ELEMENTARY MECHANICAL ENGINEERING

3RD SEMESTER – METALLURGY

KIIT POLYTECHNIC, BHUBANESWAR

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CONTENT

Shear Force & Bending Moment

BEAM:

- ♣ It is a member of a structure which can carry forces or couple acting on it.

TYPES OF BEAM:

- ♣ **Cantilever beam:** It is a beam whose one end is fixed and other end is free.
- ♣ **Simply supported beam:** It is a beam whose both ends are freely supported.
- ♣ **Overhanging beam:** It is a beam which is freely supported at any two points and having one or both ends projected beyond these two supports.
- ♣ **Continuous beam:** It is a beam which is supported at more than two supports.
- ♣ **Fixed beam:** It is a beam whose both ends are fixed or built into its supports.

TYPES OF LOADING:

- ♣ **Concentrated or point load:** It is a load which acts at a point on the beam.
- ♣ **Uniformly distributed load:** It is a load which spreads over the entire length or part of the length of the beam at a uniform rate.
- ♣ **Non-uniformly distributed or uniformly varying load:** It is a load which spreads over the entire length or part of the length of the beam at a non uniform rate.

SHEAR FORCE:

- ♣ Shear force at any cross section of the beam is the algebraic sum of the vertical components of the forces acting on the beam.

BENDING MOMENT:

- ♣ The bending moment at any point on a loaded beam is the algebraic sum of the moments of all the forces acting on one side of the point about the point.

SHEAR FORCE DIAGRAM:

- ♣ It is the diagram which represents the variation/distribution of shear force along the length of the beam.

BENDING MOMENT DIAGRAM:

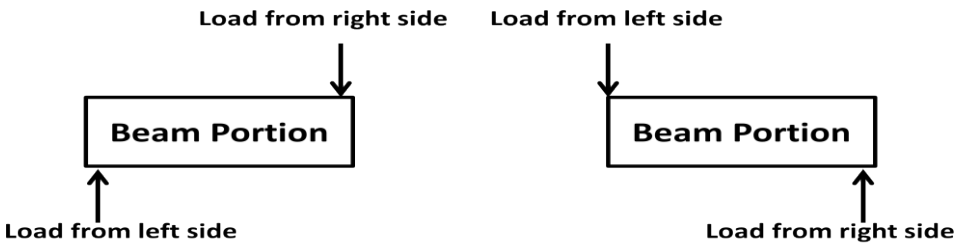
- ♣ It is the diagram which represents the variation/distribution of bending moment along the length of the beam.

SIGN CONVENTION:

Sign convention is always selected according to the selection of the beam either from the left or right side of the beam.

Sign convention of shear force:

- ♣ Shear force is taken as positive, if the left hand portion of the beam tends to slide upwards and right hand side of the beam tends to slide downward. (figure - 1)
- ♣ Shear force is taken as negative, if the left hand portion tends to slide downwards and the right hand side tends to slide upwards. (figure - 2)

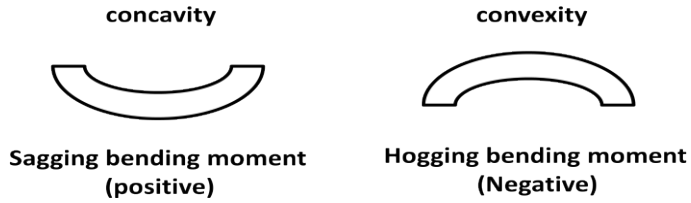


(Positive shear force) *(Negative shear force)*

FIG-1 FIG-2

Sign convention of bending moment:

- ♣ Moment due to all downward forces is taken as negative (hogging moment) and the moment due to all upward forces (sagging moment) are taken as positive.
- ♣ BM is taken as positive, if it is acting in clockwise direction to the left or in anticlockwise direction to the right.
- ♣ BM is taken as negative, if it is acting in anticlockwise direction to the left or in clockwise direction to the right.



SAGGING BENDING MOMENT:

- ♣ It represents the positive bending moment. If the bending moment tends to bend the beam to produce concavity at the point of curvature, the bending moment is known as sagging bending moment.

HOGGING BENDING MOMENT:

- ♣ It represents the negative bending moment. If the bending moment tends to bend the beam to produce convexity at the point of curvature, the bending moment is known as hogging bending moment.

RELATION BETWEEN LOADING, SHEAR FORCE AND BENDING MOMENT:

- ♣ If there is a point load at any section of a beam, then the SF suddenly changes but the BM does not change. The SF line is vertical.
- ♣ If there is no load between any two points of a beam section SF does not change but the BM changes linearly. The SF line is horizontal but BM line is an inclined straight line.
- ♣ If there is a U.D.L between two points, then the SF changes linearly and BM changes according to parabolic law. The SF line is an inclined straight line but the BM line is a parabola.

(*Solve numerical from cantilever, simply supported and overhang beam*)

Chapter End

SIMPLE MECHANISM

Q.1) Explain the term kinematic link?

Ans) ***Kinematic link*:** Each part of a machine which moves relative to some other part is called a kinematic link.

Explanation:

From the above Reciprocating steam engine (Slider crank mechanism) kinematic links are:

Link (1) - Frame & guides, Link (2) - Crank, Link (3) - Connecting rod, Link (4) – Slider.

Q.2) What is a kinematic pair? Explain different types of kinematic pairs?

Ans) ***Kinematic pair*:** The two links of a machine when in contact with each other are said to form a kinematic pair.

***Classification of kinematic pairs*:**

(a) *According to nature of relative motion*:

- **Sliding Pair:** If one link of a pair has a sliding motion relative to other, then the pair is called as sliding pair.
  Example: Rectangular rod in a rectangular hole.

- **Turning Pair / Revolving Pair:** If one link of a pair has a revolving motion relative to the other, then the pair is called as turning pair.
  Example: Circular shaft revolving in a bearing.

- **Rolling Pair:** If one link of a pair has a rolling motion relative to the other, then the pair is called as rolling pair.
  Example: Ball & roller bearings, and a rolling wheel on a flat surface.

- **Screw Pair / Helical Pair:** If two mating links of a pair have a turning as well as sliding motion between them, then the pair is called as screw pair.
  Example: Lead Screw & the Nut of a Lathe.

- **Spherical Pair:** When one link in the form of a sphere turns inside a fixed link, then the obtained pair is called as spherical pair.

Example: Ball & Socket Joint.

(b) *According to nature of contact*:

- **Lower Pair:** A pair of links having surface or area contacts between the members is called as lower pair.

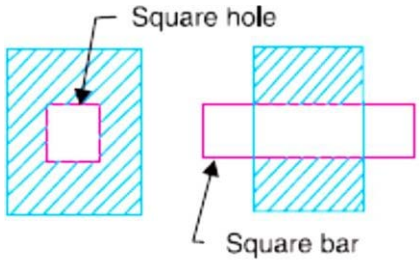
  Example: All pairs of Slider crank mechanism, nut turning on a screw, and shaft rotating in bearing.

- **Higher Pair:** A pair of links having a point or line contact between the members is called as higher pair.
  Example: Wheel rolling on a surface, cam & follower, and tooth gears.

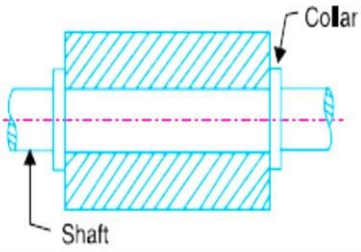
(c) *According to the nature of mechanical constraint or type of closure*:

- **Closed pair / Self closed pair:** When the elements of a pair are held together mechanically, then the pair is called as closed pair
  Example: All Lower pairs & some higher pairs.

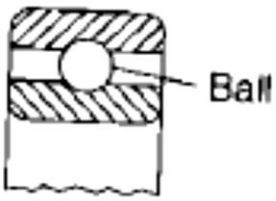
- **Unclosed / forced closed pairs:** When two links of a pair are in contact either due to force of gravity or some spring action, then the pair is called as unclosed pair.
  Example: Cam & Follower pairs.



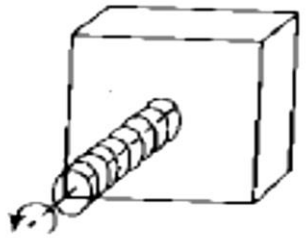
(Sliding Pair)



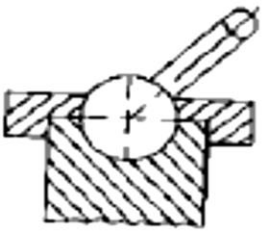
(Turning Pair)



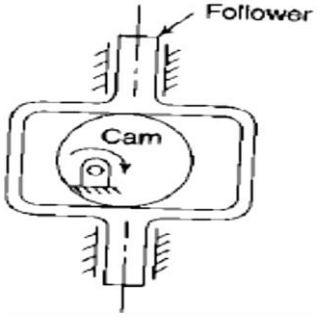
(Rolling Pair)



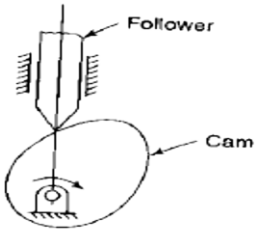
(Screw Pair)



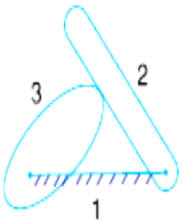
(Spherical Pair)

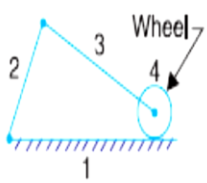


(Closed Pair)

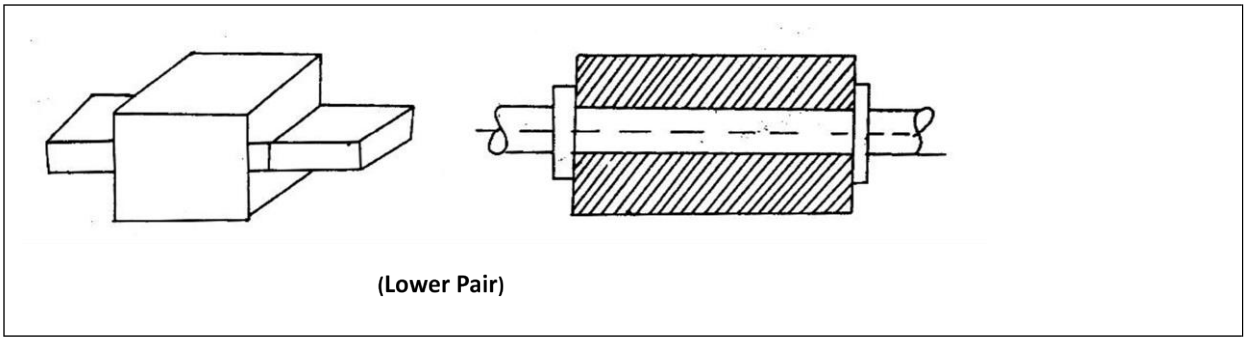


(Unclosed Pair)





(Higher Pair)



(Lower Pair)

Q.3) Define Kinematic chain.

Ans) ***Kinematic Chain*:** When the kinematic pairs are coupled in such a way that last link is joined to the first link to transmit definite motion, it is called as kinematic chain.

Q.4) Define Inversion of mechanism?

Ans) Inversion is the method of obtaining different mechanisms by fixing different links in a kinematic chain.

Q.5) Distinguish between 'Machine' and 'Mechanism'.

Ans) ***Machine*:**

- It is a mechanism which receives energy and transforms it into some useful work.
- A machine transmits power & performs some particular type of work.
- All machines are mechanisms.

