DETAILS EXPLANATIONS

ME: Paper-2 (Paper-5) [Full Syllabus]

[PART : A]

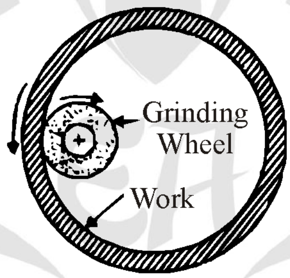
1. A material with high value of modulus of elasticity is said to be stiff and a material with low value of modulus of elasticity is said to be resilient. Consider a material undergoing tensile stress within the elastic range. If the material possesses a high value of Young's modulus (which is the modulus of elasticity corresponding to tensile stress), the material will not stretch much. It will behave as a "stiff " material. Resilience is a property which is totally opposite to stiffness. A beam made of stiff material will deflect to a lesser extent as compared to another made of resilient material under identical loading condition.

2. Boring means enlarging an existing hole. For initial drilling of a hole on the lathe machine, tailstock centre is removed and in the tailstock spindle a drill is inserted. The tailstock is brought closer to the work piece, which is held in the chuck and rotated. Now using the handwheel of the tailstock, the drill is advanced.

3. For providing better grip, some work pieces are provided with a shallow diamond shaped pattern on its circumference. Knurling rollers, which have a similar pattern cut on their surface are hardened. When a work piece surface is required to be knurled, the work piece is held in a chuck and rotated and the knurling roller is clamped in the tool post and by moving the cross slide, the roller is pressed into the surface of the work piece. As the roller and work piece surface rotate together, the pattern is etched into the surface of the work piece.

4. Counter sinking provides a tapered entrance to the hole. A special counter sinking tool with a pilot is used.

5. Internal grinding operation means, grinding of internal holes or bores. The principle of internal grinding is shown in figure.



Internal grinding is designed to grind the surface of bores; whether plain or tapered with the help of a small grinding wheel mounted on a long slender spindle which can enter in the bore. It is capable of giving improved geometry of the hole as well as the surface finish. This operation is performed on specially designed internal grinding machines. For internal grinding, a softer wheel is generally preferred.

6. It is the process of increasing the cross-section at expense of the length of the work piece.

7. Types of kinematic pairs, namely two elements have surface contact and when relative motion takes place, the surface of one element slides over the surface of the other element.

8. A mechanism for connecting two shafts having parallel misalignment. The coupling transmits a constant velocity ratio.

9. The governor is said to be stable if there is one equilibrium speed for each radius of rotation of the flyballs and this speed increases with the radius.

10. Type of lubrication in which the two surfaces have between them a more or less complete layer of oil which is only, at the most, a few molecules thick.

11. Bright, polished finish produced on the surface of a metal by rubbing it with another metallic harder surface, which smooths out small scratch marks.

12. Method of grinding metallic parts in which the piece to be ground (circular piece) is supported on a work rest, and passed between a grinding wheel running at a high speed and a controlling wheel running at a slow speed.

13.
- it meets the output goals of the master schedule and fulfills delivery promises
- It keeps a constant supply of work ahead of each machine.
- It puts manufacturing order in the shortest possible time consistent with economy.

14. Following are the work order documents used by dispatcher
- Work order
- Machine load chart
- Material requisition form
- Move ticket
- Inspection ticket

15. It is a technique of assembly in which parts are not produced to tolerance small enough to be fully interchangeable. instead components are sorted into categories according to size that all parts within a given category can be assembled with any of the parts in the corresponding category of mating component.

16. An activity that consumes no time but show precedence among activities .it is useful for proper representation in the network.

17. ***Inventory Status File :***

Inventory status file keeps an up-to-date record of each item in the inventory. Information such as, item identification number, quantity on hand, safety stock level, quantity already allocated and the procurement lead time of each item is recorded in this file.

18. ***Bill of Materials (BOM) :***

BOM represents the product structure. It encompasses information about all sub components needed, their quantity, and their sequence of buildup in the end product. Information about the work centers performing buildup operations is also included in it.

19. ***Job enrichment*** is the process of redesigning jobs to satisfy higher- level needs and organizational needs by improving worker satisfaction and task efficiency .

It gives workers more responsibility, authority, and autonomy in planning and doing their work.

