DEPARTMENT OF MECHANICAL ENGINEERING

ME8593 – DESIGN OF MACHINE ELEMENTS

TWO MARKS QUESTIONS WITH ANSWERS

UNIT –I

1. **How are the plain carbon steels designated in BIS?(Nov/Dec-21)**

   Burea of Indian standards(BIS) designates the various grades of steels by a system of codification which bears direct relationship with the important characteristics of steel such as tensile strength,chemical composition,physical and surface conditions.Steel may be designated by a group of symbols indicating the important characteristics

   (i) 1025 indicates C-25 which is plain carbon steel

2. **State four methods to reduce stress concentration.(Nov/Dec-21)**

   (i) Avoiding sharp corners.
   (ii)Providing fillets.
   (iii) Use of multiple holes instead of single hole.
   (iv)Undercutting the shoulder parts.

3. **A component is loaded with normal and shear stresses as σx= 15 MPa ; σy = 5 MPa ; and τxy = 10 MPa. Find the maximum shear stress developed in the component.(Nov/Dec-20)**

4. **Which theory of failure is suitable for the design of cast iron component subjected to steady state loading ?(Nov/Dec-20)**

   maximum normal stress (or) Rankine theory is suitable for designing cast iron component.

5. **.List the factors influencing machine design?(Nov/Dec-19)**

   i) Cost
   ii) Efficiency
   iii) Strength
   iv) Stiffness
   v) Wear resistance
   vi) Dimension

6. **Why distortion energy theory is preferred over other theories of failure in ductile materials? (Nov/Dec-19)**

   Maximum distorsion energy theory is the best theory of failure for ductile materials because it gives safe and economical design.

7. **What are preferred numbers?**

   For preferred numbers are standard guidelines for choosing exact product dimensions within a given set of constrains. They therefore help to minimize the number of different sizes that need to be manufactured or kept in stock.

8. **Brief about Soderberg and Goodman lines.**

   They are used to solve the problems of variable stresses.

9. **What is shock factor and what does it indicate?**

$$K_{shock} = \frac{\text{stress produced by impact}}{\text{Stress produced by same load applied gradually.}}$$

Value of shock factor can be calculated by the following equation:

$$K_{shock} = 1 + \sqrt{1 + 2h/y}$$

Where, h = Height of free fall of load to produce velocity for impact

Y = deformation under same static load.

10. Differentiate hardness and toughness.

S.No	Hardness	Toughness
1	It refers the energy required to deform a material.	It refers the total energy which can be used before the material breaks.
2	Hardness is characteristic of a solid material expressing its resistance to permanent deformation.	Toughness is the resistance to fracture of a material when stressed.
3	Hardness is the ability to withstand localized deformation at the surface.	Toughness is the measure of a material ability to absorb energy without breaking or fracture.

11. Why nonsymmetrical I and T sections are preferred in design of curved beams?

In a nonsymmetrical sections, It will be found that the neutral axis and the censorial axis of a curved beam, unlike a straight beam, are not coincident and also that the stress does not vary linearly from the neutral axis. Such a situation only preferred I and T sections of curved beams.

12. Define modulus of resilience and proof resilience.

The modulus of resilience is defined as the maximum energy that can be absorbed per unit volume without creating a permanent distortion.

In material science, Proof resilience is the ability of a material to absorb energy when it is deformed elastically, and release that energy upon unloading.

13. How the machine design may be classified?

Adaptive design, Development design, new design, Rational design, Empirical design, Industrial design, Optimum design, System design, Element design, Computer aided design.

14. What is an S-N curve?

An S-N curve has fatigue stress on Y axis and number of loading cycles in x axis. It is used to find the fatigue stress value corresponding to a given number of cycles.

15. Describe the material properties of hardness, stiffness and resilience.

- Hardness is the ability of material to resist scratching and indentation.
- Stiffness is the ability of material to resist deformation under loading.
- Resilience is the ability of material to resist absorb energy and to resist shock and impact load.

16. Define stress concentration.

Stress concentration is the increase in local stresses at points of rapid change in cross section (or) discontinuities.

17. Which theory of failure is suitable for the design of brittle materials?

Maximum principle stress (or) maximum normal stress (or) Rankine theory is suitable for designing brittle materials.

18. What are the common materials used in mechanical engineering design?

1. Plain carbon steel, 2.steel with alloying elements, 3.stellite, 4.ceramics, 5.steel, 6.copper, 7.aluminium,silver,8.aluminium,G.I,9.Titanium,10.cast iron.

19. Define limits and fits.

The extreme permissible value of a dimension is known as limits.

