## DETAILS EXPLANATIONS

## ME: Paper-2 (Paper-4) [Full Syllabus]

### [PART : A]

1. The two links or elements of a machine, when in contact with each other, are said to form a pair. If the relative motion between them is completely or successfully constrained (i.e. in a definite direction), the pair is known as kinematic pair.

2. Method of obtaining different mechanisms by fixing different links in a kinematic chain, is known as inversion of the mechanism.

3. The following properties of the instantaneous centre are important from the subject point of view :
   - A rigid link rotates instantaneously relative to another link at the instantaneous centre for the configuration of the mechanism considered.
   - The two rigid links have no linear velocity relative to each other at the instantaneous centre. At this point (i.e. instantaneous centre), the two rigid links have the same linear velocity relative to the third rigid link. In other words, the velocity of the instantaneous centre relative to any third rigid link will be same whether the instantaneous centre is regarded as a point on the first rigid link or on the second rigid link.

4. It is the distance measured on the circumference of the pitch circle from a point of one tooth to the corresponding point on the next tooth. It is usually denoted by pc.

   Mathematically, Circular pitch, $p_c = \pi \frac{D}{T}$

   Where D = Diameter of the pitch circle.

   and T = Number of teeth on the wheel.

   A little consideration will show that the two gears will mesh together correctly, if the two wheels have the same circular pitch.

5. It is the ability of a material to resist deformation under stress. The modulus of elasticity is the measure of stiffness.

6. These bearingsare self-aligning bearings. The self-aligning feature is achieved by grinding one of the races in the form of sphere. These bearings can normally tolerate angular misalignment in the order of $\pm 1\frac{1}{2}$ and when used with a double row of rollers, these can carry thrust loads in either direction.

7. They enhance the collapsibility, thus, reduce expansion defects and increase water capacity; but if added in high amounts, they make the mold brittle.

8. A delay screen is a small piece of perforated thin sheet placed in the pouring basin at the top of the down sprue. This screen actually melts into the sprue because of heat from metal and the process delays the entrance of the metal into the sprue, thus, filling the pouring basin fully and avoiding vortex flow generation.

9. Bite angle is defined as the roll angle covered by the metal that can be rolled into the rolls without using any pushing or pulling force(i.e. only with use of friction). If the metal input has to enter the rolls unaided,the horizontal component of the friction force for unit width must at least be equal to the horizontal component of the roll separating force.

10. Brazing is the metal joining processes in which a filler metal, having a melting temperature of more than 450°C but lower than the melting temperature of parent metal, is used to fill the joint gap with capillary action.

**11.** Diffusion wear occurs when work material or chip slides with tool face and the temperature at their interface can be sufficient to cause the alloying atoms from harder metal diffuse into the softer matrix of work material.

**12.** Comparators are used for quick checking of large number of identical dimensions. These instruments cannot be used as an absolute measuring device, but only for comparing two dimensions.

**13.** In this policy, the order quantity is fixed on the basis of intuitive method. The method is suitable for selected items having ordering costs sufficiently high to rule out in net requirement quantity per period.

**14.** Additional inventory is required to accommodate the uncertainties of the demand and the lead time. This stock is called buffer or safety inventory. However, there is a minor difference between these two terms; buffer inventory.

**15.** In transportation problem, if the number of allocations is less than (m + n – 1) then this is the case of degeneracy. In such cases, the solution cannot be improved upon because the algorithm cannot be applied.

**16.** All those activities which must be completed before the start of activity under consideration, are called its predecessor activities.

**17.** Free float of an activity is the delay that can be permitted in an activity so that succeeding activities in the path are not affected. For this, the earliest start time of the head event of the activity shall not exceed. Therefore, free float of an activity it is.

**18.** Coining is a cold working and closed-die forging operation used mainly for minting coins and making jewelry from sheet metals.

Flow of metal occurs only at the top layer and not in the entire volume. Fine details are produced by applying pressure as high as five to six times the strength of the material. Lubricants are not employed in this process because they can get entrapped in the die cavities and, being incompressible, prevent the full reproduction of fine details of the die.

**19.** Sintering involves heating of the green compact in a protective atmosphere furnace to a suitable temperature below the melting point of the metal. Typical sintering atmospheres are endothermic gas, exothermic gas, dissociated ammonia, hydrogen, and nitrogen.

Sintering is responsible for producing physical and mechanical properties by developing metallurgical bond among the powder particles.

It also serves to remove the lubricant from the powder, prevents oxidation, and controls carbon content in the part.