20. ***Therbligs :***

As result of several motion studies conducted Gilbreths concluded that any work can be done by using a combination of 17 basic motions, called Therbligs (Gilbreth spelled backward). These can be classified as effective therbligs and ineffective therbligs. Effective therbligs take the work progress towards completion. Attempts can be made to shorten them but they cannot be eliminated. Ineffective therbligs do not advance the progress of work and therefore attempts should be made to eliminate them by applying the *Principles of Motion Economy.*

[PART : B]

21. Improper welding procedure and lack of skill on the part of welder may result in many welding defects.

The major welding defects are described below :

- Incomplete fusion and lack of penetration: Incomplete fusion can be avoided by proper weld joint preparation, using adequate current and travel speed of electrode should not be too high.

- Porosity: Molten metal has a tendency to absorb gases. The entrapped gases cause porosity or blow holes in the weld bead. Remedy lies in cleaning the work piece surface of all oil, grease and paint etc. before welding and ensuring that electrode coating is free from dampness. If necessary, electrodes can be dried in an oven before use.
- Slag inclusion: It refers to slag or other non-metallic inclusions getting entrapped in the weld bead. The most common reason for slag inclusion is that between two electrode runs, the slag, has not been completely removed by chipping and wirebrushing.
- Undercut: Undercutting is often caused due to high amperage used. It denotes the melting away of the base metal at the line where the final layer of weld bead merges into the surface of the base metal. The undercut portion must be rectified by depositing weld metal on it.
- Cracking: Cracks can take place either in the weld bead itself (called hot cracks) or in the heat affected zone (cold cracks). Hot cracks may take place due to narrow deep welds and are caused due to shrinkage of weld metal, particularly if impurities like sulphur are present in the weld metal.

Excessive joint restraint can also cause such cracks. Cold cracks occur due to inadequate ductility or presence of hydrogen in hardenable steels. Preheating and post heating of base material will help in avoiding cold cracks

22. Galvanising is the name given to the process of coating steel sheets with a layer of zinc. The layer of zinc protects the steel item from corrosion and rusting by sacrificing itself. Over the years, when all zinc has been depleted due to atmospheric action, the steel surface will get exposed and begin to rust. Galvanised metal sheets, pipes and wires are used very extensively as the process of galvanising is a low cost process, but adds a lot of value to the item.

The main techniques for galvanising are :

- Hot dip galvanising,
- Cold dip galvanising, and
- By electroplating.

Hot dip galvanising: The part to be galvanised is cleaned thoroughly. The idea is to remove all grease, paint, rust and dirt etc. from the surface. If a steel sheet is to be galvanised, the sheet is annealed and cooled in an oxygen free atmosphere. When it has cooled sufficiently, it is dipped into a bath of molten zinc. The sheet is then drawn through two rollers, when all excess zinc is removed from the surface and the zinc layer becomes uniform in thickness.

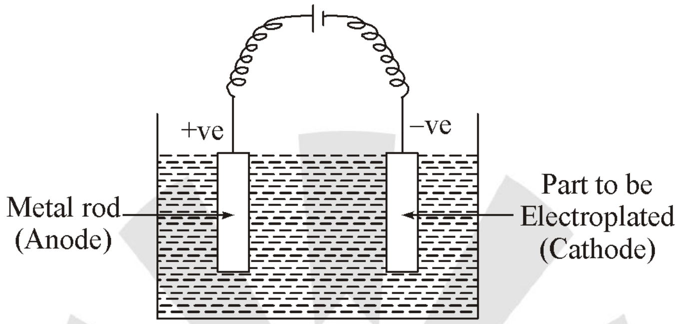
Cold dip galvanising: Cold dip galvanising process is cheaper but more time consuming. The first step is thorough cleaning of surface as in hot dip galvanising. Then the part or sheet to be galvanised is made to hang in a cold zinc bath consisting of zinc chloride, tin chloride and some other salts. The parts remain dipped or suspended in cold bath for 3 to 12 hours depending upon thickness of coating required. Bath, however has to be periodically stirred.

The process requires no power for heating the bath. Besides zinc has a tendency to sublimate and in hot dip process, lot of zinc gets wasted due to sublimation. Hence cold dip process proves ultimately cheaper and better.

By electroplating: This process is used only for depositing a layer of zinc on intricately shaped items. It is not a popular process for mass production. The basic principle of zinc electroplating is to use an electrolyte made by dissolving zinc chloride, zinc sulphate, ammonium chloride and ammonium sulphate in distilled water. The zinc metal is used as anode and the article to be plated is used as cathode. Upon using a suitable low voltage and direct current, zinc gets deposited on the cathode.

23. Principle of electroplating process: In the process of electroplating, a thin layer of a metal is deposited on another metal part with the object of corrosion prevention, or to ensure that the electroplated part looks nice and aesthetic. The part is usually electroplated with gold, silver, chromium or nickel because these platings look nice and do not tarnish.

