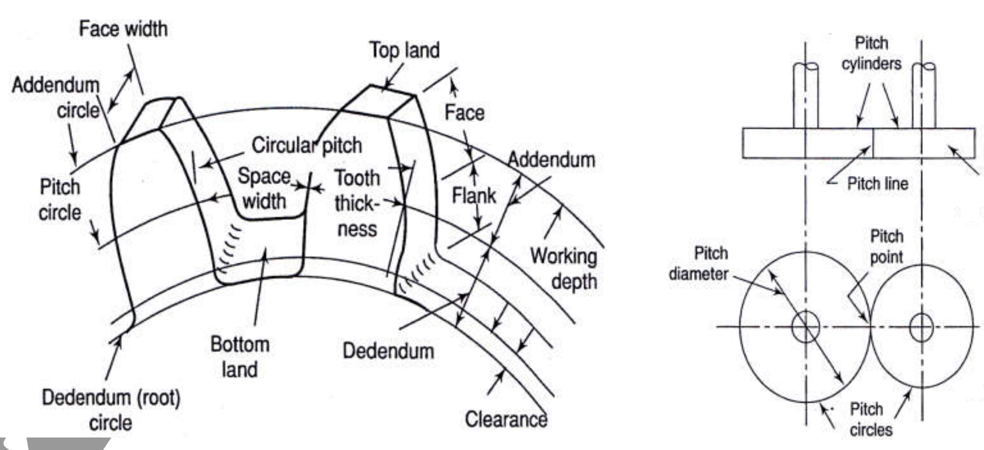
$$MA = -(3\times2) - (2\times2\times\frac{2}{2})$$

$$= -6 - 4 = -10 \text{ kN-m}$$



5. (a) Derive the condition for transmitting the maximum power in a belt drive. [15 Marks]
(b) With the help of a diagram, define the terminologies of a gear. [15 Marks]
Solution:

Gear Terminology :



(i) **Pitch Circle :** It is the circle corresponding to a section of the equivalent pitch cylinder by a plane normal to the wheel axis.
(ii) **Pitch Diameter :** It is the diameter of the pitch cylinder.
(iii) **Pitch Point :** The point of contact of two pitch circles is known as the pitch point.
(iv) **Line of Centres :** A line through the centres of rotation of rotation of a pair of mating gears is the line of centres.
(v) **Circular Pitch (p) :** It is the distance measured along the circumference of the pitch circle from a point on one tooth to the corresponding point on the adjacent tooth.

$$p = \frac{\pi d}{T}$$

Where, p = circular pitch
d = pitch diameter
T = number of teeth

(vi) **Diametral Pitch (P) :** It is the number of teeth per unit length of the pitch circle diameter in inches.

$$P = \frac{T}{d}$$

(vii) **Module (m) :** It is the ratio of the pitch diameter in mm to the number of teeth. The term is used in SI units in place of diametral pitch.

$$m = \frac{d}{T}$$

(viii) **Addendum Circle :** It is a circle passing through the tips of teeth.

(ix) **Addendum :** It is the radial height of the tooth above the pitch circle. Its standard value is one module.

(x) **Dedendum or Root Circle :** It is a circle passing through the roots of the teeth.

(xi) **Dedendum :** It is the radial depth of a tooth below the pitch circle. Its standard value is 1.57m.

(xii) **Clearance :** Radial difference between the addendum and the dedendum of a tooth. Thus,

Addendum circle diameter = d + 2m

Dedendum circle diameter = d – 2 × 1.157m

Clearance = 1.157m – m = 0.157m

(xiii) **Full Depth of Teeth :** It is the total radial depth of the tooth space.

Full depth = Addendum + Dedendum

(xiv) **Working Depth of Teeth :** The maximum depth to which a tooth penetrates into the tooth space of the mating gear is the working depth of teeth.

Working Depth = Sum of addendums of the two gears.

(xv) **Space Width :** It is the width of the tooth space along the pitch circle.

(xvi) **Tooth Thickness :** It is the thickness of the tooth measured along the pitch circle.

(xvii) **Backlash :** It is the difference between the space width and the tooth thickness along the pitch circle.

Backlash = Space width – Tooth thickness

(xviii) **Face Width :** The length of the tooth parallel to the gear axis is the face width.

(xix) **Top Land :** It is the surface of the top of the tooth.

(xx) **Bottom Land :** The surface of the bottom of the tooth between the adjacent fillets.

(xxi) **Face :** Tooth surface between the pitch circle and the top land.

(xxii) **Flank :** Tooth surface between the pitch circle and the bottom land including fillet.