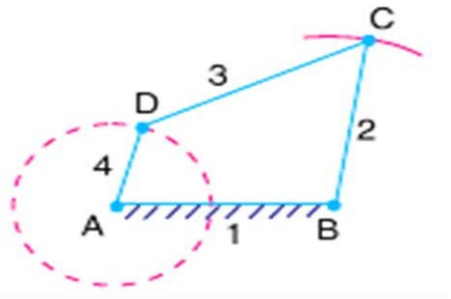
***Mechanism*:**

- When one of the links of a kinematic chain is fixed, then it is known as mechanism. Thus mechanism is a constrained chain.
- A mechanism transmits & modifies a motion.
- All mechanisms are not machines.

Q.6) Describe the four bar chain mechanism and its inversions.

Ans) ***Four Bar Chain / Quadric Cycle Chain***:

- It consists of four rigid links which are connected in the form of a quadrilateral by four pin-joints.
- A link makes complete revolution is called Crank (4).
- The link which is fixed is called fixed link (1).
- The link opposite to the fixed link is called Coupler (3).
- The fourth link is called Lever or Rocker (2).
- It is impossible to have a four bar linkage, if the length of one of the links is greater than the sum of the other three.
- *Grashof's Law*: For a four bar mechanism, the sum of the shortest and longest link lengths should not be greater than the sum of the remaining two link lengths.



(Four bar chain)

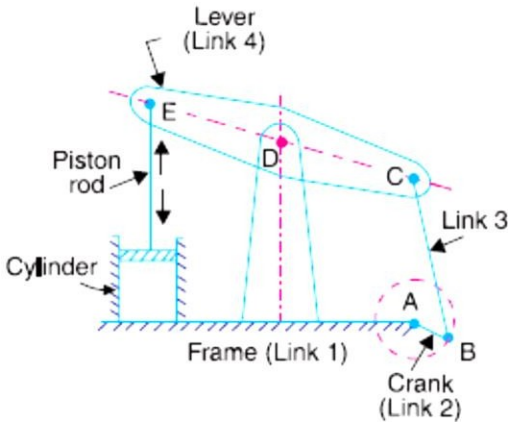
INVERSIONS OF FOUR BAR CHAIN:

(i) *First Inversion* (Crank & Lever Mechanism):

Example:- Beam Engine

In this mechanism the crank rotates aboutthe fixed centre A and the lever oscillatesabout a fixed centre D.

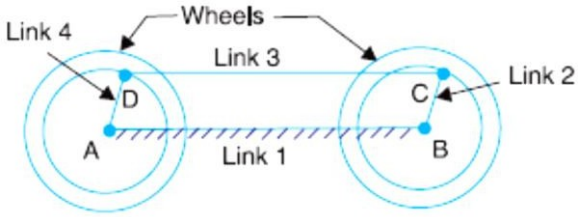
The purpose of this mechanism is to convert rotary motion into reciprocatingmotion.



(ii) *Second Inversion* (Double Crank mechanism):

Example: Coupling Rod of a Locomotive (Double Crank Mechanism):

In this mechanism the two links 2 and 4 respectively are transmitting rotarymotion between them. They are rotating with respect to link 1.

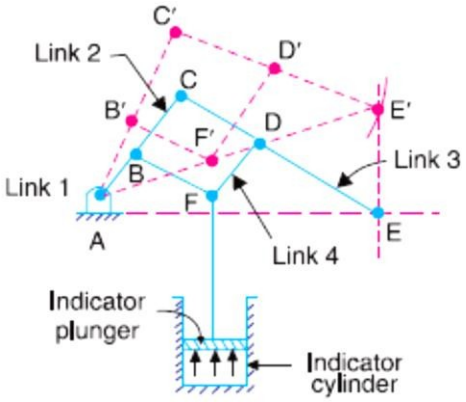


(iii) *Third Inversion* (Double Lever mechanism):

Example: Watt’s indicator (Double Lever Mechanism):

It consists of four links which are: Fixed link at A, link AC, link CE and link BFD. The links CE and BFD act aslever.

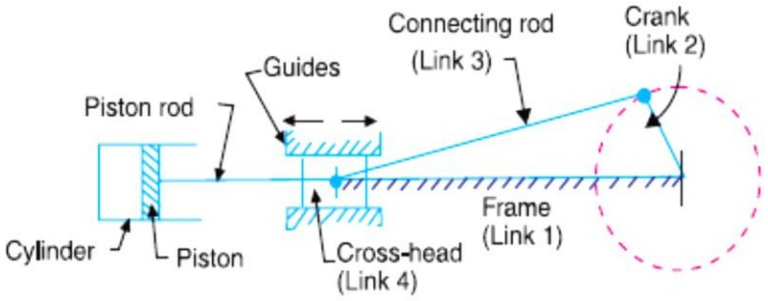
It is also called Watt's straight line mechanism and the dotted line shows the position of the mechanism.



Q.7) Sketch and describe the various inversions of a Slider Crank Chain?

Ans) ***Slider Crank Chain***:

- When one of the turning pairs of a four bar chain is replaced by a sliding pair, it becomes a single slider crank chain.
- It consists of one sliding pair and three turning pairs.
- In a single slider crank chain as shown in the above figure, the links 1&2, links 2&3, and links 3&4 form three turning pairs while the links 4&1 form a slider pair.

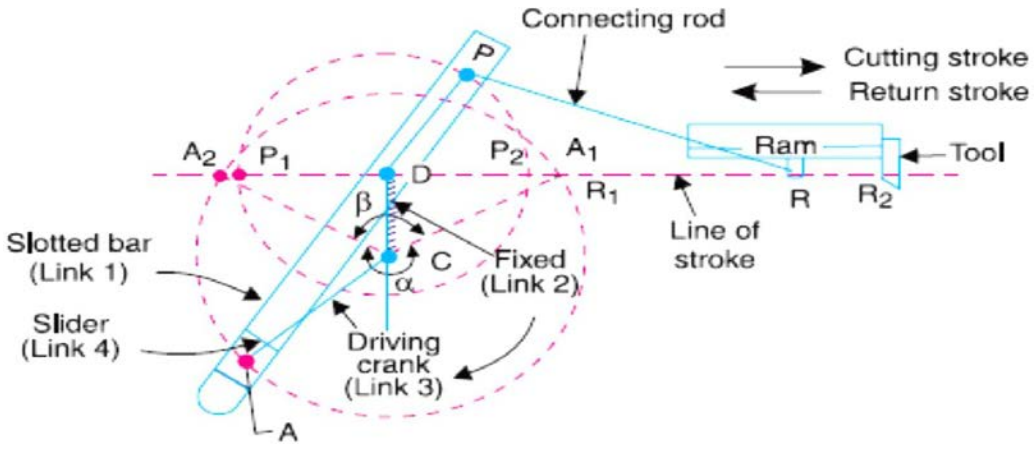


Q.8) Sketch and explain the quick return mechanism?

Ans) *Whitworth quick-return mechanism***:**

- This mechanism used in shaping and slotting machines.
- In this mechanism the link CD (link 2) forming the turning pair is fixed; the driving crank CA (link 3) rotates at a uniform angular speed and the slider (link 4) attached to the crank pin at A slides along the slotted bar PA (link 1) which oscillates at D.
- The connecting rod PR carries the ram at R to which a cutting tool is fixed and the motion of the tool is constrained along the line RD produced.
- The length of effective stroke = 2 PD. And mark $P_1R_1 = P_2R_2 = PR$.

$$\frac{\text{Time of cutting stroke}}{\text{Time of return stroke}} = \frac{\alpha}{\beta} = \frac{\alpha}{360^\circ - \alpha} \quad \text{or} \quad \frac{360^\circ - \beta}{\beta}$$



Q.10) Write a short note on Cam and Follower.

Ans) ***Cam & Follower***:

- A cam may be defined as a rotating, reciprocating or oscillating machine part, designed to produce reciprocating and oscillating motion of another mechanical part, called a follower.
- A follower is a reciprocating or oscillating member which follows motion of cam.
- A cam and follower have a line contact between them and as such they constitute a higher pair. The contact between them is maintained by an external force which may provide by a spring or sometimes by the sufficient weight of the follower itself.
- Cams are classified according to its Shape, Follower movement and Type of constraints.
- Followers may be classified according to the type of motion, the axis of the motion and the shape of their contacting end with the cam.
- Various types of cams are flat cams, disc cams, spiral cams, cylindrical cams and spherical cams etc.
- Various types of follower are knife-edge, roller, reciprocating, oscillating, radial follower etc.
- Applications:

  The cams are widely used for inlet and exhaust valve of internal combustion engine, automatic attachment of machineries, paper cutting machines, feed mechanism of automatic lathe etc.

Chapter End

BELT ROPE & CHAIN DRIVE

Q.1) Define the velocity ratio of the belt drive. State its expressions.

Ans) It is defined as the ratio between the velocities of driver and driven or follower.
Mathematically it may be expressed as - $\frac{N2}{N_1} = \frac{d_1}{d_2}$

where, N_2 = speed of the follower, N_1 = speed of the driver,
d_1 = diameter of the driver, d_2 = diameter of the follower

Q.2) State the expression for the length of an open belt drive.

Ans) It is given by the relation - $L = \pi (r_1 + r_2) + 2x + \frac{(r_1 - r_2)^2}{x}$

Where, r_1 = radius of larger pulley r_2 = radius of smaller pulley

x = distance between the centre of two pulleys L = length of belt

Q.3) *State the expression for the length of a cross belt drive.*

Ans) it is given by the relation - $L = \pi (r_1 + r_2) + 2x + \frac{(r_1 + r_2)^2}{x}$

Where, r_1 = radius of larger pulley r_2 = radius of smaller pulley

x = distance between the centre of two pulleys L = length of belt

Q.4) *Derive an expression for length of an open belt drive.*

Ans) Consider an open belt drive as shown in figure.

Let, r_1 and r_2 are the radii of larger and smaller pulley,

x = distance between the centres of two pulleys and L = total length of the belt.

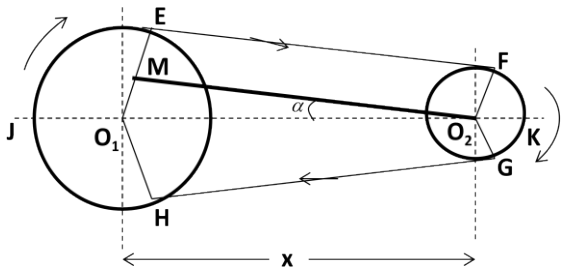
Let, O_2M parallel to EF and perpendicular to O_1E.