The principle of electroplating is simple. If two electrodes are immersed partially in a suitable electrolyte and a direct current is passed by joining the two electrodes in an external circuit, the metal from the anode gets transferred through electrolyte-action on the cathode. A simple arrangement for electroplating is shown in figure.



Electroplating Process

Electroplating is a metal deposition process. The amount of metal deposited can be calculated easily, it is remembered that 96500 coulombs of electrical charge (1 coulomb = 1 amp current × 1 second) deposits one electrochemical equivalent of the substance at the electrode, irrespective of what the substance is. Electrochemical equivalent of a substance is equal to

$$\frac{\text{Atomic weight of the substance}}{\text{Valency}} \text{(gms)}$$

For example, if copper is being deposited from $CuSO_4$ solution, electrochemical equivalent of copper is atomic weight of copper ÷ 2 (valency of copper). Atomic weight of copper is 63.5, and its equivalent will be = 31.75 gms.

24. Sometimes, it may become necessary to join two pieces of metal. Forge welding of steel is quite common and consists of heating the two ends to be joined to white heat (1050°C – 1150°C). Then the two ends of steel are brought together having previously been given a slight convex shape to the surfaces under joining. The surfaces are cleaned of scale. They are then hammered together using borax as flux. The hammering is started from centre of the convex surface and it progresses to the ends. This results in the slag being squeezed out of the joint.

Hammering is continued till a sound joint is produced. Several types of joints can be made viz., butt joint, scarf joint or splice joint

25. Given :

$$h = 10 \text{ mm}$$
$$l = 3 \text{ m} = 3000 \text{ mm}$$
$$A = 600 \text{ mm}^2$$
$$\delta l = 2 \text{ mm}$$
$$E = 200 \text{ kN/mm}^2 = 200 \times 10^3 \text{ N/mm}^2$$

Stress in the bar :

Let σ = Stress in the bar.

We know that Young's modulus,

$$E = \frac{\text{Stress}}{\text{Strain}} = \frac{\sigma}{\varepsilon} = \frac{\sigma . l}{\delta l}$$

∴ $\sigma = \frac{E.\delta l}{l} = \frac{200 \times 10^3 \times 2}{3000} = \frac{400}{3} = 133.3 \text{ N/mm}^2$

Value of the unknown weight :

Let, W = Value of the unknown weight

We know that $\sigma = \frac{W}{A}\left[1+\sqrt{1+\frac{2hAE}{Wl}}\right]$

$$\frac{400}{3} = \frac{W}{600}\left[1+\sqrt{1+\frac{2 \times 10 \times 600 \times 200 \times 10^3}{W \times 3000}}\right]$$

$$\frac{400 \times 600}{3W} = 1+\sqrt{1+\frac{800000}{W}}$$

Squaring both sides,

$$\frac{6400 \times 10^6}{W^2}+1-\frac{160000}{W} = 1+\frac{800000}{W}$$

$$\frac{6400 \times 10^2}{W} - 16 = 80 \text{ or } \frac{6400 \times 10^2}{W} = 96$$

∴ $W = 6400 \times \frac{10^2}{66} = 6666.7 \text{ N}$

26. Given : d = 50 mm

l = 2.5 m = 2500 mm

U = 100 N-m = 100 × 10^3 N-mm

E = 200 GN/m^2 = 200 × 10^3 N/mm^2

Maximum instantancous stress

Let σ = Maximum instantancous stress

We know that volume of the bar, $V = \frac{\pi}{4} \times d^2 \times l = \frac{\pi}{4}(50)^2 \times 2500 = 4.9 \times 10^6 \text{ mm}^3$

We also know that shock or strain energy stored in the body (U),

$$100 \times 10^3 = \frac{\sigma^2 \times V}{2E}$$

$$= \frac{\sigma^2 \times 4.9 \times 10^6}{2 \times 200 \times 10^3} = 12.25\ \sigma^2$$

∴ $\sigma^2 = 100 \times \frac{10^3}{12.25}$

$= 8163$ or $\sigma = 90.3 \text{ N/mm}^2$

Elongation Produced

Let, δl = Elongation Produced

We know that Young's modulus, $E = \frac{\text{Stress}}{\text{Strain}} = \frac{\sigma}{\varepsilon} = \frac{\sigma}{\delta l / l}$

∴ $\delta l = \frac{\sigma \times 1}{E} = \frac{90.3 \times 2500}{200 \times 10^3} = 1.13 \text{ mm}$