(xxiii) **Fillet :** It is the curved portion of the tooth flank at the root circle.

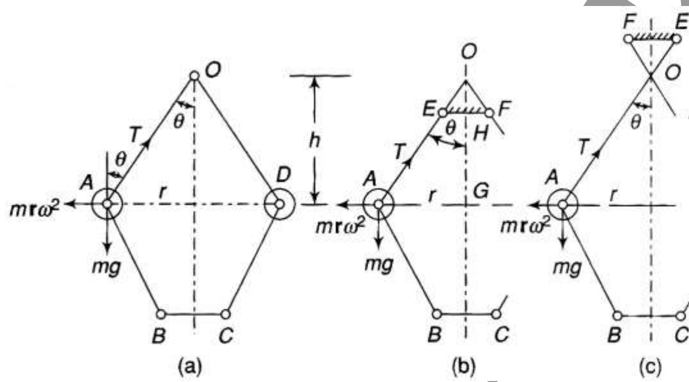
(c) **Explain the term "height of the governor". Derive an expression for the height in the case of a watt governor.** **[15 Marks]**

Solution:

Watt Governor (Simple Conical Governor) : It is a pendudum type governor, figure shows upper links are connected by a horizontal link and the governor is known as the open-arm type Watt governor. On extending the upper arms, they still meet at O. In Fig. (c), the upper links cross the spindle and are connected by a horizontal link and the governor is known as a crossed-arm Watt governor. In this type also, the two links intersect at O. The lower links in every case are fixed to a sleeve free to move on the vertical spindle.

As the spindle rotates, the balls take up a position depending upon the speed of the spindle. If it lowers, they move near to the axis due to reduction in the centrifugal force on the balls and the ability of the sleeve to slide on the spindle.

The vertical distance from the plane (horizontal) of rotation of the balls to the point of intersection of the upper arms along the axis of the spindle is called the height of the governor. The height of the governor decreases with increase in speed, and increases with decrease in speed.



Let, m = mass of each ball

h = height of governor

w = weight of each ball (= mg)

ω = angular velocity of the balls, arms and the sleeve

T = tension in the arm

r = radial distance of ball-centre from spindle-axis

Assuming the links to be massless and neglecting the friction of the sleeve, the mass m at A is in static equilibrium under the action of

- Weight w (= mg)
- Centrifugal force $mr\omega^2$
- Tension T in the upper link

If the sleeve is massless and also friction in neglected, the lower links will be tension free.

The equilibrium of the mass provides

$$T\cos\theta = mg \quad \text{and} \quad T\sin\theta = mr\omega^2$$

$$\therefore \quad \tan\theta = \frac{mr\omega^2}{mg} = \frac{r\omega^2}{g}$$

$$\frac{r}{h} = \frac{r\omega^2}{g}$$

$$h = \frac{g}{\omega^2} = \frac{g}{\left(\frac{2\pi N}{60}\right)} = \left(\frac{60}{2\pi}\right)^2 \times \frac{9.81}{N^2}$$

or $$h = \frac{895}{N^2} mm$$

or $$h = \frac{895000}{N^2} mm$$

Thus, the height of a Watt governor is inversely proportional to the square of the speed.

(d) Write short notes on cams and followers. **[15 Marks]**

Solution:

A cam is mechanical member used to impart desired motion to a follower by direct contact. The cam may be rotating or reciprocating whereas the follower may be rotating, reciprocating or oscillating. Complicated output motions which are otherwise difficult to achieve can easily be produced with the help of came. Cams are widely used in automatic machines, internal combustion engines, machine tools, printing control mechanisms, and so on. They are manufactured usually by die-casting, milling or by punch-presses.

Types of Followers :

Cam followers are classified according to the

1. Shape,
2. Movement, and
3. Location of line of movement.

1. According to Shape :

(i) Knife-edge follower: It is quite simple in construction. Figure 1(a) shows such a follower. However, its use is limited as it produces a great wear of the surface at the point of contact.

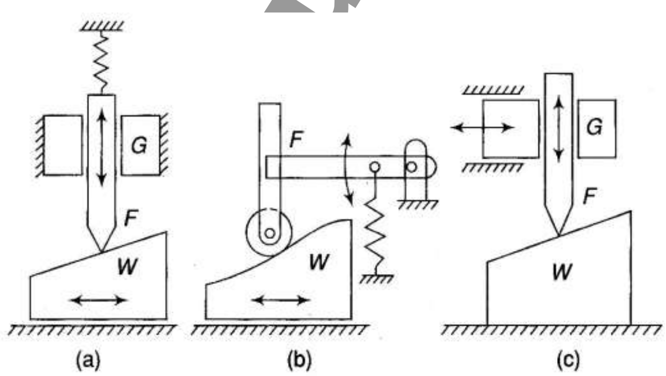


Fig.1

(ii) Roller follower : It is a widely used cam follower and has a cylindrical roller free to rotate above pin joint [Figs 1(b)]. At low speeds, the follower has a pure rolling action but at high speeds, some sliding also occurs.