**20.** The work done during shearing is

$$W = 5 \times 10^5 \times \frac{8}{1000} \times \frac{30}{100} = 1200 \text{ J}$$

## [PART : B]

**21.** Given :

$$d_1 = 300 \text{ mm or } r_1 = 150 \text{ mm}$$
$$d_2 = 200 \text{ mm or } r_2 = 100\text{mm}$$
$$p = 0.1 \text{ N/mm} ; \mu = 0.3$$
$$N = 2500 \text{ r.p.m. or } \omega = 2\pi \times 2500/60 = 261.8 \text{ rad/s}$$

Since the intensity of pressure (p) is maximum at the inner radius ($r_2$), therefore for uniform wear,

$$p.r_2 = C \quad \text{or} \quad C = 0.1 \times 100 = 10 \text{ N/mm}$$

We know that the axial thrust,

$$W = 2\pi C (r_1 - r_2) = 2\pi \times 10 (150 - 100) = 3142 \text{ N}$$

and mean radius of the friction surfaces for uniform wear,

$$R = \frac{r_1 + r_2}{2} = \frac{150+100}{2} = 125 \text{ mm} = 0.125 \text{ m}$$

We know that torque transmitted, $T = n.\mu.W.R$

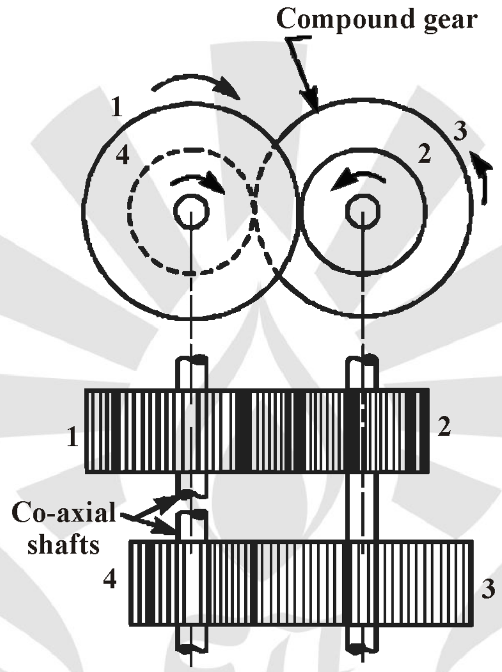
$= 2 \times 0.3 \times 3142 \times 0.125 = 235.65$ N-rn

...($\because$ n = 2,for both sides of plate effective)

$\therefore$ Power transmitted by a clutch, $P = T.\omega = 235.65 \times 261.8$

$= 61693$ W $= 61.693$ kW

**22.** When the axes of the first gear (i.e. first driver) and the last gear (i.e. last driven or follower) are co-axial, then the gear train is known as reverted gear train as shown in figure.




We see that gear 1 (i.e. first driver) drives thegear 2 (i.e. first driven or follower) in the opposite direction. Since the gears 2 and 3 are mounted on the same shaft, therefore they form a compound gear and the gear 3 will rotate in the same direction as that of gear 2. The gear 3 (which is now the second driver) drives the gear 4 (i.e. the last driven or follower) in the same direction as that of gear 1. Thus we see that in a reverted gear train, the motion of the first gear and the last gear is like.

**23.** The free cutting steels contain sulphur and phosphorus. These steels have higher sulphur content than other carbon steels. In general, the carbon content of such steels vary from 0.1 to 0.45 percent and sulphur from 0.08 to 0.3 percent. These steels are used where rapid machining is the prime requirement. It may be noted that the presence of sulphur and phosphorus causes long chips in machining to be easily broken and thus prevent clogging of machines. Now a days, lead is used from 0.05 to 0.2 percent instead of sulphur, because lead also greatly improves the machinability of steel without the loss of toughness. According to Indian standard, IS : 1570 (Part III)-1979 (Reaffirmed 1993), carbon and carbon manganese free cutting steels are designated in the following order:

- Figure indicating 100 times the average percentage of carbon.
- Letter 'C'.
- Figure indicating 10 times the average percentage of manganese.
- Symbol 'S' followed by the figure indicating the 100 times the average content of sulphur.

If instead of sulphur, lead (Pb) is added to make the steel free cutting, then symbol 'Pb' may be used.