27. Given :

$P = 100\text{ kW} = 100 \times 10^3\text{ W}$

$N = 160\text{ rpm}$

$T_{max} = 1.25\ T_{mean}$

$\tau = 70\text{ MPa} = 70\text{ N/mm}^2$

Let, T_{mean} = Mean torque transmitted by the shaft in N-m

and d = Diameter of the shaft in mm

We know that the power transmitted (P),

$$100 \times 10^3 = \frac{2\pi N.T_{mean}}{60} = \frac{2\pi \times 160 \times T_{mean}}{60} = 16.76\ T_{mean}$$

$$\therefore \quad T_{mean} = 100 \times \frac{10^3}{16.76} = 5966.6\text{ N-m}$$

and maximum torque transmitted

$$T_{max} = 1.25 \times 5966.6 = 7458\text{ N-m} = 7458 \times 10^3\text{ N-mm}$$

We know that maximum torque (T_{max}),

$$7458 \times 10^3 = \frac{\pi}{16} \times \tau \times d^3 = \frac{\pi}{16} \times 70 \times d^3 = 13.75\ d^3$$

$$\therefore \quad d^3 = 7458 \times \frac{10^3}{13.75} = 542.4 \times 10^3 \text{ or } d = 81.5\text{ mm}$$

28. Using exponential smoothing average :

$$F_{May} = \alpha \times D_{April} + (1 - \alpha)F_{April}$$
$$= 0.2 \times 200 + (1 - 0.2) \times 100 = 120$$
$$F_{June} = \alpha \times D_{May} + (1 - \alpha)F_{May}$$
$$= 0.2 \times 50 + (1 - 0.2) \times 120 = 106$$
$$F_{July} = \alpha \times D_{June} + (1 - \alpha)F_{Junel}$$
$$= 0.2 \times 150 + 0.8 \times 106 = 114.8 \simeq 115$$

29. ***Master schedule :***

The first step in scheduling is to prepare the Master Schedule.

A master schedule specifies the product to be manufactured, the quality to be produced and the delivery date to the customer.

It also indicates the relative importance or manufacturing orders. The scheduling periods used in the master schedule are usually months. Whenever a new order is received, it is scheduled on the master schedule taking into account the production capacity of the plant Based on the master schedule, individual components and sub-assemblies that make up each product are planned and :

- Orders are placed for purchasing raw materials to manufacture the various components
- Orders are placed for purchasing components from outside vendors.
- Shop or production schedules are prepared for parts to be manufactured within the plant.

The objectives of master schedule are :

- It helps in keeping a running total of the production requirements.
- With its help, the production manager can plan in advance for any necessity of shifting from one product to another or for a possible overall increase or decrease in production requirements.
- It provides the necessary data for calculating the back log of work or load ahead of each major machine.
- After an order is placed in the master schedule, the customer can be supplied with probable or definite date of delivery.

30. • ***Duties of a Despatcher :*** Initiate the work by issuing the current work order instructions and drawings to the different production departments, work stations, machine operators or foremen The various documents despatched include detailed machine schedules, route sheets, operations sheets, materials requisition forms, machine loading cards, move or material ticket and inspection ticket plus work order.

Note : *It is not raw material it is material from store.*

- Release materials from stores
- Release production tooling, that is, all tools, jigs, f xtures and gauges for each operation before operation is started
- Keep a record of the starting and completion date of each operation.
- Getting reports back from the men when they finish the jobs.

31. ***Capacity Planning :***

Capacity planning forms the second principal step in the production system, the Product and Service design step being the first. The term "Capacity" of a plant is used to denote the maximum rate of production that the plant can achieve under given set of assumed operating conditions, for instance, number of shifts and number of plant operating days etc.

Capacity planning is concerned with determining labour and equipment capacity requirements to meet the current master production schedule and long term future needs of the plant.

Short term capacity planning involves decisions on the following factors :

- Employment levels
- Number of work shifts
- Labour overtime hours
- Inventory stock piling
- Order back logs
- Subcontracting jobs to other plants/shops In busy periods.

Long term capacity planning involves decisions on the following factors :

- Investment in new machines/equipments
- New plant construction
- Purchase of existing plants
- Closing down/selling obsolete facilities.

32. This allowance can be divided into two parts :

- Basic fatigue allowance
- Variable fatigue allowance.

The basic fatigue allowance is given to the operator to compensate for the energy expended for carrying out the work and to alleviate monotony. For an operator who is doing light work while seated, under good working conditions and under normal demands on the sensory or motor system, a 4% of normal time is considered adequate This can be treated as a constant allowance.