Angle M O_2 O_1 = α

so, $\sin\alpha = \frac{O_1M}{O_1O_2} = \frac{O_1E - EM}{O_1O_2} = \frac{r_1 - r_2}{x}$

since α is very small so

$\sin\alpha = \alpha = \frac{r1 - r2}{x}$



(Open belt drive)

In figure total length of belt (L) = (2 × arc JE) + EF + (2 × arc FK) + GH

$\Rightarrow$ L = (2 × arc JE) + EF + (2 × arc FK) + GH

$\Rightarrow$ L = (2 × arc JE) + (2 × EF) + (2 × arc FK)

$\Rightarrow$ L = 2 [arc JE + EF + arc FK]

We know that, arc JE = $r_1 \times (\frac{\pi}{2} + \alpha)$

arc FK = $r_2 \times (\frac{\pi}{2} - \alpha)$ EF = M O_2 = $\sqrt{(O_1O_2)^2 - (O_1M)^2}$

$= \sqrt{x^2 - (r_1 - r_2)^2} = x\sqrt{1 - \frac{(r_1 - r_2)^2}{x^2}}$

Expanding this equation by binomial theorem, we get

$EF = x \times [1 - \frac{1}{2}\frac{(r_1 - r_2)^2}{x^2} + ...] = x - \frac{(r1 - r2)^2}{2x}$

Putting the all the obtained values in the below equation, we get

$\Rightarrow$ $L = 2\left[r_1 \times \left(\frac{\pi}{2} + \alpha\right) + x - \frac{(r1-r2)^2}{2x} + r_2 \times \left(\frac{\pi}{2} - \alpha\right)\right]$

$= 2\left[r_1 \times \frac{\pi}{2} + r_1 \times \alpha) + x - \frac{(r1-r2)^2}{2x} + r_2 \times \frac{\pi}{2} - r_2 \times \alpha)\right]$

$= 2\left[\frac{\pi}{2}(r_1 + r_2) + \alpha(r_1 - r_2) + x - \frac{(r1-r2)^2}{2x}\right]$

$= \pi(r_1 + r_2) + 2\alpha(r_1 - r_2) + 2x - \frac{(r1-r2)^2}{x}$

$= \pi(r_1 + r_2) + 2 \times \frac{r1-r2}{x}(r_1 - r_2) + 2x - \frac{(r1-r2)^2}{x}$

$= \pi(r_1 + r_2) + 2 \times \frac{(r1-r2)^2}{x} + 2x - \frac{(r_1-r_2)^2}{x}$

$\Rightarrow$ $\mathbf{L = \pi(r_1 + r_2) + 2x + \frac{(r_1-r_2)^2}{x}}$ ---------- (in terms of pulley radii)

$\Rightarrow$ $\mathbf{L = \frac{\pi}{2}(d_1 + d_2) + 2x + \frac{(d_1-d_2)^2}{4x}}$ ---------- (in terms of pulley diameter)

Q.5) ***Derive an expression for length of a crossed belt drive.***

Ans) Consider a crossed belt drive as shown in figure.

Let, r_1 and r_2 are the radii of largerand smaller pulley,

x = distance between the centres of two pulleysand

L = total length of the belt.

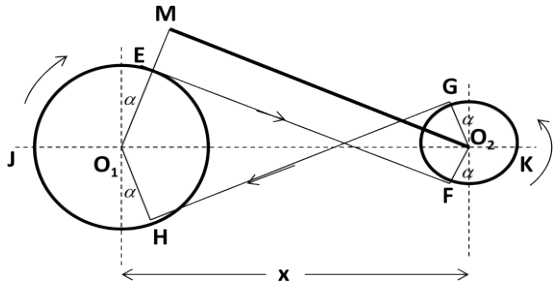
Let, O_2M parallel to EF and perpendicular to O_1E.

Angle M O_2 O_1 = α

so, $\sin\alpha = \frac{O_1M}{O_1O_2} = \frac{O_1E + EM}{O_1O_2} = \frac{r_1 + r_2}{x}$

since α is very small so

$\sin\alpha = \alpha = \frac{r1 + r2}{x}$



(Crossed belt drive)

In figure total length of belt (L) = (2 × arc JE) + EF + (2 × arc FK) + GH

$\Rightarrow$ L = (2 × arc JE) + EF + (2 × arc FK) + GH

$\Rightarrow$ L = (2 × arc JE) + (2 × EF) + (2 × arc FK)

$\Rightarrow$ L = 2 [arc JE + EF + arc FK]

We know that, arc JE $= r_1 \times \left(\frac{\pi}{2} + \alpha\right)$ arc FK $= r_2 \times \left(\frac{\pi}{2} + \alpha\right)$

EF = M O_2 = $\sqrt{(O_1O_2)^2 - (O_1M)^2} = \sqrt{x^2 - (r_1 - r_2)^2}$

$= x\sqrt{1 - \frac{(r_1-r_2)^2}{x^2}}$

Expanding this equation by binomial theorem, we get

$$EF = x \times \left[1 - \frac{1}{2}\frac{(r_1-r_2)^2}{x^2} + \ldots\ldots\ldots\ldots\right] = x - \frac{(r1-r2)^2}{2x}$$

Putting the all the obtained values in the below equation, we get

$\Rightarrow$ $L = 2\left[r_1 \times \left(\frac{\pi}{2} + \alpha\right) + x - \frac{(r1+r2)^2}{2x} + r_2 \times \left(\frac{\pi}{2} + \alpha\right)\right]$

$$= 2\left[r_1 \times \frac{\pi}{2} + r_1 \times \alpha\right) + x - \frac{(r1+r2)^2}{2x} + r_2 \times \frac{\pi}{2} + r_2 \times \alpha)\right]$$

$$= 2\left[\frac{\pi}{2}(r_1 + r_2) + \alpha(r_1 + r_2) + x - \frac{(r1+r2)^2}{2x_2}\right]$$

$$= \pi(r_1 + r_2) + 2\alpha(r_1 + r_2) + 2x - \frac{(r1+r2)^2}{x}$$

$$= \pi(r_1 + r_2) + 2 \times \frac{r1+r2}{x}(r_1 - r_2) + 2x - \frac{(r1+r2)^2}{x}$$

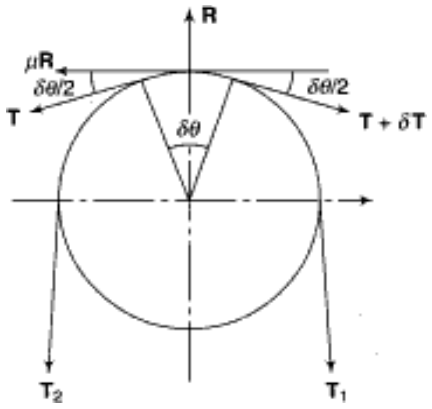
$$= \pi(r_1 + r_2) + 2 \times \frac{(r1+r2)^2}{x} + 2x - \frac{(r_1+r_2)^2}{x}$$

$\Rightarrow$ **$L = \pi(r_1 + r_2) + 2x + \frac{(r_1+r_2)^2}{x}$** ---------- (in terms of pulley radii)

$\Rightarrow$ **$L = \frac{\pi}{2}(d_1 + d_2) + 2x + \frac{(d_1+d_2)^2}{4x}$** ---------- (in terms of pulley diameter)

Q.6) ***Derive an expression for ratio of driving tension for a belt drive.***

Ans) Consider a driven pulley rotating in clockwise direction as shown in figure.



Let, T_1 = tension in tight side,

T_2 = tension in slack side,

θ= angle of contact in radian

Now consider a small portion of the belt PQ, which subtends with an angle $\delta\theta$at the centre of the pulley. The belt PQ remains in equilibrium under the action following forces.

Tension T in the belt

Tension (T +δT)

Normal reaction R_N

Frictional force F = μ R_N

Resolving the forces horizontally, $\Rightarrow R_N = (T + \delta T)\sin\frac{\delta\theta}{2} + T\sin\frac{\delta\theta}{2}$ ---------- (1)

since the angle $\delta\theta$is very small, considering $\sin\frac{\delta\theta}{2} = \frac{\delta\theta}{2}$ in equation-1, we get

$R_N = (T + \delta T) \times \frac{\delta\theta}{2} + T \times \frac{\delta\theta}{2} = T \times \delta\theta$ ----(2), (neglecting the smaller terms)

Resolving the forces vertically, $\Rightarrow \mu R_N = (T + \delta T)\cos\frac{\delta\theta}{2} - T\cos\frac{\delta\theta}{2}$ ------ (3)

since the angle $\delta\theta$is very small, considering $\cos\frac{\delta\theta}{2} = 1$,

in equation-3, we get: $\mu R_N = T + \delta T - T = \delta T$ --------- (4)

From equation 2 and 4, we get: $\mu \times T \times \delta\theta = \delta T$

$$\Rightarrow T \times \delta\theta = \frac{\delta T}{\mu} \quad \Rightarrow \quad \frac{\delta T}{T} = \mu \times \delta\theta$$

Integrating both sides between the limits T_2 and T_1 and from 0 to θ, we get

$$\int_{T_2}^{T_1} \frac{\delta T}{T} = \mu \times \int_0^{\theta} \delta\theta$$

$\Rightarrow$ **$\log_e\left(\frac{T_1}{T_2}\right) = \mu\theta$** ---------- **(5)**

$\Rightarrow$ **$\frac{T1}{T_2} = e^{\mu\theta}$** ---------- **(6)**

$\Rightarrow$ **$2.3 \log\left(\frac{T_1}{T_2}\right) = \mu\theta$** ---------- **(7)**

Q.7) ***State the expression for ratio of tension in belt drive.***

Ans) It is given by the relation - $\frac{T1}{T_2} = e^{\mu\theta}$

where, T_1 = tension in tight side in N

T_2 = tension in slack side in N

μ = coefficient of friction

θ = angle of lap

Q.8) ***State the expression for power transmitted in a belt drive.***

Ans) It is given by the relation - $P = (T_1 - T_2) \times v$ *N-m/s* (1 N-m/s = 1 watt)

where, T_1 = tension in the tight side of the belt in N

T_2 = tension in the slack side of the belt in N

v = velocity of the belt in m/s

Q.9) ***State the expression for angle of contact or lap (θ).***

Ans) For an open belt drive, $\theta = (180^0 - 2\,\alpha) \times \frac{\pi}{180}$ radian

for a crossed belt drive, $\theta = (180^0 + 2\,\alpha) \times \frac{\pi}{180}$ radian

Q.10) ***what do you mean by slip and creep in belt.***

Ans) **SLIP** - There is a firm frictional grip between the belt and pulley, but in some time due to insufficient frictional grip, some forward motion of the driver without carrying the belt or some forward motion of the belt without carrying the driven pulley occurs. This is called slip of the belt.

CREEP – When a belt passes over pulleys it expands or contracts due to which a relative motion takes place between the belt and pulley. This relative motion reduces slightly the speed of driven pulley which is known as creep in belt.

Q.11) ***Classify bearings and explain them.***

Ans) Bearings are classified as sliding bearing and rolling bearing. Sliding bearing is including journal bearing and thrust bearing. Rolling bearing is including ball bearing, roller bearing and needle roller bearing.

***Journal bearing*:**

Journal bearing is used to support the load in the direction of diameter.

***Thrust bearing*:**

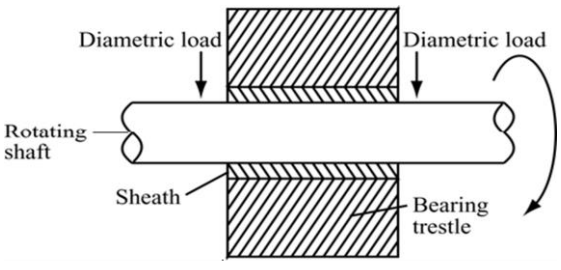
Thrust bearing is used to support the axle which carries the axial load.

***Rolling bearing*:**

Rolling bearing can reduce the friction produced by the rotating shaft when it rotates.

***Ball bearing*:**

Ball bearing uses balls as a medium between the fixed components and the rotating components, such as the moving parts at the bottom of a gate



(Journal bearing)

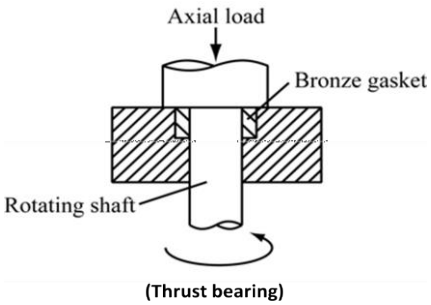
and reduces the friction.

***Roller bearing*:**

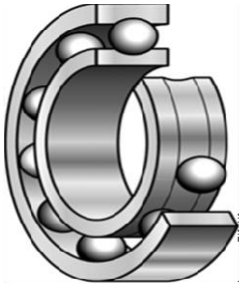
Roller bearing works similarly as ball bearing but it uses cylinders instead of balls.