(iii) Mushroom follower : A mushroom follower (Fig. 2) has the advantage that it does not pose the problem of jamming the cam. However, high surface stresses and wear are quite high due to deflection and misalignment if a flat-faced follower is used [Fig. 2(a)]. These disadvantages are reduced if a spherical-faced follower [Fig. 2(b)] is used instead of a flat-faced follower.

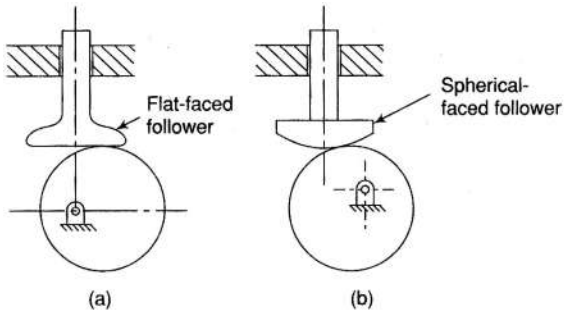


Fig.2

2. According to Movement :

(i) Reciprocating Follower : In this type, as the cam rotates, the follower reciprocates or translates in the guides [Fig. 1(a)].

(ii) Oscillating Follower : The follower is pivoted at a suitable point on the frame and oscillates as the cam makes the rotary motion [Fig. 1(b)].

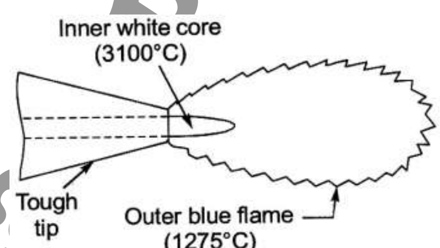
3. According to Location of Line of Movement :

(i) Radial Follower : The follower is known as a radial follower if the line of movement of the follower passes through the centre of roation of the cam [Figs 2(a) and (b)].

(ii) Offset Follower : If the line of movement of the roller follower is offset from the centre of rotation of the cam, the follower is known as an offset follower [Fig.

6.(a) WIth the help of diagrams, explain the different types of flames obtained in the oxy- acetylene gas welding process. Also give the advantages and disadvantages of oxy- acetylene gas welding. [15 Marks]

Solution :



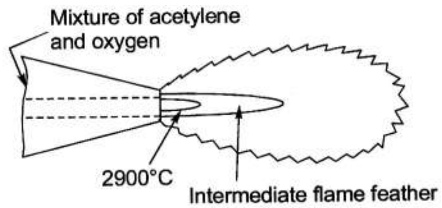
Schematic of an oxy-acetylene gas-welding flame (neutral flame)

Neutral Flame :

- In any neutral flame, there is one to one ratio of acetylene and oxygen.
- It obtains additional oxygen from the air and provides complete combustion. It is generally preferred for welding.
- The neutral flame has a clear, well-defined, or luminous cone indicating that combustion is complete.
- Neutral welding flames are commonly used to weld:
  - Mild steel
  - Stainless steel
  - Cast Iron
  - Copper
  - Aluminum

Carburizing Flame :

The carburizing flame has excess acetylene, the inner cone has a feathery edge extending beyond it. This white feather is called the acetylene feather. If the acetylene feather is twice as long as the inner cone it is known as a 2X flame, which is a way of expressing the amount of excess acetylene. The carburizing flame may add carbon to the weld metal.

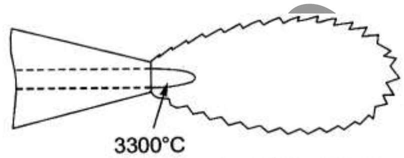


Carburizing flame

When a strongly carburizing flame is used for welding, the metal boils and is not clear. The steel, which is absorbing carbon from the flame, gives off heat. This causes the metal to boil. When cold, the weld has the properties of high carbon steel, being brittle and subject to cracking.

Oxidizing Flames :

- Oxidizing welding flames are produced when slightly more than one volume of oxygen is mixed with one volume of acetylene. To obtain this type of flame, the torch should first be adjusted to a neutral flame. The flow of oxygen is then increased until the inner cone is shortened to about one-tenth of its original length.