The magnitude of variable fatigue allowance given to the operator depends upon the seventy of the factor or conditions, which cause extra (more than normal) fatigue to him. As we know, fatigue is not homogeneous, it range from strictly physical to purely psychological and includes combinations of the two. on some people it has a marked effect while on others, it has apparently little or no effect. Whatever may be the kind of fatigue-physical or mental, the result is same-it reduces the work output of operator. The major factors that cause more than just the basic fatigue includes sever working conditions, especially with respect to noise, illumination, heat and humidity; the nature of work, especially with respect to posture, muscular exertion and tediousness and like that.

It is true that in modern industry, heavy manual work, and thus muscular fatigue is reducing day by day but mechanization is promoting other fatigue components like monotony and mental stress. Because fatigue in totality cannot be eliminated, proper allowance has to be given for adverse working conditions and repetitive ness of the work.

[PART : C]

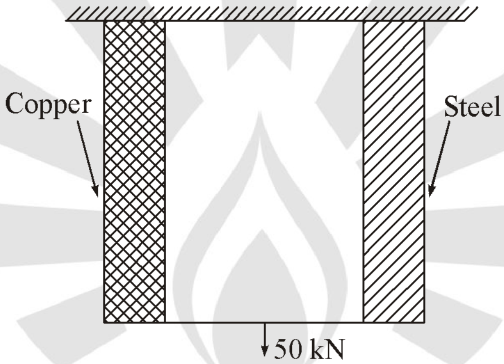
33. Given :

$$l_c = l_s = 3 \text{ m} = 3 \times 10^3 \text{ mm}$$
$$E_c = 105 \text{ GN/m}^2 = 105 \text{ kN/mm}^2$$
$$E_s = 210 \text{ GN/m}^2 = 210 \text{ kN/mm}^2$$
$$b = 25 \text{ mm} ; t = 12.5 \text{ mm} ; P = 50 \text{ kN}$$

Increase in length of the compound bar :

Let, δl = Increase in length of the compound bar.

The compound bar is shown in figure.



We know that cross sectional area of each bar,

$$A_c = A_s = b \times t = 25 \times 12.5 = 312.5 \text{ mm}^2$$

$\therefore$ Load shared by the copper bar,

$$P_c = P \times \frac{A_c.E_c}{A_c.E_c + A_s.E_s} = P \times \frac{E_c}{E_c + E_s} \quad ...(\because A_c = A_s)$$

$$= 50 \times \frac{105}{105 + 210} = 16.67 \text{ kN}$$

and load shared by the steel bar, $P_s = P - P_c = 50 - 16.67 = 33.33$ kN

Since the enlongation of both the bars is equal, therefore,

$$\delta l = \frac{P_c.l_c}{A_c.E_c} = \frac{P_s.l_s}{A_s.E_s} = \frac{16.67 \times 3 \times 10^3}{312.5 \times 105} = 1.52 \text{ mm}$$

Stress produced in the steel and Copper bar :

$$\sigma_s = \frac{E_s}{E_c} \times \sigma_c = \frac{210}{105} \times \sigma_c = 2\sigma_c$$

and total load, $P = P_s + P_c = \sigma_s A_s + \sigma_c A_c$

$$50 = 2\sigma_c \times 312.5 + \sigma_c \times 312.5 = 937.5\ \sigma_c$$

or $\sigma_c = \dfrac{50}{937.5} = 0.053 \text{ kN/mm}^2 = 53 \text{ N/mm}^2 = 53 \text{ MPa}$

and $\sigma_c = 2\sigma_c = 2 \times 53 = 106 \text{ N/mm}^2 = 106 \text{ MPa}$

34. Given :

$$D = 1.2 \text{ m} = 1200 \text{ mm}$$
$$\sigma = 100 \text{ MPa} = 100 \text{ N/mm}^2$$
$$E = 200 \text{ kN/mm}^2 = 200 \times 10^3 \text{ N/mm}^2$$
$$\alpha = 6.5 \times 10^{-6} \text{ per } ^\circ C$$

Internal Diameter of the tyre :

Let, d = Internal Diameter of the tyre

We know that hoop stress (σ),

$$100 = \frac{E(D-d)}{d} = \frac{200\times10^3(D-d)}{d}$$

$$\therefore \quad \frac{D-d}{d} = \frac{100}{200\times10^3} = \frac{1}{2\times10^3} \quad ...[1]$$

$$\frac{D}{d} = 1+\frac{1}{2\times10^3} = 1.0005$$

$$\therefore \quad d = \frac{D}{1.0005} = \frac{1200}{1.0005} = 1199.4 \text{ mm} = 1.19994 \text{ m}$$

Least temperature to which the tyre must be heated :

Let, t = Least temperature to which the tyre must be heated.