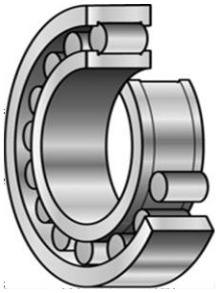
***Needle roller bearing*:**

A needle roller bearing works similarly as ball bearing but it uses the typical structure consists of a needle cage which orients and contains the needle rollers. Needle bearings have a large surface area that is in contact with the bearing outer surfaces compared to ball bearings.



(Thrust bearing)


(Cross-section of ball bearing)


(Cross-section of roller bearing)

Q.12) ***State the function of governor.***

Ans) A governor is used to maintain the mean equilibrium speed of an engine, when there is fluctuation of speed of an engine due to variation of load upon the engine.

Q.13) ***State the function of flywheel.***

Ans) A flywheel stores the excess energy in an engine and supplies it when there is a requirement of energy. It also controls the fluctuation of speed but does not control the speed variations caused by the varying loads.

Q.14) ***Distinguish among the governor and flywheel.***

Ans)

	Flywheel	***Governor***
1.	Flywheel controls the variation of speed of engine during each revolution of engine shaft.	Governor controls the variation of speed of the engine over a number of revolutions.
2.	Variation of speed controlled by flywheel is caused due to fluctuation in turning moment during cycle.	Variation of mean speed controlled by governor is caused due to fluctuation in load on engine over a period of time.
3.	It controls the variation of speed by providing stored energy during the cycle.	It controls the mean speed of the engine by regulating the fuel supply.

4. A flywheel has no control over the quantity of charge.	4. A governor takes care of the quantity of working fluid.
5. It is not an essential element for prime mover.	5. It is an essential element for prime mover.

Q.15) What is the function of dynamometer? Classify.

Ans) It is used to measure the frictional resistance. By finding the frictional resistance, we can find out the torque transmitted and power absorbed.

1) ***Absorption type dynamometer*** – In these dynamometers the entire energy of the engine is absorbed by the frictional resistances of the brake and is transformed into heat. It is classified as: 1) prony brake dynamometer & 2) rope brake dynamometer.
2) ***Transmission dynamometers*** – In these dynamometers the energy is not wasted in friction but is used to do work. The energy produced by the engine is transmitted to the other machines through the dynamometers.

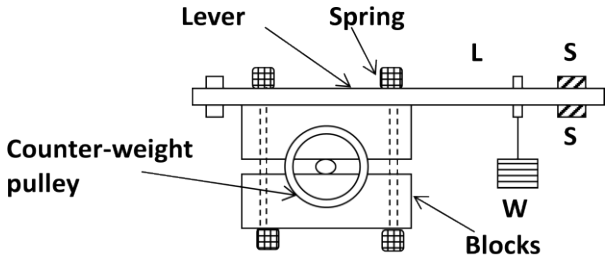
Q.16) Explain the working of absorption type dynamometer.

Ans) ***Absorption type dynamometer*** – In these dynamometers the entire energy of the engine is absorbed by the frictional resistances of the brake and is transformed into heat. It is classified as: 1) prony brake dynamometer & 2) rope brake dynamometer.

Prony brake dynamometer:

An absorption type prony brake dynamometer is shown in figure. It consists of two wooden blocks placed around a pulley. It is fixed with the engine shaft. The blocks are clamped by nut and bolts. A helical spring is provided between nut and upper block to control the pressure on the pulley or to control its speed. A long lever is attached to the upper block, which carries weights at its outer end. A counter weight is provided at the other end of lever to balance the brake when unloaded. Two stops 'S' is provided to limit the motion of the lever.

When the brake comes in action, the long end of lever is loaded with weights W and nuts are tightened until the engine shaft runs at mean speed and lever lies in horizontal position. For this case the moment due to weight W must be balance the moment of frictional resistance between the blocks and the pulley.



(Prony brake dynamometer)

Let, W = weight at the outer end of lever in N

L = horizontal distance of weight W from centre of pulley in metres

F = frictional resistance between block and pulley in N

R = radius of pulley in metres N = speed of shaft in r.p.m

Moment of frictional resistance or torque on shaft (T) = W.L = F.R N-m

Work done in one revolution = torque × angle turned in radian = T × 2π N-m

Work done per minute = T × 2π × N N-m

Brake power of the engine = B.P = $\frac{T \times 2\pi N}{60}$ Watt

Rope brake dynamometer:

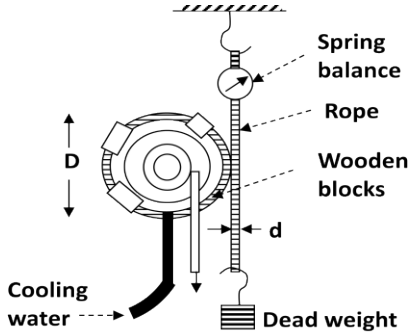
It is most common dynamometer which is used to measure the brake power of the engine. It consists of one, two or more ropes wound around the fly wheel or rim of the pulley which is fixed to the shafof the engine. The upper end of the shaft is attached to a spring balance and the lower end of the rope is attached with a dead weight. Wooden blocks are provided in the intervals around the circumference of flywheel to prevent the slipping of rope from flywheel.

Let, W = dead load in N

S = spring balance reading in N

D = diameter of wheel in 'm' d = diameter of rope in 'm'

N = speed of the engine in r.p.m Net load on the brake = (W - S) in N



(Rope brake dynamometer)

Distance moved in one revolution = π (D + d) in m
Work done per revolution = (W - S) π (D + d) N in N-m

Brake power (B.P) = $\frac{(W - S)\ \pi\ (D + d)\ N}{60}$ in Watts

If the diameter of the rope is neglected, then B.P = $\frac{(W - S)\ \pi\ D\ N}{60}$ in Watts

The frictional torque due to rope equals to torque transmitted by the engine.

Q.17) What is the function of frictional brakes.

Ans) A brake is a device which is used to offer frictional resistance to moving machine elements to stop the motion of the element or retard its motion. It absorbs the kinetic or potential energy when applied.

Chapter End

HEAT & WORK

Heat:

- Heat is a transfer form of energy that flows between two systems or between system and surrounding due to temperature difference between them.
- Amount of heat transfer between state 1 and 2 is given by $Q_{1\text{-}2}$.
- The S.I unit of heat is Joule (J) or KiloJoule (kJ) and in M.K.S it is given by Calorie.
- Heat transfer to a system is considered as positive and heat transfer from a system is considered as negative.
- Heat is a form of energy in transit.
- It is a path function.
- It is low grade energy.
- It is a boundary phenomenon.
- It is associated in a process not in a state.

Work:

- Work is said to be done when the point of application of a force on a body results in its motion.
- Work is defined as the product of the force (F) and the distance moved (s) in the direction the force. Mathematically, work done, W= **F**× s,
- The mechanical work on a body is the amount of mechanical energy transferred to the body by a force.
- Amount of work transfer between two state 1 and 2 is given by $W_{1\text{-}2}$.
- The S.I unit of work is Joule (J) or kilojoule (kJ).
- Work transfer to a system is considered as negative and work transfer from a system is considered as positive.
- Work is form energy in transit.
- Itis a path function.
- It is high grade energy.
- It is a boundary phenomenon.
- It is associated in a process not in a state.

Specific heat:

- It is the amount of heat energy required to change the temperature of unit mass of a substance by one degree.

Sensible heat (enthalpy of saturated water-h_f):

- Sensible heat is defined as an amount of heat energy absorbed by 1 kg of water during its heating from 0^0C to the saturation temperature at a given pressure.

Latent heat of fusion:

- It is defined as the amount of heat required to convert one kg of ice into water at constant temperature of 0^0C.

Latent heat of vaporization (h_{fg}):

- It is defined as the amount of heat required to convert 1 kg of saturated water into dry saturated steam at constant temperature and pressure.

Steam:

- ♣ Steam is the gaseous phase of water.

Saturated steam:

- ♣ The steam which is about to condense is called as saturated steam.

Wet steam:

- ♣ It is the mixture of dry steam and water particles as moisture.

Dry steam:

- ♣ It is the saturated vapor free from moisture.

Superheated steam:

- ♣ It is the steam existing at higher temperature than its saturation temperature.

Dryness fraction:

- ♣ It is the measure of quality of wet steam. It is the ratio of mass of dry steam (m_g)to the total mass of wet steam (m).

Enthalpy of steam or Total heat:

- ♣ It is the sum of enthalpy of saturated water (h_f) and enthalpy of vaporization (h_{fg}).

Steam table and their uses:

- ♣ The properties of dry superheat steam like its temperature of formation (saturation temperature), sensible heat, latent heat of vaporization, enthalpy or total heat, specific volume, entropy etc., vary with pressure and can be found by experiments only. These properties have been carefully determined and made available in a tabular form known as steam tables.

(Solve numerical to find out the enthalpy and entropy of steam using steam table)

Chapter End

STEAM GENERATOR

Steam generator:

- ♣ A boiler is a steam generator which is used to convert steam from water by heating it.
- ♣ A steam generator or boiler, usually, a closed vessel made of steel. Its function is to transferthe heat produced by the combustion of fuel (solid, liquid or gas) to water, and ultimately to generate steam. The steam produced may be supplied:
    - o To an external combustion engine, i.e. steam engines and turbines.
    - o At low pressures for industrial process work in cotton mills, sugar factories, breweries etc.
    - o For producing hot water.

Fire tube boiler:

- ♣ Fire tube boilers are those in which flue gas flows inside the tubes and the water that is to be heated remains outside the tube.
- ♣ Examples of fire tube boilers are: Simple vertical boiler, Cochran boiler, Lancashire boiler, Cornish boiler.

Water tube boiler:

- ♣ Water tube boilers are those in which water flows inside the tube and flue gas remains outside the tube to heat the water.
- ♣ Examples of water tube boilers are: Babcock and Wilcox boiler, Stirling boiler, La-Mont boiler, Benson boiler.

COCHRAN BOILER:

Cochran boiler is a vertical multi-tubular fire tube boiler. It produces steam at low pressure from the heat exchange between water and flue gas. It has the Steam capacity up to 3500 kg/hr.

Construction of Cochran boiler:

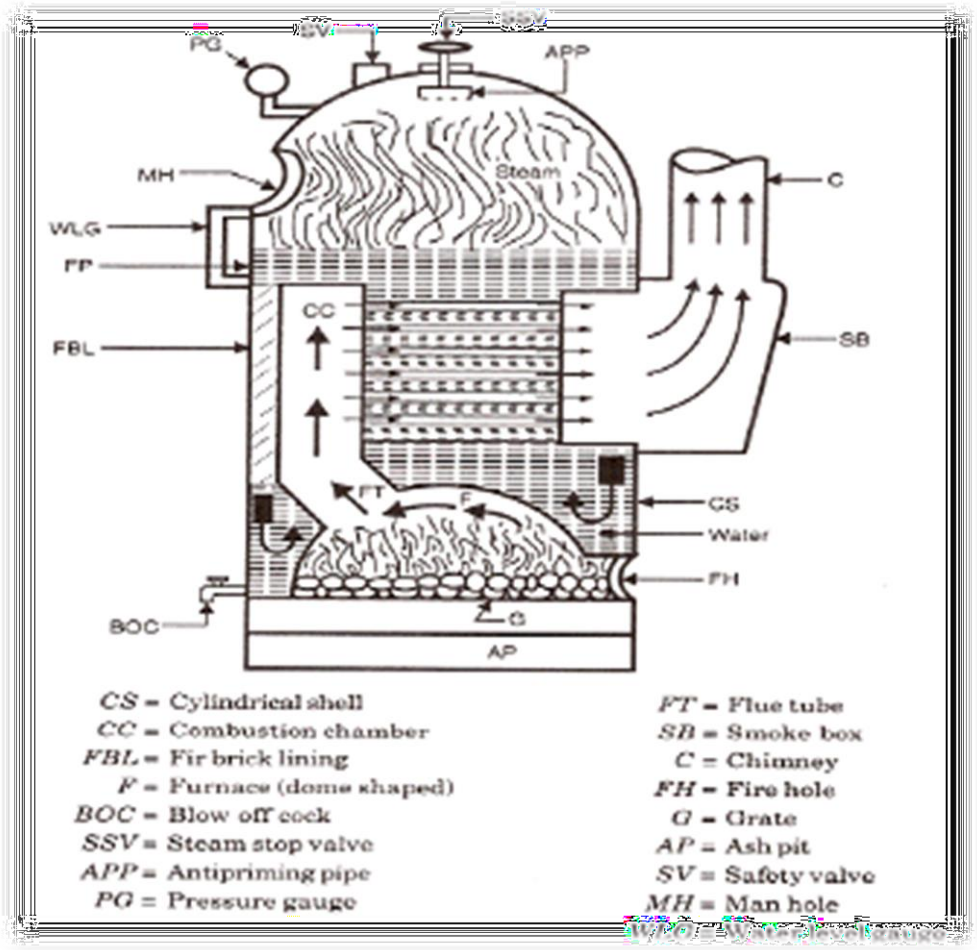
It consists of a cylindrical shell with a dome shaped top where the space is provided for steam. The furnace is one piece construction and is seamless. Its crown has a hemispherical shape and thus provides maximum volume of space. It has the following parts and mountings.