**24.** Given:

Lower limit of hole = 25 mm

Upper limit of hole = 25.02 mm

Upper limit of shaft = 24.97 mm

Lower limit of shaft = 24.95 mm

***Hole Tolerance:***

We know that hole tolerance = Upper limit of hole – Lower limit of hole

= 25.02 – 25 = 0.02 mm

***Shaft Tolerance :***

We know that shaft tolerance = Upper limit of shaft – Lower limit of shaft

= 24.97 – 24.95 = 0.02 mm

***Allowance :***

We know that allowance = Lower limit of hole – Upper limit of shaft

= 25.00 – 24.97 = 0.03 mm

**25.** Following are the two types of rolling contact bearings :

- Ball bearings
- Roller bearings

The ball and roller bearings consist of an inner race which is mounted on the shaft or journal and an outer race which is carried by the housing or casing. In between the inner and outer race, there are balls or rollers as shown in figure.

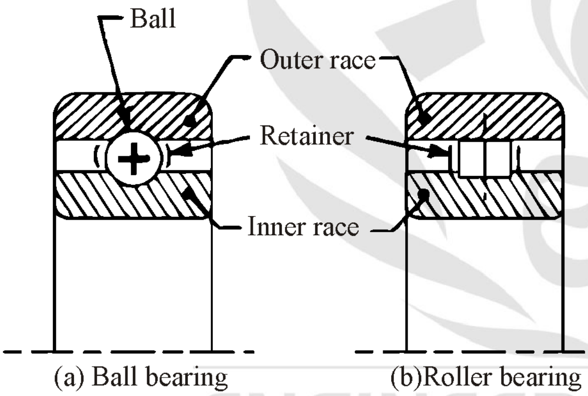



***Figure : Ball and Roller Bearings***

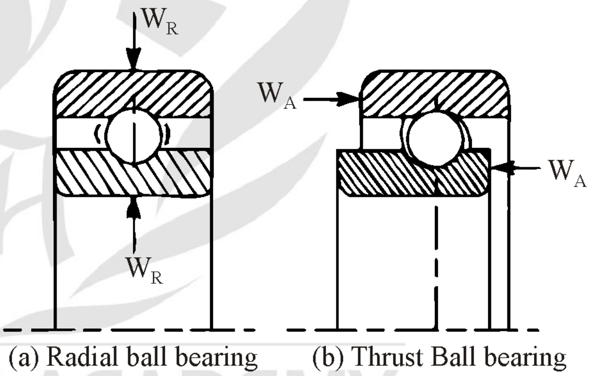



***Figure : Radial and Thrust Ball Bearings***

A number of balls or rollers are used and these are held at proper distances by retainers so that they do not touch each other. The retainers are thin strips and is usually in two parts which are assembled after the balls have been properly spaced. The ball bearings are used for light loads and the roller bearings are used for heavier loads.

***The rolling contact bearings, depending upon the load to be carried, are classified as :***

(a) Radial bearings

(b) Thrust bearings

The radial and thrust ball bearings are shown in Fig. respectively. When a ball bearing supports only a radial load (WR), the plane of rotation of the ball is normal to the centre line of the bearing, as shown in figure (a). The action of thrust load (WA) is to shift the plane of rotation of the balls, as shown in figure (b). The radial and thrust loads both may be carried simultaneously.

**26.** Machining Allowance Machining allowance is the excess in dimensions of castings to take care of machining. It depends upon the cast material, type of molding used, class of surface finish, complexity of details and, obviously, the overall dimensions of the job. Molding sand has greater strength in compression than in tension, therefore, heavier and intricate sections should be included into drag flask to reduce machining allowances.

**27.** Shell molding, also known as croning process5, is a process in which the pattern is made in the form of shells. For this, a master pattern made of cast iron is heated to 175 – 370°C, coated with silicon (as parting agent) and is clamped into a box which contains fine sand mixed with 2.5 – 4% thermosetting resin binder, such as phenol formaldehyde that coats the sand particles. The box is then rotated upside down, allowing the sand to coat the pattern. The pattern assembly is then placed in an oven for a short period of time to complete the curing process of the resin. The hardened shell is then removed from around the pattern using built-in injector pins. Two halve shells made are bonded or clamped together in preparation of pouring. The thickness of shell (≈5 – 10 mm) depend upon the curing time. The fine sand used in shell molds has much lower permeability and decomposition of shell sand binder generates high volume of gases. Shell molding is used for casting of small mechanical parts requiring high precision, gear housing, cylinder heads, connecting rods, turbine blades, etc.