We know that $\pi D = \pi d + \pi d.\alpha.t = \pi d(1 + \alpha.t)$

$$\alpha.t = \frac{\pi D}{\pi d}-1 = \frac{D-d}{d} = \frac{1}{2\times10^3} \quad \text{(From equation [1])}$$

$$\therefore \quad t = \frac{1}{\alpha\times2\times10^3} = \frac{1}{6.5\times10^{-6}\times2\times10^3} = 77^\circ C$$

35. Given : $\sigma_b = 100 \text{ MPa} = 100 \text{ N/mm}^2$

Let R_A and R_B = Reactions at A and B respectively.

taking moments about A, we have

$$R_B \times 950 = 35 \times 750 + 25 \times 150 = 30000$$

$$\therefore \quad R_B = \frac{30000}{950} = 31.58 \text{ kN} = 31.58 \times 10^3 \text{ N}$$

and $R_A = (25 + 35) - 31.58 = 28.42 \text{ kN} = 28.42 \times 10^3 \text{ N}$

$\therefore$ Bending moment at C $= R_A \times 150 = 28.42 \times 10^3 \times 150 = 4.263 \times 10^6$ N-mm

and Bending moment at D $= R_B \times 200 = 31.58 \times 10^3 \times 200 = 6.316 \times 10^6$ N-mm

We see that the maximum bending moment is at D, therefore, maximum bending moment,

$$M = 6.316 \times 10^6 \text{ N-mm}$$

Let d = Diameter of the shaft

$\therefore$ Section modulus, $Z = \frac{\pi}{32}\times d^3 = 0.0982\, d^3$

We know that bending stress (σ_b),

$$100 = \frac{M}{Z} = \frac{6.316\times10^6}{0.0982d^3} = \frac{64.32\times10^6}{d^3}$$

$$d^3 = 64.32 \times \frac{10^6}{100} = 643.2 \times 10^3$$

or d = 86.3 say 90 mm

36. Average speed, $N = 1200$ rpm

Co-efficient of fluctuation of speed $= c_s = \frac{\omega_1 - \omega_2}{\omega} = 2\% = 0.02$

Fluctuation of kinetic energy $= \Delta E = 2 \times 10^3$ J

Now, $$\Delta E = \frac{1}{2}I\omega_1^2 - \frac{1}{2}I\omega_2^2 = \frac{1}{2}I(\omega_1^2 - \omega_2^2)$$

Since, $$\frac{\omega_1 + \omega_2}{2} = \omega = I\left(\frac{\omega_1 + \omega_2}{\omega}\right)(\omega_1 - \omega_2)$$

$$= I\omega\frac{(\omega_1 - \omega_2)}{\omega}.\omega = I\omega^2 c_s$$

$\Rightarrow$ $$2 \times 10^2 = \frac{1}{2}MR^2.\omega^2.c_s^2$$

Where, R = Radius of disc

$$= \frac{1}{2}M \times \left(\frac{1}{2}\right)^2 \times \left(\frac{2176200}{60}\right) \times 0.02$$

$$M = \frac{2 \times 10^3 \times 60 \times 60 \times 8}{0.02 \times (2 \times \pi \times 1200)^2} = 50.65 \approx 51 \text{ kg}$$

37. Given : M = Mass of the reciprocating parts = 40 kg

$m_p = 30$ kg ; $N = 150$ rpm

L = Length of the stroke = 350 mm

$c = 60\%$, $r_c = 320$ mm

(i) Balance mass required at a radius of 350 mm

$$\omega = \frac{2\pi N}{60} = \frac{2\pi \times 150}{60} = 15.7 \text{ rad/s}$$

$$r = \frac{L}{2} = \frac{350}{2} = 175 \text{ mm}$$

Mass to be balanced at the crank pin = m

$$M = cm + m_p = 0.60 \times 40 + 30 = 54 \text{ kg}$$

and $m_c r_c = Mr$, therefore $m_c = \frac{Mr}{r_c}$

i.e., $$m_c = \frac{54 \times 175}{320} = 29.53 \text{ kg}$$

(ii) Unbalanced force when the crank has turned 45° from the top dead centre.