Oxidizing flame

- When the flame is properly adjusted, the inner cone is pointed and slightly purple. An oxidizing flame can also be recognized by its distinct hissing sound.
- Oxidizing welding flames are commonly used to weld these metals:
  - zinc
  - copper
  - manganese steel
  - cast iron

Advantages and disadvantages of oxy acetelene gas welding.

Advantages:-

(i) It is easy to learn.

(ii) the equipment is cheaper than most other types of welding rigs.

(iii) The equipment is more portable than most other types of welding rigs.

(iv) Oxy-acetylene equipment can also be use to "flame cut" large pieces of waterial.

Disadvantages

(i) Oxy-acetylene weld lines are much rougher in appearance than other kinds of welds

(ii) Oxy-acetylene welds have large heat affacted zones (areas around the weld line that have had their mechanical properties adversely affected by the welding process)

(b) Briefly explain the different types of defects in the casting process and their remedies.

[15 Marks]

Solution :

Following are the common defects of casting :

1. Blowhole :

Blowhole is a kind of cavities defect, which is also divided into pinhole and subsurface blowhole. Pinhole is very tiny hole. Subsurface blowhole only can be seen after machining. Gases entrapped by solidifying metal on the surface of the casting, which results in a rounded or oval blowhole as a cavity. Frequently associated with slag's or oxides. The defects are nearly always located in the cope part of the mould in poorly vented pockets and undercuts.

Causes :

(i) Inadequate core venting
(ii) Excessive release of gas from core
(iii) Excessive moisture absorption by the cores
(iv) Low gas permeability of the core sand
(v) Moisture content of sand too high, or water released too quickly
(vi) Gas permeability of the sand too low
(vii) Sand temperature too high
(viii) Too much gas released from lustrous carbon producer

Remedies :

(i) Improve core venting, provide venting channels, ensure core prints are free of dressing
(ii) Reduce amounts of gas. Use slow-reacting binder. Reduce quantity of binder. Use coarser sand if necessary.
(iii) Apply dressing to cores, thus slowing down the rate of heating and reducing gas pressure.
(iv) Dry out cores and store dry, thus reducing absorption of water and reducing gas pressure.
(v) Reduce moisture content of sand. Improve conditioning of the sand. Reduce inert dust content.
(vi) Improve gas permeability. Endeavour to use coarser sand.
(vii) Reduce sand temperature. Install a sand cooler if necessary. Increase sand quantity.

2. Cold shut :

It is a crack with round edges. Cold shut is because of low melting temperature or poor gating system. When the metal is unable to fill the mould cavity completely and thus leaving unfilled portion called miss-run.

Causes :

(i) Lack of fluidity in molten metal
(ii) Faulty design
(iii) Faulty gating

Remedies :

(i) Adjust proper pouring temperature
(ii) Modify design
(iii) Modify gating system

3. Miss-run :

Miss-run defect is a kind of incomplete casting defect, which causes the casting uncompleted. The edge of defect is round and smooth. When the metal is unable to fill the mould cavity completely and thus leaving unfilled portion called miss-run.

Causes :

(i) Lack of fluidity in molten metal
(ii) Faulty design
(iii) Faulty gating

Remedies :

(i) Adjust proper pouring temperature
(ii) Modify design
(iii) Modify gating system

4. Porosity :

The gas can be from trapped air, hydrogen dissolved in aluminum alloys, moisture from water based die lubricants or steam from cracked cooling lines.

Causes :

(i) Metal pouring temperature too low.
(ii) Insufficient metal fluidity
(iii) Pouring too slow
(iv) Slag on the metal surface.
(v) Interruption to pouring during filling of the mould.
(vi) High gas pressure in the mould
(vii) Low permeability.
(viii) Metal section too thin.

Remedies :

(i) Increase metal pouring temperature.
(ii) Modify metal composition to improve fluidity.
(iii) Pour metal as rapidly as possible
(iv) Remove slag from metal surface and clean it properly
(v) Reduce gas pressure in the mould
(vi) Ensure adequate venting of moulds and cores

5. Distortion :

Distortion in the casting may come and can cause residual stresses in the casted parts.

Causes :

(i) Improper design
(ii) Improper filling of mould.
(iii) Too high temperature of molten metal
(iv) Less dry strength of the moulding sand.

Remedies :

(i) Heat treatment after the casting
(ii) Improve casting design
(iii) Use proper sand as per requirement.