**28.** Wire drawing is a cold working operation for fabrication of long lengths of small diameter wire (upto 0.01 mm) with good dimensional accuracy. This is done by preparing pointed tip by using swaging process. The ductile material is drawn through the tungsten carbide die by pulling it out. Indirect compression during the drawing causes plastic deformation of the work metal.

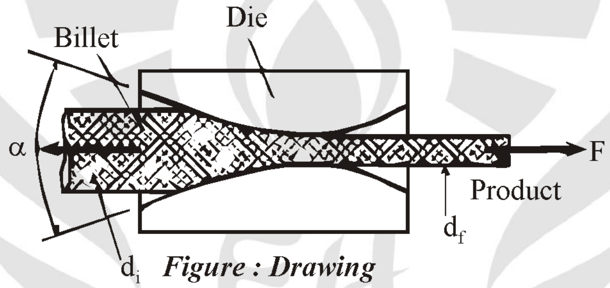



***Figure : Drawing***

To avoid the deformation after the wire has emerged from die, maximum drawing stress is limited to 60% of the yield stress of the emerging product, which limits the reductions to about 35%. A lubricant is used to reduce friction on the die surface. This can also be achieved by applying coating of ferrous hydroxide (by sulling process) or phosphate of manganese iron or zinc (by phosphating process). Intermediate annealing is required to restore the ductility. Let a rod of diameter $d_i$ is reduced to diameter $d_f$ by wire drawing operation. Yield strength of the work material is ó and coefficient of friction between work material and die is μ.

Small diameter wire is generally drawn on tandom machines which consists of a series of dies, each held in a water cooled die block. Each die reduces the cross section by a small amount so as to avoid excessive strain in the wire. Intermediate annealing of material between different states of wire can also be done, if required.

**29.** Laser is defined as a concentrated beam of coherent monochromatic radiations, a high energy source of heat to melt (even evaporate) the joint for fusion welding. The laser beam can be highly focused to as small a diameter as 10 μm. It has high energy density, therefore, deep penetrating capability. Therefore, laser beam welding (LBW) is used for deeper penetration welds even with dissimilar metals and multilayer materials. The process can be carried out in open atmosphere. The technique is mostly used in electronic industry.

**30.** Tapping is a machining process that uses a multi-point cutting tool (tap) to produce uniform, internal, helical threads. A tap is simply a hardened tool steel screw with length wise groves called fleets, milled or ground across the threads. The leading end is tapered to facilitate entry of the tool into the work material. Once started, the tap is automatically drawn into the hole by threads. Hence, it is not be forced in but to be rotated only.

The feed per revolution of the tap is equal to the lead of the thread. Taps with long chamfer can be run at higher speeds because long chamfer reduces chip load per tooth.

**31.** If s is cost of stock out cost, then the safety level of stock is determined as

$$Q_s = Q^* \times \sqrt{\frac{s}{s+h}}$$

Given that,
$D = 1000$ units
$A = ₹100$/order
$h = ₹100$/unit year
$s = ₹400$

Therefore,

$$Q_s = \sqrt{\frac{2AD}{h}} \times \sqrt{\frac{s}{s+h}} = \sqrt{\frac{2\times100\times1000}{100}} \times \sqrt{\frac{400}{400+100}} = 40$$

**32.** Given that,
$\lambda = 5$ per hour
$\mu = 6$ per hour

Therefore, $\rho = \frac{\lambda}{\mu}$

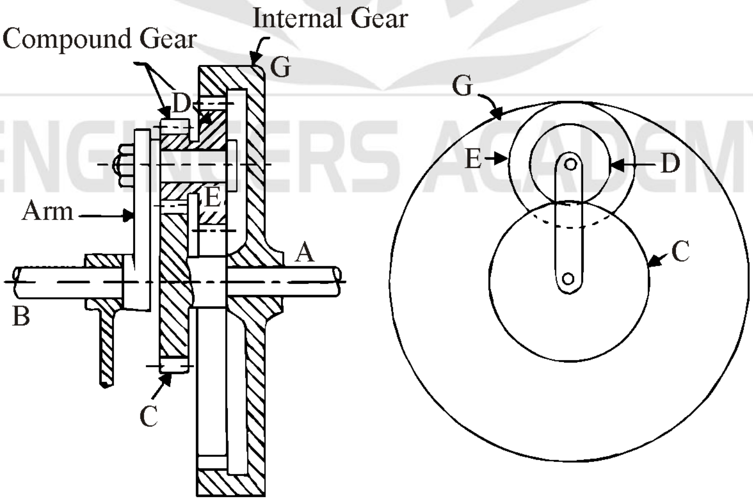
Average waiting time in the queue is

$$t_q = \frac{\rho}{\mu-\lambda} = \frac{5}{6}\text{ hours} = 50\text{ min}$$

## [PART : C]

**33.** Given, $T_C = 50$ ; $T_D = 20$ ; $T_E = 35$ ; $N_A = 110$ rpm

The arrangement is shown in figure.