- ❖ Boiler shell (cylindrical, top is dome shaped, hemispherical crown)
- ❖ Grate and furnace (Internally fired boiler)
- ❖ Combustion chamber and fire tubes
- ❖ Smoke box and chimney
- ❖ *Mountings*: water gauge, pressure gauge, fusible plug, feed check valve, steam stop valve, safety valve and blow off cock.

Working of Cochran boiler:

When the fuel burns inside the fire box/furnace flue gas produces and flows into the combustion chamber after striking through the fire brick linings. Then the flue gas passes through the fire tubes

to exchange heat with water surrounding to them. Then the flue gas is collected in a smoke box and escape to the atmosphere through chimney. In this way the steam produces at the top of the boiler shell and collected.



Mountings:These are the fitting and devices which are necessary for the operation and safety of a boiler.

- **Steam Stop Valve:**
  It is use to regulate the flow of steam from the boiler to the steam pipe.
- **Safety Valve:**
  It is use for releasing the excess steam when the pressure of steam inside the boiler exceeds the rated pressure. Types of safety valve are the following: · Dead weight safety valve, Lever safety valve, Spring loaded safety valve, Gravity safety valve
- **Water Level Indicator:**
  It is use to indicate the level of water in the boiler constantly.
- **Pressure Gauge:**
  It is use to measure the pressure exerted inside the vessel.
- **Fusible Plug:**
  It is use to protect the boiler against damage due to overheating for low water level.
- **Feed Check Valve:**
  It is use to control the supply the water to the boiler and to prevent the escaping of water from the boiler when the pump is stopped.

- **Blow Off Cock:**
  It is use to discharge a portion of water when the boiler is empty when necessary for cleaning, inspection, repair, mud, scale and sludge.
- **Man Hole:**
  It is used for inspection and maintenance purpose.

Accessories: These are auxiliary parts required for steam boilers for the proper operation and for the increase of their efficiency.

- **Super heater:**
  It is use to increase the temperature of steam above it saturation point.
- **Economizer:**
  It is a device in which the waste heat of flue gases is utilized for heating the feed water before supplying into the boiler.
- **Air pre heater:**
  It is use to increase the temperature of air before it enters the furnace.
- **ESP:**
  It is used to collect dust or harmful particle from flue gas before escape into the atmosphere.
- **Boiler feed pump:**
  It is used to deliver feed water to the boiler.\

BABCOCK WILCOX BOILER:

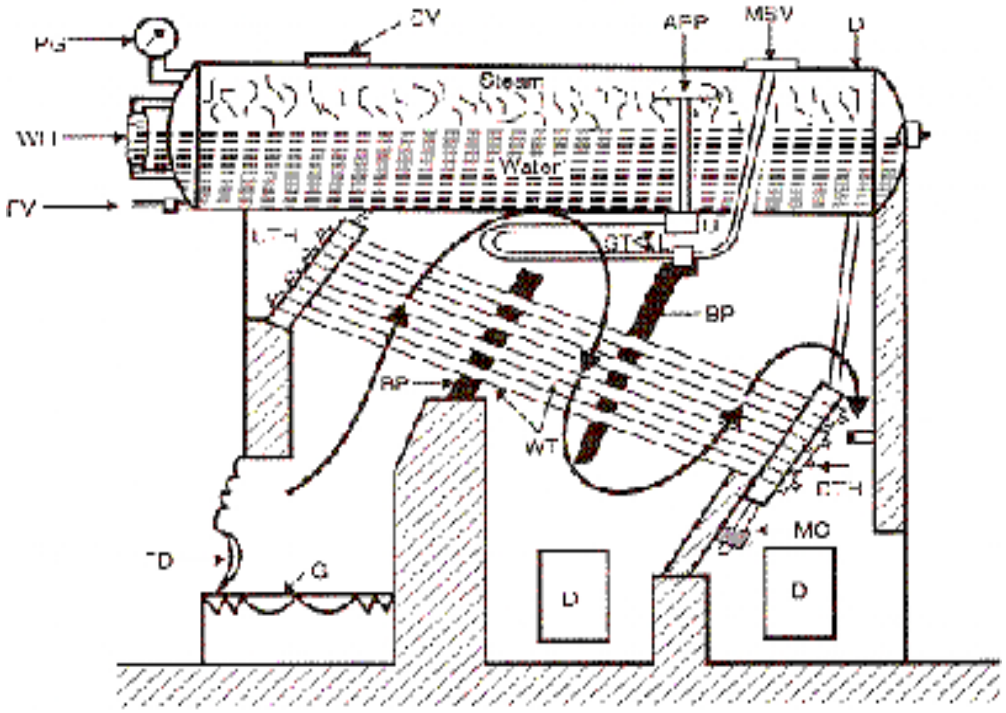
It is a horizontal inclined tube, water tube boiler. In this boiler high pressure steam produces from the heat exchange between water and hot flue gas.

Construction:

It consists of a longitudinal drum connected to a series of front end and rear end header by short riser tubes. These headers are connected by a series of inclined water tubes. The angle of inclination of the water tubes to the horizontal is about 15° or more. Mountings are mounted over the boiler shell for safe operation such as: steam stop valve, safety valve, water level indicator, pressure gauge, thermometer, fusible plug, feed check valve, blow- off cock, man hole etc.

Working:

Fuel is supplied to grate through fire door where it is burnt. The hot gases are forced to move upwards between the tubes by baffle plates provided. The water from the drum flows through the inclined tubes via down take header and goes back into the shell in the form of water and steam via uptake header. The steam gets collected in the steam space of the drum. The steam then enters through the anti-priming pipe and flows in the super heater tubes where it is further heated and is finally taken out through the main stop valve and supplied to the Steam turbine or Steam engine when needed.



D = Drum
DTa = Down take header
WT = Water tubes
BP = Baffle plates
D = Doors
G = Grate
FD = Fire door
MC = Mud collector
WLI = Water level indicator

PG = Pressure gauge
ST = Superheater tubes
SV = Safety valve
MSV = Main stop valve
AFP = Auxiliary feed pipe
L = Lower junction box
U = Upper junction box
FV = Feed valve

Difference between Water tube and Fire tube boiler:

Water tube boiler	Fire tube boiler
1. The water circulates inside the tubes which are surrounded by hot gases from the furnace.	1. The hot gases from the furnace pass through the tubes which are surrounded by water.
2. The rate of generation of steam is high.	2. The rate of generation of steam is low.
3. It generates steam at a higher pressure up to 165 bar.	3. It generates steam at up to 24.5 bar.
4. For a given power, the floor area required for the generation is less.	4. For a given power, the floor area required for the generation is more.
5. The operating cost is high.	5. The operating cost is less.
6. The bursting chance is more.	6. The bursting chance is less.
7. It is used for large power plants.	7. It is not suitable for large power plants.

TURBINE:

A steam turbine is a machine which converts the available thermal energy into mechanical energy. These are classified as Impulse and Reaction turbine.

Difference between Impulse and reaction turbine:

Impulse turbine	Reaction turbine
1. The steam flows through the nozzles and impinges on the moving blades.	1. The steam flows first through guide mechanism and then through the moving blades.
2. The steam impinges on the buckets with kinetic energy.	2. The steam glides over the moving vanes with pressure and kinetic energy.
3. The steam may or may not be admitted over the whole circumference.	3. The steam must be admitted over the whole circumference.
4. The steam pressure remains constant during its flow through the moving blades.	4. The steam pressure is reduced during its flow through the moving blades.
5. The negative velocity of steam while gliding over the blades remains constant.	5. The relative velocity of steam while gliding over the moving blades increase
6. The blades are symmetrical.	6. The blades are not symmetrical
7. The number of stages required is less for the same power developed.	7. The number of stages required is more for the same power developed.

Chapter End

INTERNAL COMBUSTION ENGINE

Internal Combustion (I.C) engine:

- When the combustion of fuel supplied to the engine takes place inside the engine cylinder, the engine is called as an internal combustion engine.
- *Examples* – 2-stroke and 4-stroke petrol and diesel engines.

Terminology:

- ***Bore*:** It is the diameter of the engine cylinder or piston.
- ***Stroke*:** It is the distance moved by piston between two dead centres.
- ***Swept volume*:** It is the maximum volume swept by the piston when it moves from one dead centre to another.
- ***Compression ratio*:** It is the minimum volume between the cylinder head and top of the piston when the piston is at the top dead centre.
- ***Air standard efficiency*:** It is ratio between work done and heat supplied for air standard cycle.

Main Components of I.C engine:

The main components of an I.C engine are cylinder, cylinder head, piston, piston rings, connecting rod, crank, crank shaft and flywheel.

Classification of I.C engine:

The classification of I.C engine is as follows:

- According to number of strokes:
  - Four stroke engine
  - Two stroke engine
- According to fuel used
  - Petrol engine
  - Diesel engine
  - Gas engine
- According to method of ignition
  - Spark ignition engine
  - Compression ignition engine
- According to cooling system
  - Air cooled engine
  - Water cooled engine
- According to number of cylinder
  - Single cylinder engine
  - Multi cylinder engine
- According to speed of engine
  - Low speed engine
  - Medium speed engine
  - High speed engine

BASIC ENGINES COMPONENTS:

CYLINDER: - It is a cylindrical space or container inside which the piston executes reciprocating motion and also it support the cylinder block.

PISTON: - it is a cylindrical component that fits perfectly into the cylinder to providing a gas tight space.

INLET VALVE /PORT: -it is providing either on top up the cylinder head or side of the cylinder to provide air and fuel (charging) to the cylinder.

OUTLET VALVE/PORT: -it is providing either on top up the cylinder head or side of the cylinder for discharging the products of combustion from the cylinder.

SPARK PLUG: -it is the component fitted on the cylinder to produce spark for ignition in 2 stroke/4 stroke engine.

CONNECTING ROD: - it connects the piston and crankshaft therefore it transmitted the force from piston to crankshaft i.e. it transmit the linear motion of piston to rotational motion of crank.

PISTON PIN: - it connects the piston and connecting rod.