Unbalanced force at $\theta = 45°$

$$= \sqrt{\left[(1-c)Mr\omega^2\cos\theta\right]^2 + \left[cmr\omega^2\sin\theta\right]^2}$$

$$= \sqrt{\left[(1-0.60) \times 40 \times 0.175 \times (15.7)^2\cos 45°\right]^2 + \left[0.60 \times 40 \times 0.175 \times (15.7)^2\sin 45°\right]^2}$$

$= 880.7$ N

38. ***Damping Coefficient :***

Let, c = Damping coefficient in N/m/s

We know that natural circular frequency of the exicting force,

$$\omega_n = \frac{2\pi}{t_p} = \frac{2\pi}{0.2} = 31.42 \text{ rad/s}$$

We also know that the maximum amplitude of vibration at resonance (x_{max}),

$$0.0125 = \frac{F}{c.\omega_n} = \frac{25}{c \times 31.42} = \frac{0.796}{c} \text{ or } c = 63.7 \text{ N/m/s}$$

Percentage Increase in amplitude :

Since the system is excited by a harmonic force of frequency (f) = 4 Hz, therefore corresponding circular frequency.

$$w = 2p \times f = 2p \times 4 = 25.14 \text{ rad/s}$$

We know that maximum amplitude of vibration with damping.

$$x_{max} = \frac{F}{\sqrt{c^2.\omega^2 + (s - m.\omega^2)^2}}$$

$$= \frac{25}{\sqrt{(63.7)^2(25.14)^2 + [2(31.42)^2 - 2(25.14)^2]^2}}$$

$$\ldots\left[\because (\omega_n)^2 = \frac{s}{m} \text{ or } s = m(\omega_n)^2\right]$$

$$= \frac{25}{\sqrt{2.56\times10^6 + 0.5\times10^6}} = \frac{25}{1749} = 0.0143 \text{ m} = 14.3 \text{ mm}$$

and the maximum amplitude of vibration when damper is removed,

$$x_{max} = \frac{F}{m\left[(\omega_n)^2 - \omega^2\right]} = \frac{25}{2[(31.42)^2 - (25.14)^2]} = \frac{25}{710}$$

$$= 0.0352 \text{ m} = 35.2 \text{ mm}$$

$\therefore$ Percentage increase in amplitude $= \frac{35.2 - 14.3}{14.3} = 1.46$ or 146%

39. Given :

$$T = (5000 + 1500 \sin 3\theta) \text{ N-m}$$

$$I = 1000 \text{ kg-m}^2$$

$$N = 300 \text{ rpm}$$

or $\omega = 2\pi \times \frac{300}{60} = 31.42$ rad/s

(i) Power of the Engine :

We know that work done per revolution :

$$= \int_0^{\pi} (5000 + 1500 \sin 3\theta) d\theta = \left[5000\theta - \frac{1500 \cos 3\theta}{3}\right]_0^{2\pi}$$

$$= 10000\ \pi \text{N-m}$$

$\therefore$ Mean resisting torque, $T_{mean} = \frac{\text{Work done / rev}}{2\pi} = \frac{10000\pi}{2\pi} = 5000$ N-m

We know that power of the engine,

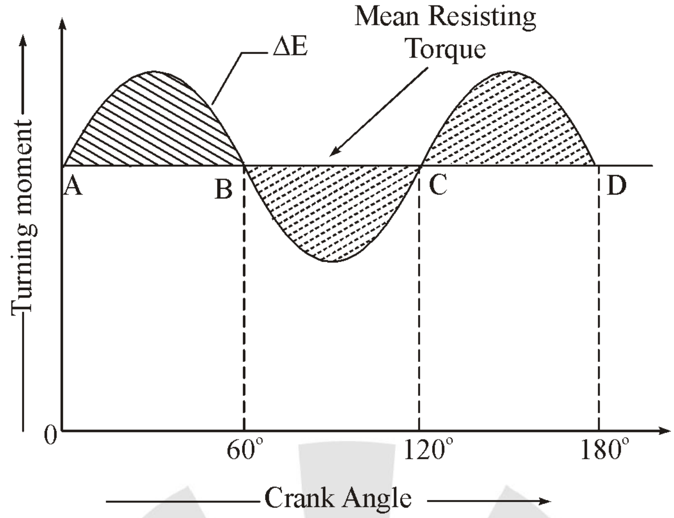
$$P = T_{mean}.\omega = 5000 \times 31.42 = 157100 \text{ W} = 157.1 \text{ kW}$$

(ii) Maximum Fluctuation of the speed of the Flywheel :