***Number of teeth on internal gear G***

Let $d_C$, $d_D$, $d_E$ and $d_G$ be the pitch circle diameters of gear C, D, E and g respectively. For the geometry of the figure.

$$\frac{d_G}{2} = \frac{d_C}{2} + \frac{d_D}{2} + \frac{d_E}{2}$$

or $$d_G = d_C + d_D + d_E$$

Let $T_C$, $T_D$, $T_E$ and $T_G$ be the number of teeth on gear C, D, E and G respectively. Since all the gears have the same module, therefore, number of teeth are proportional to their pitch circle diameters.

$\therefore$ $$T_G = T_C + T_D + T_E$$
$$= 50 + 20 + 35 = 105$$

***Speed of Shaft B :*** The table of motions is given below :

| Conditions of motion | Revolutions of Elements | | | |
|---|---|---|---|---|
| | **Arm** | **Gear C (or Shaft A)** | **Compound Gear D-E** | **Gear G** |
| Arm fixed - gear C rotates through + 1 revolution | 0 | +1 | $-\frac{T_C}{T_D}$ | $-\frac{T_C}{T_D}\times\frac{T_E}{T_G}$ |
| Arm fixed - gear C rotates through + x revolutions | 0 | +x | $-x\times\frac{T_C}{T_D}$ | $-x\times\frac{T_C}{T_D}\times\frac{T_E}{T_G}$ |
| Add + y revolutions to all elements | +y | +y | +y | +y |
| **Total Motion** | +y | x + y | $y-x\times\frac{T_C}{T_D}$ | $y-x\times\frac{T_C}{T_D}\times\frac{T_E}{T_G}$ |

Since the gear G is fixed, therefore form the fourth row of the table,

$$y - x \times \frac{T_C}{T_D}\times\frac{T_E}{T_G} = 0$$

or $$y - x \times \frac{50}{20}\times\frac{35}{105} = 0$$

$\therefore$ $$y - \frac{5}{6}x = 0 \qquad ...(1)$$

Since the gear C is rigidly mounted on shaft A, therefore speed of gear C and shaft A is same. We know that speed of shaft A is 110 rpm, therefore from the fourth row of the table.

$$x + y = 100 \qquad ...(2)$$

From equation (1) and (2), $x = 60$ and $y = 50$

$\therefore$ Speed of shaft B = Speed for arm = +y = 50 rpm anticlockwise.

**34.** Given, $W_1 = 3$ kN; $n_1 = 0.1$ n; $W_2 = 2$ kN; $n_2 = 0.2$ n ;

$W_3 = 1$ kN ; $n_3 = 0.3$ n; $W_4 = 0$ ;

$n_4 = (1 - 0.1 - 0.2 - 0.3)n = 0.4$ n ; $L_{95} = 20 \times 10^6$ rev

Let, $L_{90}$ = Life of the bearing corresponding to reliability of 90%

$L_{95}$ = Life of the bearing corresponding to reliability of 95%

$= 20 \times 10^6$ revolutions ...(Given)

We know that $$\frac{L_{95}}{L_{90}} = \left[\frac{\log_e(1/R_{95})}{\log_e(1/R_{90})}\right]^{1/b} = \left[\frac{\log_e(1/0.95)}{\log_e(1/0.90)}\right]^{1/1.17} \qquad ...(\because b = 1.17)$$

$$= \left(\frac{0.0513}{0.1054}\right) = 0.54$$

$$\therefore \qquad L_{90} = \frac{L_{95}}{0.54} = \frac{20\times10^6}{0.54} = 37 \times 10^6 \text{ rev}$$