6. Casting cracks :

Cracks can appear in castings from a number of causes. Some cracks are very obvious and can easily be seen with the naked eye. Other cracks are very difficult to see without magnification.

Causes :

(i) Shrinkage of the casting within the die
(ii) Damages in die cavities
(iii) Uneven, or excessive, ejection forces
(iv) Improper draft of the die
(v) Product design improper
(vi) Inadequate die design

Remedies :

(i) Use chills for proper cooling
(ii) Improve casting design
(iii) Use defect free die

(iv) Simplify the design

(c) Explain the different taper turning methods used in the Lathe machine tool. [15 Marks]

Solution :

To create cylindrincal parts from bar stock, manual lathes are used. The most complex turned parts often have a tapered form.

(i) A taper is a uniform change in the diameter of a workpiece when measured along its axis. While tapers created on a lathe are cylindrical, a taper created on a mill can be flat-sided or angular, like a wedge.

(ii) Tapers are common in machine tool components because tapers give an accurate way to align parts and hold tools.

(iii) For example, machine tool spindles have internal tapers that provide firm and reliable placement of tool holders and work holders.

(iv) A number of standard tapers are used in machine tools, such as the Morse taper often found in lathe spindles and tailstocks. Turning a taper on a lathe can be complicated, depending on the method chosen to perform the operation. Simply put, a taper is created by angling the workpiece and cutting tool relative to one another as the tool travels along the workpiece.

(v) As the tool travels along the workpiece, it gradually cuts deeper or shallower, creating a tapered surface.

(vi) Turning a taper on a lathe is done in one of three ways. The easiest is to use a taper attachment, although not every lathe is equipped with this option. Taper attachments are especially useful for long tapers without a steep angle, because the guide can be attached to the back of the lathe bed.

(vii) A guide shoe travels along the taper bar, which is set to the desired taper angle, measured in degrees of taper. The guide shoe is attached to the cross-slide and moves the cross-slide at an angle to create the taper as the carriage moves the tool holder.

(viii) Turning a steep taper with a shorter overall length can be accomplished by using the compound rest method. The work can be mounted between centers or in a chuck, and only the rest needs to be set for the operation. However, the scale on the rest is typically graduated in 1° increments, so accuracy is sometimes difficult to achieve.

(d) With the help of a diagram, explain two different methods of the milling process. [15 Marks]

Solution :

Classification of Milling Machines are as follows :

1. Column and knee type milling machines
   (a) Plain column & knee type milling machine
      - Horizontal spindle type
      - Vertical spindle type
2. Bed type milling machine
3. Planer type milling machine
4. Special purpose milling machine
   (a) Tracer controlled milling machine
   (b) Thread milling machine
   (c) CNC milling machine

Based on direction of movement of the milling cutter and the feeding direction of the work piece, there are two types of milling operations-

1. Up Milling : The cutting tool rotates in the opposite direction to the table movement. The chip starts as zero thickness and gradually increases to the maximum size. This tends to lift the work piece from the table. Tool may rub the work piece before starting the material removal. Initial rubbing of tool with work piece causes to dull the cutting edge and lowers the tool life. Due to the sliding of tool machining marks may appear on machined surface.

2. Down Milling : The cutting tool rotates in the same direction as that of the table movement. The chip starts as maximum thickness and goes to zero thickness gradually. This is suitable for fine surface finish. It is good for thin work pieces because cutting force will act downward. This requires rigid lead screw for table feeding because backlash is prominent.

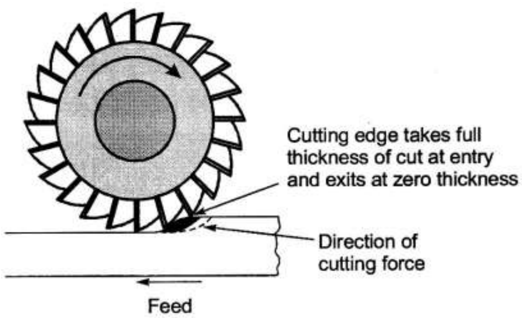


Fig. : *Down Milling*

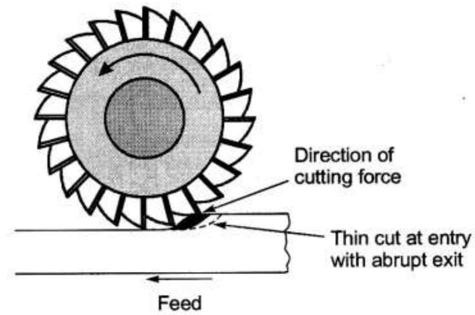


Fig. : *Up Milling*