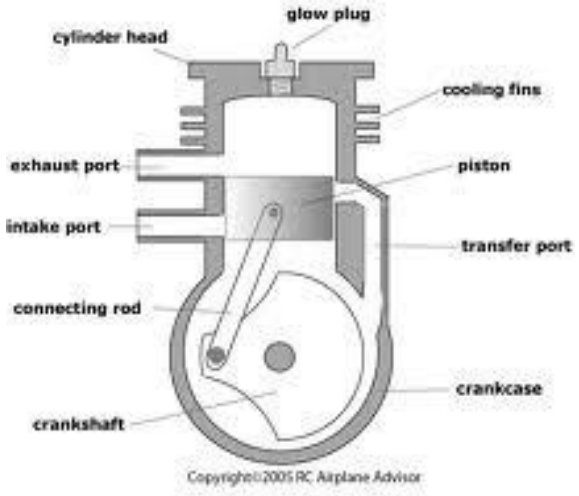
CAMSHAFT: -it controls the opening and closing of valves**.**

CRANK CASE: - it forms the base of the engine block which supports the cylinder and the crankshaft.

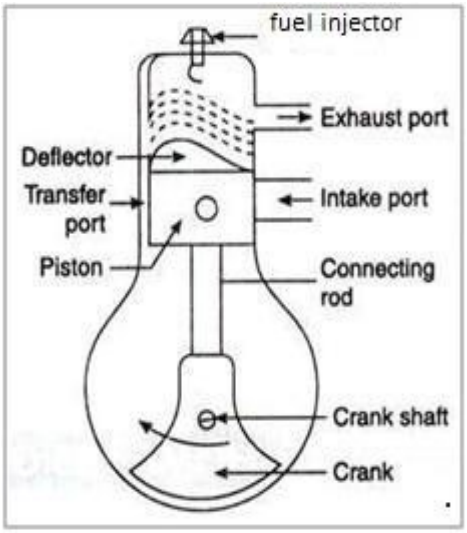
Two stroke petrol engine:-

Working: -

- In two stroke engines the entire cycle is completed in one revolution of the crankshaft. In a two stroke engine, the charge is filled in the cylinder. The air charge is induced through the inlet port due to the suction created in the crankcase by upward movement of the piston during the compression stroke.
- Initially the piston is moves from TDC to BDC and uncovers the exhaust port to exhaust the burnt gases from the cylinder and then uncovers the transfer port for the flow of air-fuel mixture into the cylinder from the crank case. In this stage mechanical power produces due to the high temperature & pressure force acting on the piston. In this stage both expansion and exhaust completes in one stroke.
- When the piston moves from BDC to TDC, fresh air-fuel mixture gets compressed and ignited by a spark plug. In this stage fresh air-fuel mixture flows into the crank case. Both suction and compression completes in one stroke.
- In this way the entire process completes in two strokes and one revolution of crank shaft. Due to this, the engine is known as 2-stroke engine.



Two stroke diesel engine: -

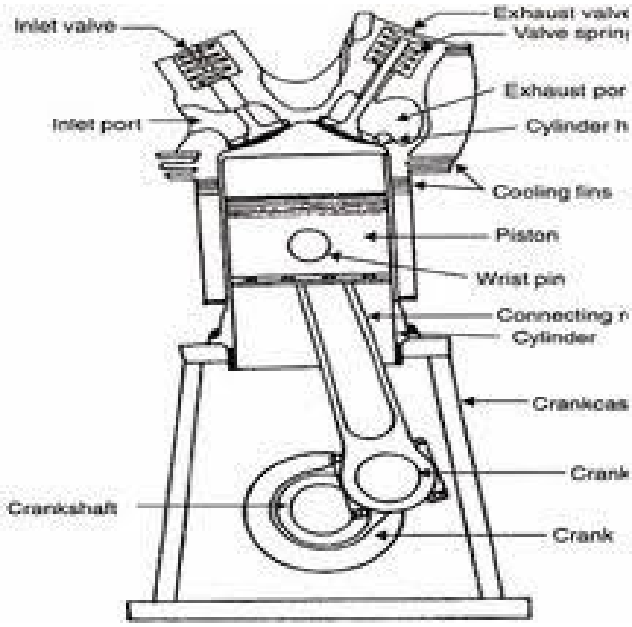


Working: -

- In two stroke engines the entire cycle is completed in revolution of the crankshaft. In a two stroke engine, the air is filled in the cylinder. The air is induced through the inlet port due to the suction created in the crankcase by upward movement of the piston during the compression stroke.
- Initially the piston is moves from TDC to BDC and uncovers the exhaust port to exhaust the burnt gases from the cylinder and then uncovers the transfer port for the flow of air into the cylinder from the crank case. In this stage mechanical power produces due to the high temperature & pressure force acting on the piston. In this stage both expansion and exhaust completes in one stroke.

- When the piston moves from BDC to TDC, fresh air gets compressed and ignited due to inject of fuel from the fuel injector. In this stage fresh air flows into the crank case. Both suction and compression completes in one stroke.
- In this way the entire process completes in two strokes and one revolution of crank shaft. Due to this, the engine is known as 2-stroke engine.

4 STROKE PETROL ENGINE:-



WORKING:-

- **Suction Stroke:**
  In this stroke piston moves from TDC to BDC. Inlet valve get opened and fresh air-fuel mixture flows into the engine cylinder. Exhaust valve remains closed. Crank rotates through 180^0.
- **Compression Stroke:**
  During this stroke both valves (inlet & exhaust) remains closed. The piston moves from BDC to TDC& compresses the charge in the cylinder.. As the piston reaches the TDC position, the mixture is ignited by an electric spark.
- **Power or Expansion stroke:**
  During expansion stroke both valves remains closed. The high pressure & temperature burnt gases pushes the piston from TDC to BDC and produce mechanical power. As work is done this is called power stroke. Exhaust valve opens as piston reaches to BDC. Pressure falls down to atmospheric pressure.
- **Exhaust stroke:**
  During this stroke piston moves from BDC to TDC. Exhaust valve is open & inlet valve is closed. This causes the burnt gases to escape out from the cylinder. As piston reaches TDC, again the inlet valve opens & fresh charge is taken during next suction stroke.
- In this way the cycle completes in four strikes of piston and two revolution of crank, due to which the engine is known as four stroke engine.

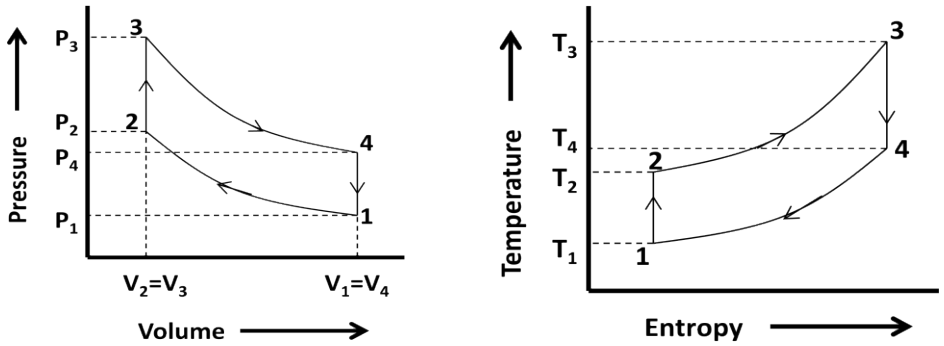
4 STROKE DIESEL ENGINE:-

WORKING:-

- **Suction Stroke:**
  In this stroke piston moves from TDC to BDC. Inlet valve get opened and fresh air flows into the engine cylinder. Exhaust valve remains closed. Crank rotates through 180^0.
- **Compression Stroke:**
  During this stroke both valves (inlet & exhaust) remains closed. The piston moves from BDC to TDC& compresses the air in the cylinder.As the piston reaches the TDC position, the mixture is ignited due to inject of fuel (diesel) from fuel injector.
- **Power or Expansion stroke:**
  During expansion stroke both valves remains closed. The high pressure & temperature burnt gases pushes the piston from TDC to BDC and produce mechanical power. As work is done this is called power stroke. Exhaust valve opens as piston reaches to BDC. Pressure falls down to atmospheric pressure.
- **Exhaust stroke:**
  During this stroke piston moves from BDC to TDC. Exhaust valve is open & inlet valve is closed. This causes the burnt gases to escape out from the cylinder. As piston reaches TDC, again the inlet valve opens & fresh air is taken during next suction stroke.
- In this way the cycle completes in four strikes of piston and two revolution of crank, due to which the engine is known as four stroke engine.

Explain the Otto cycle with its P-V and T-s diagram and determine the air standardefficiency of the cycle.

Otto cycle is an air standard cycle. It is used in S.I engines. Air fuel mixture is used as the working substance. It is also known as constant volume cycle. The P-V diagram of the cycle is shown in the following figure.



Otto cycle is consisting of four processes as described below.

- ***Process 1-2*:** This process is a reversible adiabatic or isentropic compression process. In this process, the working substance is compressed in the engine cylinder when the piston moves from bottom dead centre to top dead centre. At constant entropy, pressure increases from P_1 to P_2, temperature increases from T_1 to T_2 and volume decreases from V_1 to V_2. There is no heat absorbed or rejected in this process.

- ***Process 2-3*:** This process is a constant volume heating process. In this process, the working substance is heated in the engine cylinder when the piston reaches the top dead

centre. At constant volume, pressure increases from P_2 to P_3, temperature increases from T_2 to T_3 and entropy increases from s_2 to s_3.

Heat absorbed by working substance = $Q_{2-3} = mc_v(T_3 - T_2)$

♣ ***Process 3-4*:** This process is a reversible adiabatic or isentropic expansion process. In this process, the working substance expands in the engine cylinder after heating and piston moves from top dead centre to bottom dead centre. At constant entropy, pressure decreases from P_3 to P_4, temperature decreases from T_3 to T_4 and volume increases from V_3 to V_4. There is no heat absorbed or rejected in this process but mechanical work is obtained.

♣ ***Process 4-1*:** This process is a constant volume cooling process. In this process, the burnt working substance is exhausted out from cylinder and fresh working substance enters. Piston moves from the top dead centre to bottom dead centre. At constant volume, pressure decreases from P_4 to P_1, temperature decreases from T_4 to T_1 and entropy decreases from s_4 to s_1.

Heat rejected by working substance = $Q_{4-1} = mc_v(T_4 - T_1)$

***Air standard efficiency of Otto cycle*:**

Work done during the cycle = W = heat absorbed – heat rejected

$$= mc_v(T_3 - T_2) - mc_v(T_4 - T_1)$$

Heat absorbed by working substance = $Q_{2-3} = mc_v(T_3 - T_2)$

Air standard efficiency = $\eta = \dfrac{\textit{Work done}}{\textit{Heat absorbed}} = \dfrac{mc_v(T_3 - T_2) - mc_v(T_4 - T_1)}{mc_v(T_3 - T_2)}$

$$= 1 - \frac{T_4 - T_1}{T_3 - T_2} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

We know that, compression or expansion ratio = $r = \dfrac{V_1}{V_2} = \dfrac{V_4}{V_3}$

For process 1-2, $\dfrac{T_1}{T_2} = \left(\dfrac{V_2}{V_1}\right)^{\gamma-1} = \left(\dfrac{1}{r}\right)^{\gamma-1}$

For process 3-4, $\dfrac{T_4}{T_3} = \left(\dfrac{V_3}{V_4}\right)^{\gamma-1} = \left(\dfrac{1}{r}\right)^{\gamma-1}$

From above, we get $\dfrac{T_1}{T_2} = \dfrac{T_4}{T_3} \qquad \Rightarrow T_4 = \dfrac{T_1 T_3}{T_2}$

Replacing the value of T_4 in equation we get,

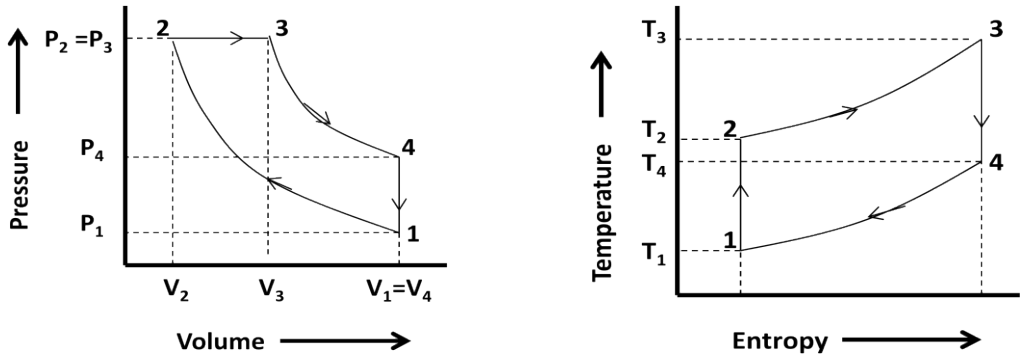
$$\text{Efficiency} = \eta = 1 - \frac{T_4 - T_1}{T_3 - T_2} = 1 - \frac{\frac{T_1 T_3}{T_2} - T_1}{T_3 - T_2} = 1 - \frac{\frac{T_1 T_3 - T_1 T_2}{T_2}}{T_3 - T_2} = 1 - \frac{\frac{T_1(T_3 - T_2)}{T_2}}{T_3 - T_2}$$

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

$\therefore$ **Air standard efficiency for Otto cycle =** $\eta_{Otto} = 1 - \frac{1}{(r)^{\gamma-1}}$ ..... **(2)**

Explain the Diesel cycle with its P-V and T-s diagram and determine the air standard efficiency of the cycle.