We know that equivalent radial load,

$$W = \left[\frac{n_1(W_1)^3 + n_2(W_2)^3 + n_3(W_3)^3 + n_4(W_4)^3 + n_1(W_1)^3}{n_1 + n_2 + n_3 + n_4}\right]^{1/3}$$

$$= \left[\frac{0.1n\times3^3 + 0.2n\times2^3 + 0.3n\times1^3 + 0.4n\times0^3}{0.1n + 0.2n + 0.3n + 0.4n}\right]^{1/3}$$

$$= (2.7 + 1.6 + 0.3 + 0)^{1/3} = 1.663 \text{ kN}$$

We also know that dynamic load rating,

$$C = W\left(\frac{L_{90}}{10^6}\right)^{1/k} = 1.663\left(\frac{37\times10^6}{10^6}\right)^{1/3} = 5.54 \text{ kN}$$

...($\because$ k = 3, for ball bearing)

**35.** The scientific analysis of cutting forces was carried out by H. Ernst and M. E. Merchant in 1941. Figure 14.6 shows free body diagram of the chip, considered as a rigid body.

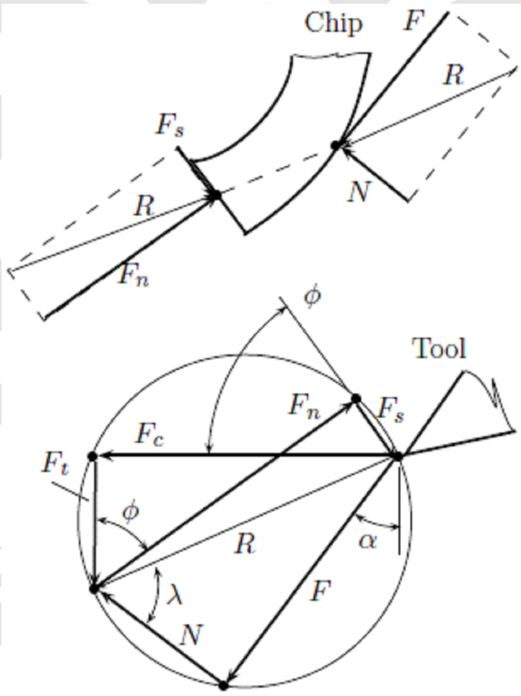



***Figure : Merchant's Circle***

***The chip is in equilibrium under the actionof the following forces :***

- Shear Force The resistance to shear in chip formation, acting along the shear plane ($F_s$).
- Normal Reaction The reaction offered by workpiece, acting normal to shear plane ($F_n$).
- Friction Force The frictional resistance offered by tool along the tool rake (F).
- Normal Reaction The reaction offered by tool normal to the rake (N).

These forces can be drawn within a circle pivoted at the cutting edge This circle is known as Merchant's circle diagram or composite cutting force circle, first suggested by Merchant. This circle can be used for the analysis of forces acting on the chip. Such an analysis is called Merchant's analysis

If coefficient of friction between chip and tool rake is $\mu$ (friction angle $\lambda$), then forces acting at the rake are related as

$$\frac{F}{N} = \mu = \tan\lambda$$

Merchant's circle reflects the effect of friction on shear Force ($F_s$) and shear angle ($\phi$). Large friction force results in thick chip having low shear angle. Power consumption is low when friction force is minimized. Therefore. Merchant's analysis has two basic objectives :

- ***Cutting Forces :*** The shear force acting on the chip at shear plane is determined as

$$F_s = b\frac{t_1}{\sin\phi}\tau_s$$

Where t is the width of the workpiece and $\tau_s$ is the shear strength of the work material. The resultant of $F_s$ and $F_n$ is also equal to R. Therefore, using Merchant's circle (shown in figure), one obtains

$$R = \frac{F_s}{\cos(\phi + \lambda - \alpha)}$$

The resultant force (R) acting on tool rake can be resolved into horizontal and vertical components to find the cutting force ($F_c$) and thrust force ($F_t$), respectively. Therefore,

$$F_c = R\cos(\lambda - Q)$$

$$F_t = R\sin(\lambda - \alpha)$$

Friction and normal forces at tool rake can be determined as

$$F = F_c\sin\alpha + F_t\cos\alpha$$

$$N = F_c\cos\alpha - F_t\sin\alpha$$

Coefficient of friction can be expressed as

$$\mu = \frac{F}{N} = \frac{F_c\sin\alpha + F_t\cos\alpha}{F_c\cos\alpha - F_t\sin\alpha} = \frac{F_t + F_c\tan\alpha}{F_c - F_t\tan\alpha}$$

- ***Power Consumption :*** Power consumption in metal cutting can he determined as

$$P = F_c \times V_c$$

For minimum power consumption,

$$\frac{dP}{d\phi} = 0$$

Which is possible when

$$2\phi + \lambda - \alpha = \frac{\pi}{2}$$

$$\phi = \frac{\pi}{4} + \frac{\alpha - \lambda}{2}$$

This equation is known as Ernst-Merchant for-mula which indicates that the shear angle de-creases with decrease in rake angle and increase in friction at the tool-chip interface. This results in increased chip thickness that causes increase in power consumption and heat dissipation.