Let, C_S = Maximum or total fluctuation of speed of the flywheel

(a) When Resisting torque is constant :

The turning moment diagram is shown in figure. Since the resisting torque is constant, therefore, the torque exerted on the shaft is equal to the mean resisting torque on the flywheel.



$$\therefore \quad T = T_{mean}$$

$$5000 + 1500 \sin 3\theta = 5000$$

$$1500 \sin 3\theta = 0 \text{ or } \sin 3\theta = 0$$

$$\therefore \quad 3\theta = 0^\circ \text{ or } 180^\circ$$

$$\theta = 0^\circ \text{ or } 60^\circ$$

$\therefore$ Maximum fluctuation of energy,

$$\Delta E = \int_0^{60^\circ} (T - T_{mean})d\theta = \int_0^{60^\circ} (5000 + 1500 \sin 3\theta - 5000)d\theta$$

$$= \int_0^{60^\circ} 1500 \sin 3\theta d\theta = \left[-\frac{1500 \cos 3\theta}{3}\right]_0^{60^\circ} = 1000 \text{ N-m}$$

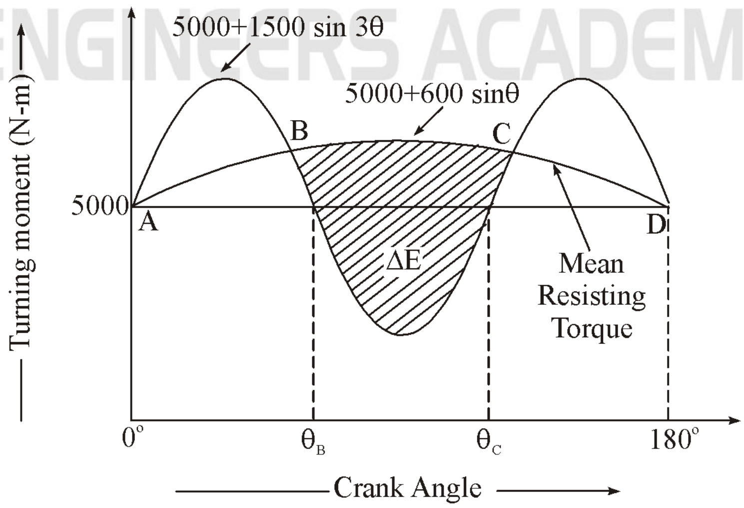
We know that maximum fluctuation of energy (ΔE),

$$1000 = I.\omega^2.C_S = 1000 \times (31.42)^2 \times C_S = 987216\ C_S$$

$$\therefore \quad C_S = \frac{1000}{987216} = 0.001 \text{ or } 0.1\%$$

(b) When resisting torque is (5000 + 600 sin θ) N-m

The turning moment diagram is shown in figure. Since at points B and C, the torque exerted on the shaft is equal to the mean resisting torque on the flywheel, therefore,



$$5000 + 1500 \sin 3\theta = 5000 + 600 \sin\theta$$

or $$2.5 \sin 3\theta = \sin\theta$$

$$2.5(3 \sin\theta - 4 \sin^3\theta) = \sin\theta \quad ...(\because \sin 3\theta = 3\sin\theta - 4\sin^3\theta)$$

$$3 - 4 \sin^2\theta = 0.4 \text{....(Dividing by } 2.5 \sin\theta)$$

$$\sin^2\theta = \frac{3 - 0.4}{4} = 0.65 \text{ or } \sin\theta = 0.8062$$

$\therefore$ $\theta = 53.7^\circ$ or 126.3° i.e., $\theta_B = 53.7^\circ$, and $\theta_C = 126.3^\circ$

$\therefore$ Maximum fluctuation of energy,

$$*\Delta E = \int_{53.7^\circ}^{126.3^\circ} \left[(5000 + 1500 \sin 3\theta) - (5000 + 600 \sin\theta)\right] d\theta$$

$$= \int_{53.7^\circ}^{126.3^\circ} (1500 \sin 3\theta - 600 \sin\theta)\, d\theta$$

$$= \left[-\frac{1500 \cos 3\theta}{3} + 600 \cos\theta\right]_{53.7^\circ}^{126.3^\circ} = 1656 \text{ N-m}$$

We know that maximum fluctuation of energy (ΔE),

$$1656 = I.\omega^2.C_S = 1000 \times (31.42)^2 \times C_S = 987216\ C_S$$

$\therefore$ $$C_S = \frac{1656}{987216} = 0.00168 \text{ or } 0.168\%$$

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