Diesel cycle is an air standard cycle. It is used in C.I engines. Air is used as the working substance. It is also known as constant pressure cycle. The P-V diagram of the cycle is shown in the following figure.



Diesel cycle is consisting of four processes as described below.

- ***Process 1-2*:** This process is a reversible adiabatic or isentropic compression process. In this process, the working substance is compressed in the engine cylinder when the piston moves from bottom dead centre to top dead centre. At constant entropy, pressure increases from P_1 to P_2, temperature increases from T_1 to T_2 and volume decreases from V_1 to V_2. There is no heat absorbed or rejected in this process.

- ***Process 2-3*:** This process is a constant pressure heating process. In this process, the working substance is heated in the engine cylinder when the piston reaches the top dead centre. At constant pressure, volume increases from V_2 to V_3, temperature increases from T_2 to T_3 and entropy increases from s_2 to s_3.

  Heat absorbed by working substance = $Q_{2-3} = mc_p(T_3 - T_2)$

- ***Process 3-4*:** This process is a reversible adiabatic or isentropic expansion process. In this process, the working substance expands in the engine cylinder after heating and piston moves from top dead centre to bottom dead centre. At constant entropy, pressure decreases from P_3 to P_4, temperature decreases from T_3 to T_4 and volume increases from V_3 to V_4. There is no heat absorbed or rejected in this process but mechanical work is obtained.

- ***Process 4-1*:** This process is a constant volume cooling process. In this process, the burnt working substance is exhausted out from cylinder and fresh working substance enters. Piston moves from the top dead centre to bottom dead centre. At constant volume, pressure decreases from P_4 to P_1, temperature decreases from T_4 to T_1 and entropy decreases from s_4 to s_1.

  Heat rejected by working substance = $Q_{4-1} = mc_v(T_4 - T_1)$

***Air standard efficiency of Diesel cycle*:**

Work done during the cycle (W) = heat absorbed – heat rejected

$= mc_p(T_3 - T_2) - mc_v(T_4 - T_1)$

Heat absorbed by working substance = $Q_{2-3} = mc_p(T_3 - T_2)$

Air standard efficiency = $\eta = \dfrac{\textit{Work done}}{\textit{Heat absorbed}} = \dfrac{mc_p(T_3 - T_2) - mc_v(T_4 - T_1)}{mc_p(T_3 - T_2)}$

$$= 1 - \frac{c_v}{c_p}\left(\frac{T_4 - T_1}{T_3 - T_2}\right) = 1 - \frac{1}{\gamma}\left(\frac{T_4 - T_1}{T_3 - T_2}\right) \quad \ldots\ldots\ldots (1)$$

$\left(\because \dfrac{c_p}{c_v} = \gamma\right)$ We know that, compression ratio = $r = \dfrac{V_1}{V_2}$

cut-off ratio = $\rho = \dfrac{V_3}{V_2}$ expansion ratio = $r_1 = \dfrac{V_4}{V_3} = \dfrac{V_1}{V_3} = \dfrac{V_1}{V_2} \times \dfrac{V_2}{V_3} = \dfrac{r}{\rho}$

For process 1-2, $\dfrac{T_1}{T_2} = \left(\dfrac{V_2}{V_1}\right)^{\gamma-1} = \left(\dfrac{1}{r}\right)^{\gamma-1} \Rightarrow T_2 = T_1 r^{\gamma-1}$ …….. (i)

For process 2-3, $\dfrac{V_2}{T_2} = \dfrac{V_3}{T_3} \Rightarrow T_3 = T_2 \times \dfrac{V_3}{V_2} = T_2\rho = T_1\rho r^{\gamma-1}$ …….. (ii)

For process 3-4, $\dfrac{T_4}{T_3} = \left(\dfrac{V_3}{V_4}\right)^{\gamma-1} = \left(\dfrac{1}{r_1}\right)^{\gamma-1} = \left(\dfrac{\rho}{r}\right)^{\gamma-1}$

$$\Rightarrow T_4 = T_3\left(\frac{\rho}{r}\right)^{\gamma-1} = T_1\rho r^{\gamma-1}\left(\frac{\rho}{r}\right)^{\gamma-1} = T_1\rho^{\gamma} \quad \ldots\ldots\ldots\ldots\ldots (iii)$$

Replacing the value of T_2, T_3 and T_4 in equation-1 we get,

Efficiency = $\eta = 1 - \dfrac{1}{\gamma}\left(\dfrac{T_4 - T_1}{T^3 - T^2}\right)$

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

$$= 1 - \frac{1}{\gamma}\left(\frac{\rho^{\gamma} - 1}{\rho r^{\gamma-1} - r^{\gamma-1}}\right)$$

$$\boxed{\eta = 1 - \frac{1}{\gamma}\left[\frac{\rho^{\gamma} - 1}{r^{\gamma-1}(\rho - 1)}\right]}$$

$$1\left[\frac{\rho^{\gamma} - 1}{}\right]$$

∴ **Air standard efficiency for Diesel cycle =** $\eta_{diesel} = 1 - \left[\dfrac{}{r^{\gamma-1}\,\gamma\,(\rho-1)}\right]$ ..... **(2)**

Difference between Petrol engine and Diesel engine:

	Petrol engine		**Diesel engine**
1.	Air fuel mixture is drawn into the engine cylinder in suction stroke.	**1.**	Only Air mixture is drawn into the engine cylinder in suction stroke.
2.	The carburetor is used to mix air and petrol in a proper ratio.	**2.**	Fuel injector is used to inject fuel.

3.	Pressure at the end of compression is about 10 bar.	**3.**	Pressure at the end of compression is about 35 bar.
4.	The air fuel mixture is ignited by using the spark plug.	**4.**	Mixture is self ignited at high compression ratio.
5.	Combustion of fuel takes place at constant volume.	**5.**	Combustion of fuel takes place at constant pressure.
6.	It has compression ratio approximately 6 to 10.	**6.**	It has compression ratio approximately 15 to 25.
7.	It has easy starting.	**7.**	Its starting is difficult.
8.	It is lighter and cheaper.	**8.**	It is heavier and costlier.
9.	Its running cost is high.	**9.**	Its running cost is low.
10.	Its maintenance cost is less.	**10.**	Its maintenance cost is high.
11.	It has thermal efficiency up to 26%.	**11.**	It has thermal efficiency up to 40%.
12.	It is used in light vehicles.	**12.**	It is used in heavy vehicles.

Difference between 2-stroke and 4-stroke engine:

	2-Stroke engine		**4-Stroke engine**
1.	Two stroke engines give one power stroke for each revolution of crank.	**1.**	Four stroke engines give one power stroke for every two revolutions of crank.
2.	Power produced by this engine is almost double than four stroke cycle engine.	**2.**	Power produced by this engine is almost half than two stroke cycle engine.
3.	To produce same power it requires less space.	**3.**	To produce same power it requires more space.
4.	It has inlet, exhaust and transfer ports.	**4.**	It has inlet and outlet valves.
5.	Its thermal efficiency is low.	**5.**	Its thermal efficiency is high.
6.	It requires lighter fly wheels.	**6.**	It requires larger flywheels.
7.	It is used in light vehicles.	**7.**	It is used in light, medium and heavy vehicles.
8.	Its initial cost is less.	**8.**	Its initial cost is high.

Indicated horse Power of I.C engine:

Indicated power is defined as the rate of work done on the piston by the combustion of charge inside the engine cylinder.Indicated power in terms of horse power is called as *Indicated horse power*.

Mathematically: $I.P = \frac{P_m LAnk}{60}$

Brake horse power of I.C engine:

It is the net power available at the engine shaft.Brake power in terms of horse power is called as *Brake horse power*.

Mathematically: $B.P = \frac{2\pi RNF}{60} = \frac{2\pi NT}{60}$

Mechanical efficiency of I.C engine:

It is defined as the ratio of brake power to the indicated power or I.H.P to B.H.P.

Chapter End

REFRIGERATION & AIR CONDITIONING

Refrigeration:

Refrigeration may be defined as, the process of maintaining a temperature below that of the surroundings. It is required to cool some product or space to the required temperature.

Purpose & Applications of refrigeration & air–conditioning:

- ♣ Ice making
- ♣ Transportation of foods above and below freezing
- ♣ Industrial air-conditioning
- ♣ Comfort air conditioning
- ♣ Chemical and related industries
- ♣ Medical and surgical aids
- ♣ Processing food products and beverages
- ♣ Oil refining and synthetic rubber manufacturing

One tone of refrigeration:

One tonne of refrigeration is defined as the amount of refrigeration effect produced by the uniform melting of one tonne (1000kg) of ice from and at 0℃ in 24 hours.

Since the latent heat of ice is 335 kJ/kg, therefore one tonne of refrigeration,

1 TR = 1000X335 kJ in 24 hours $= \frac{1000\times335}{24\times60} =$ 232.6 kJ/min

In actual practice, one tonne of refrigeration is taken as equivalent to 210 kJ/min or 3.5 kW

Coefficient of performance of a refrigerator:

The coefficient of performance (C.O.P.) is the ratio of heat extracted in the refrigerator to the work done on the refrigerant.

Mathematically, Theoretical C.O.P. $= \frac{Q}{W}$

Where Q = Amount of heat extracted in the refrigerator (or the amount of refrigeration produced, or the capacity of a refrigerator),

W = Amount of work done.

Construction and working of ideal Vapor compression cycle with its schematic diagram.

Thefigure shows the schematic diagram of a simple vapor compression refrigeration system. It consists of the following five essential parts.

- ***Compressor:***

  The low pressure and temperature vapor refrigeration from evaporator is drawn into the compressor through the inlet or suction valve A, where it is compressed to a high pressure and temperature. This high pressure and temperature vapor refrigerant is discharged into the condenser through the delivery or discharge valve B.

- ***Condenser:***

  The condenser or cooler consists of pipe in which the high pressure and temperature vapor refrigerant is cooled and condensed. The refrigerant, while passing through the condenser, gives up its latent heat to the surrounding condensing medium which is normally air or water.