Apart from Ernst -Merchant formula above, the following are important relationships :

(i) Stabler theory $\phi = \frac{\pi}{4} - \lambda + \frac{\alpha}{2}$

(ii) Lee-Shaffer theory $\phi = \frac{\pi}{4} - \lambda + \alpha$

36. • Simple Average Method A simple average method forecasts the demand of the next time period as the average of demands occurring in all previous time periods.

- Simple Moving Average Method In simple moving average method, the average of the demands from several of the most recent periods is taken as the demand forecast for the next time period. The number of past periods to be used in calculations is selected in the beginning and is kept constant.
- Weighted Moving Average Method In weighted moving average method, unequal weights are assigned to the past demand data while calculating simple moving average as the demand forecast for the next time period. Usually, the most recent data is assigned the highest weight factor.
- Exponential Smoothing In exponential smoothing method, weights are assigned in exponential order. The forecast for time period t is related to the demand for the previous period $D_{t-1}$ and forecast of previous period $F_{t-1}$ as

$$F_t = F_{t-1} + \mu(D_{t-1} - F_{t-1})$$

Where, μ is called smoothing constant. This method takes care of error $(D_{t-1} - F_{t-1})$ in old forecasting. The weights decrease exponentially from most recent demand data to older demand data.

**37.** Simple EOQ model is based on the assumptions evident from the inventory replenishment cycle depicted in Fig. The demand is deterministic and constant. The depletion rate of the inventory is also constant. The inventory is replenished immediately when stock level reaches zero level.

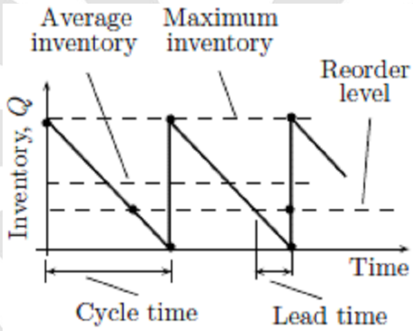



***Figure : Simple EOQ model***

Let Q units be the order quantity to cover annual demand D (units per annum). The components of inventory costs are determined as follows :

- ***Ordering Cost :*** There will he D/Q numher of orders per year. Therefore, annual ordering cost of the inventory is determined as

$$O(Q) = \frac{D}{Q}A$$

Where A is the cost of one order.

- ***Holding Cost :*** The inventory is maximum (Q) at the replenishment and gradually decreases to zero. Annual average holding cost of the inventory is determined as

$$H(Q) = \frac{Q}{2}h$$

where h is the annual holding cost per unit of the inventory.

Total inventory cost is determined as

$$T(Q) = \frac{D}{Q}A + \frac{Q}{2}h$$

Figure shows the variation of O(Q), H(Q), T(Q) with respect to order quantity Q.

The order quantity associated with the minimum value of T(Q) can be determined as

$$\frac{dT(Q)}{dQ} = 0 \; ; \quad -\frac{DA}{Q^2} + \frac{h}{2} = 0$$

$$Q = \sqrt{\frac{2AD}{h}}$$

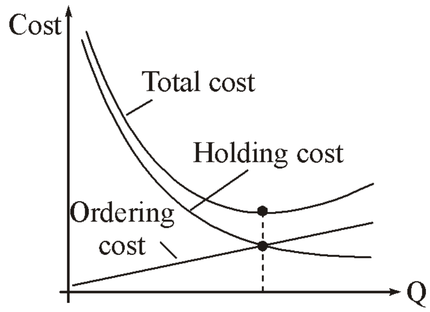



***Figure : Total Cost in Simple EOQ model***

This value of order quantity is called the economic order quantity and it is denoted by Q*. Therefore,

$$Q^* = \sqrt{\frac{2AD}{h}}$$

This equation is called wilson Harris formula.

**38.** From the torque equation, we get

$$I\ddot{\theta} = \text{Restoring torque}$$

$$ml\ddot{\theta} = (mg \sin\theta)l - ka \sin\theta(a \cos\theta) - kb \sin\theta (b \cos\theta)$$

For small θ, $\sin\theta = \theta$ and $\cos\theta = 1$

$$ml^2\theta = mgl\theta - ka^2\theta - kb^2\theta$$

$$ml^2\theta + (mgl + ka^2 + kb^2)\theta = 0$$

$$\ddot{\theta} = \frac{(mgl + ka^2 + kb^2)\theta}{ml^2} = 0$$

So, $$f_a = \frac{1}{2\pi}\sqrt{\frac{mgl + ka^2 + kb^2}{ml^2}} \text{ Hz}$$

If no spring is used, the system becomes a simple pendulum.

**39.** This mechanism is mostly used in shaping and slotting machines. In this mechanism, the link CD (link 2) forming the turning pair is fixed, as shown in figure.

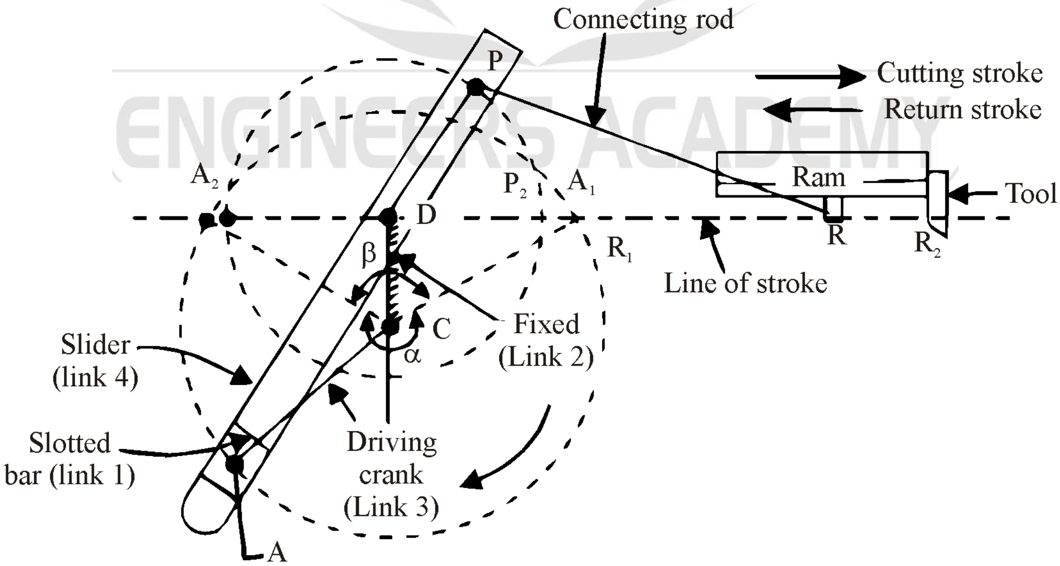



***Figure : Whitworth quick return motion mechanism***

The link 2 corresponds to a crank in a reciprocating steam engine. The driving crank CA (link 3) rotates at a uniform angular speed. The slider (link 4) attached to the crank pin at A slides along the slotted bar PA (link 1) which oscillates at a pivoted point D. The connecting rod PR carries the ram at R to which a cutting tool is fixed. The motion of the tool is constrained along the line RD produced, i.e. along a line passing through D and perpendicular to CD.

When the driving crank CA moves from the position $CA_1$ to $CA_2$ (or the link DP from the position $DP_1$ to $DP_2$) through an angle a in the clockwise direction, the tool moves from the left hand end of its stroke to the right hand end through a distance 2 PD.

Now when the driving crank moves from the position $CA_2$ to $CA_1$ (or the link DP from $DP_2$ to $DP_1$) through an angle fi in the clockwise direction, the tool moves back from right hand end of its stroke to the left hand end.

A little consideration will show that the time taken during the left to right movement of the ram (i.e. during forward or cutting stroke) will be equal to the time taken by the driving crank to move from $CA_1$ to $CA_2$. Similarly, the time taken during the right to left movement of the ram (or during the idle or return stroke) will be equal to the time taken by the driving crank to move from $CA_2$ to $CA_1$.

Since the crank link CA rotates at uniform angular velocity therefore time taken during the cutting stroke (or forward stroke) is more than the time taken during the return stroke. In other words. the mean speed of the ram during cutting stroke is less than the mean speed during the return stroke. The ratio between the time taken during the cutting and return strokes is given by

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

***Note :*** *In order to find the length of effective stroke $R_1$ $R_2$ mark $P_1R_1 = P_2R_2 = PR$. The length of effective stroke is also equal to 2 PD.*

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