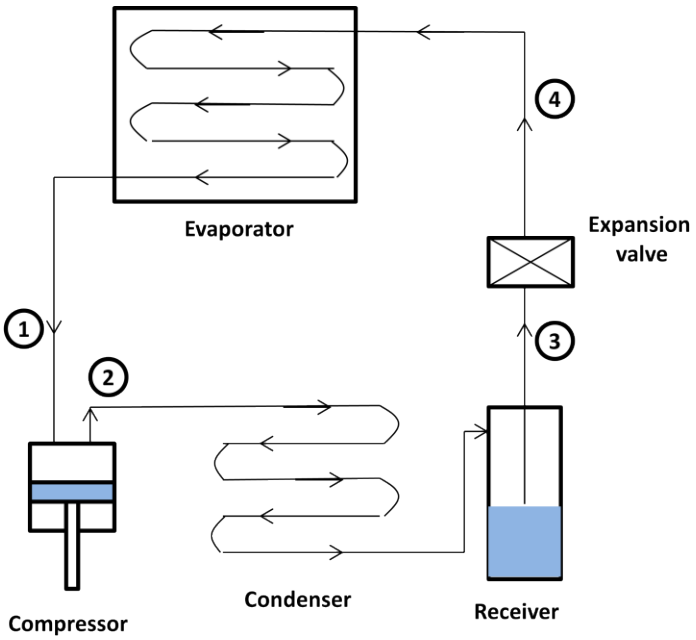
- ***Receiver:***

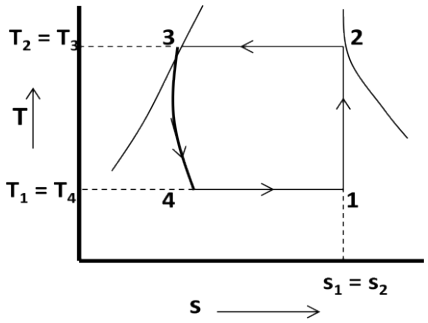
  The condensed liquid refrigerant from the condenser is stored in a vessel known as receiver from where it is supplied to the evaporator through the expansion valve or refrigerant control valve.

- ***Expansion valve:*** It is also called throttle valve or refrigerant control valve. The function of the expansion valve is to allow the liquid refrigerant under high pressure and temperature to pass at a controlled rate after reducing its pressure and temperature. Some of the liquid refrigerant evaporates as it passes through the expansion valve, but the greater portion is vaporized in the evaporator at the low pressure and temperature.

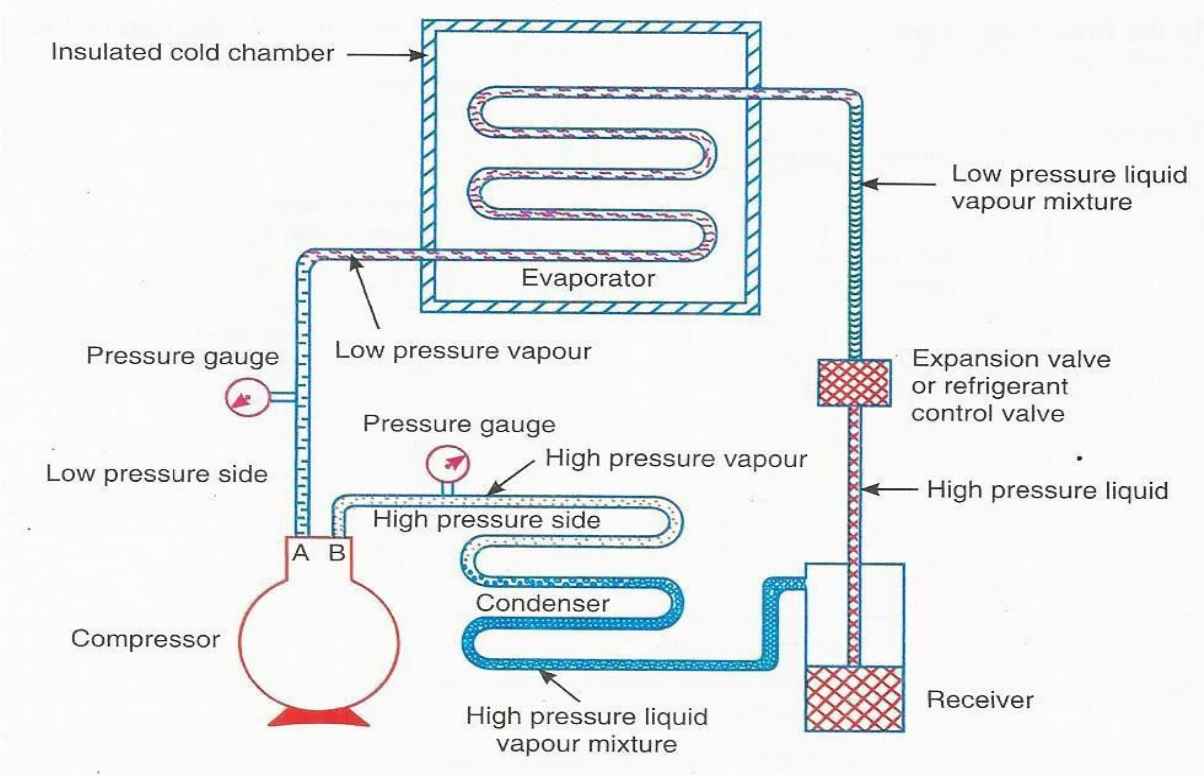
- ***Evaporator:***

  An evaporator consists of coils of pipe in which the liquid-vapor. Refrigerant at low pressure and temperature is evaporated and changed into vapor refrigerant at low pressure and temperature. In evaporating, the liquid vapor refrigerant absorbs its latent heat of vaporization from the medium (air, water or brine) which is to be cooled.





Schematic Diagram:



AIR CONDITIONING

- Air conditioning refers to the treatment of air so as to simultaneously control its temperature, moisture content, quality and circulation.

- So why do we want to do this because, this is required for occupants in thermal comforts and it required for a process or products in the space.

AIR CONDITIONING SYSTEM

- An air conditioning system is defined as “an assembly of different parts of the system used to produce a specified condition of air within a required space of building”.

<u>The basic elements of air conditioning system are</u>

- Fan
- Filter
- Refrigerating plant
- Means of warming
- Means of humidification/ dehumidification

- Control system

Classification of refrigerant:

- ♣ The refrigerants are classified as Primary and Secondary refrigerants.
- ♣ The refrigerants which directly take part in refrigeration process are called as ***primary refrigerants***. The refrigerants which are first cooled by primary refrigerant and then used for cooling purpose are called as ***secondary refrigerant***.
- ♣ The primary refrigerants are further classified as:
    - **Halo carbon refrigerants**:*Examples*> R-11, R-12 (CCl_2F_2), R-13, R- 14, R-21, R-22, R-30, R-40, R-100, R-113, R-114, R-115.
    - **Azeotrope refrigerants**:*Example*>R-500, R-502, R-503, R-504
    - **Inorganic refrigerants**:*Example*> R-717 (Ammonia), R-729, R-744, R-764, R-118
    - **Hydro carbon refrigerants**:*Example*> R-170, R-290, R-600

Properties of refrigerants:

Thermal properties:

- Low boiling point
- Low freezing point
- Positive pressure in evaporator and condenser
- High saturation point.
- High latent heat of evaporation.

Chemical properties:

- Non-toxicity
- Non flammable and non explosives
- Chemical stability in reacting
- Non irritating and odorless.

Physical properties

- Low specific volume of vapour
- High electric insulation.
- Low specific heat.
- Low viscosity
- High thermal conductivity.

Other properties:

- Ease of leakage location
- Low cost
- High C.O.P.
- Easy handling
- Low power consumption per ton.
- Low pressure ratio and pressure difference.

Chapter End

MACHINE AND MACHINE TOOL

Introduction:-

- A machine tool is a motor driven machine for machining parts of a given shape, size and accuracy by removing metal from the blank. Since the parts produced in a machine tool are used to fabricate other machine, equipment, tolls etc.

Metal cutting process:

Lathe:-

- In a lathe the work piece is rotated and if the cutting tool moves parallel to the axis of rotation, cylindrical surface is produced and if the tool moves perpendicular to the axis, flat surface is produced.

Drilling:-

- Work piece is fixed to the table and the cutting tool, the drill is given the primary cutting and feed motion, feed motion being parallel to the axis of the drill.
- Drilling is performing mostly in drilling machines.

Milling:-

- In this process the milling cutter rotates and the work piece is given feed motion. This type of metal cutting is generally performed in milling machines.

Shaping:-

- In a shaping machine the tool reciprocates and the work piece moves perpendicular to the motion of the tool.
- The work piece is feed against the tool at the beginning of each stroke.

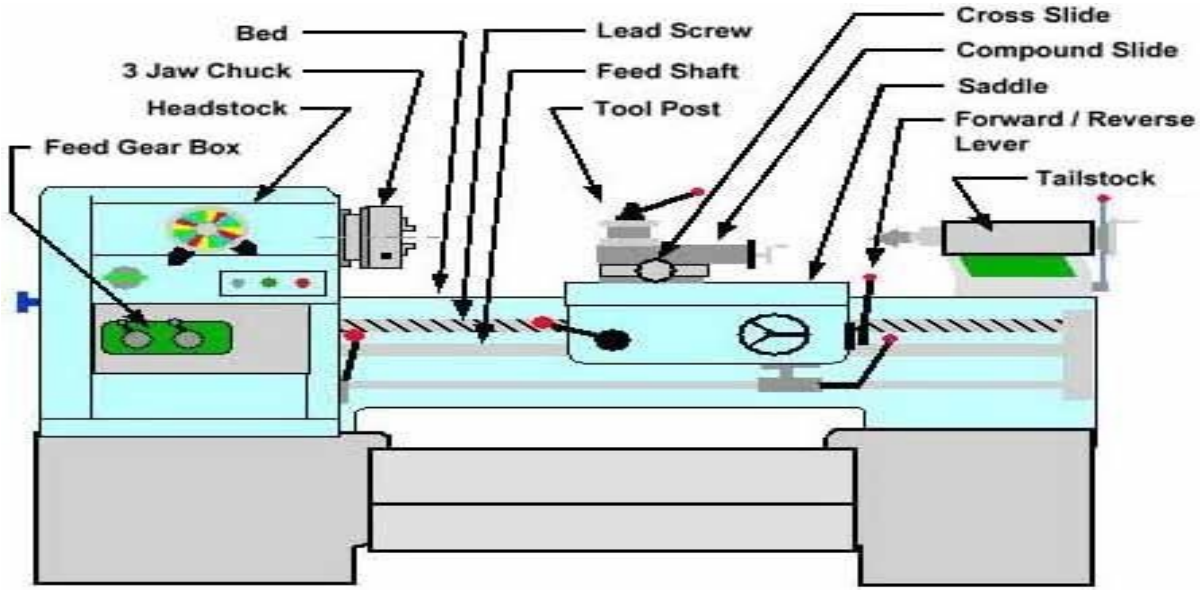
Grinding:-

- It is the process of removing metal by abrasive wheels. The primary cutting motion is giving to the grinding wheel.
- The feed motion is imparted to the work piece, i.e. rotation and reciprocation of the work piece.

LATHE:-

THE PRINCIPAL PARTS ARE:

1. BED
2. HEADSTOKE
3. TAILSTOKE
4. CARRIAGE
5. FEED MECHANISM.



BED:-

It is the base of the lathe. It is a single heavy casting and has the rigidity to resist deflection twist and vibrations. itcarries headstock, tailstock, and carriage.

Head stock:

It is permanently fitted to the left hand end of the bed. The spindle is supported in bearing which are housed in the headstock.

Tailstock:-

It is on the right hand end of the bed. The spindle can be moved in or out of tailstock by rotating the hand wheel.

Carriage:-

It is movable on guide ways and it carries the cutting tool. by moving the entire carriage longitudinal feed is given to the tool.

Saddle:-

Base of carriage which slides along the lathe guide ways.

Chapter End