The degree of tightness or looseness between two mating parts that are intended to act together is known as fit.

20. What is an adaptive design?

It is a design process where a new product is developed just by making small changes to the existing product. It is used where no limited scope to go for an entropy new design.

21. List at least two methods to improve the fatigue strength.

- Cold working like shot penning, brushing.

- Pre stressing or auto fretting.
- Heat treatments like induction hardening, case hardening, nitrating.

22. Differentiate between hardness and toughness of materials.

Toughness: Ability of a material to withstand a suddenly applied load. It can also be defined as the energy absorbed by the material before failure.

Stiffness: Stiffness and Hardness are more or less the same things; it refers to the ability of a material to resist deformation.

23. Define stress concentration factor.

Stress concentration factor is the ratio of the highest stress to a reference stress of the gross cross-section. As the radius of curvature approaches zero, the maximum stress approaches infinity. Note that the stress concentration factor is a function of the geometry of a crack, and not of its size.

24. What are the factors to be considered for deciding the magnitude of factor of safety?

Which variation is permitted in both directions from the specified direction to decrease the magnitude of factors design of safety.

25. List out the methods of reducing stress concentration factor.

- Avoiding sharp corners.
- Providing fillets.
- Use of multiple holes instead of single hole.
- Undercutting the shoulder parts.

26. List the important factors that influence the magnitude of factor of safety?

There are many factors as

- Materials strength (if the material is a brittle or ductile)
- Possible misuse: the designer must consider any responsible of for foreseeable use
- Loading (static. Impact, repeated).
- Complexity of stress analysis

27. State the significance of S-N curve.

An S-N curve has fatigue stress on y axis and number of loading cycles in x axis. It is used to find the fatigue stress value corresponding to a given number of cycles.

28. How do you classify materials for engineering use?

Basically **Engineering Materials** can be classified into two categories:

- Metals and Non – Metals

29. How is the working stress calculated from the yield stress of a material?

Maximum stress / working stress

30. What are steps in machine design process?

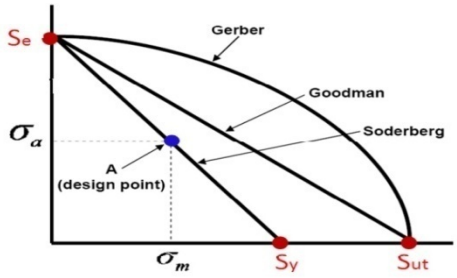
Recognition of need, definition of problem, synthesis, analysis and optimization.

31. How will you account for the stress concentration in design of the machine parts?

- Material properties
- nature of load
- Presence of localized stresses
- Node of failure.

32. What is Gerber theory?

Gerber parabolic joints endurance stress and ultimate stress, according to Gerber method.



33. Mention some standard codes of specification of steels.

It is a plan carbon steel

Average % of carbon = 0.5%

Average % of manganese =0.04%

34. What are the methods to reduce stress concentration?

A number of methods are available to reduce stress concentration in machine parts. Some of them are as follows:

1. Provide a fillet radius so that the cross-section may change gradually.
2. Sometimes an elliptical fillet is also used.

35. Differentiate the stress distribution in a bar subjected to axial force and beam subjected to bending?

Strength, stiffness and manufacturability

36. For ductile material which of the strength is considered for designing a (a) component subjected to static loading (b) Component subjected to fatigue loading.

Stiffness is the resistance offered by the shaft for twisting and rigidity is frame.

37. Define The Morphology Of Design?

Morphology of design consisting of problem formulation analysis search for alternative an Evaluation decision taking and specification of the solution.

38. State the different failure theories and the type of materials for which these are applicable?

1. Maximum principal theory –brittle material.
2. Shear Stress Theory –Ductile Material.

39. What are the three important points while designing member for impact loads?

1. Parts for impact load should be designed to have maximum volume of material Stresses to highest existing stress.
2. Stress concentration must be eliminated.

40. Define Goodman line.

It is a straight line connecting the endurance limit and ultimate strength in variable Stress diagram and Goodman line is applicable for designing of brittle materials.

41. Differentiate between direct shear stresses and torsional shear stress.

The induced stress due to tangential load to the specific cross section is direct shear Stress and distribution is uniform throughout.

Pure twisting moment acting on the machine member of a circular cross section induces torsional shear stress. This stress is zero at the centre and increases with increase in radius.

42. Design of a part subjected to bending moment is done on the basis of safe tensile stress. Why?

Due to bending loads, the stress is tensile at outer fiber and compressive at inner fiber.

All materials are weak under tension than compression, hence the design of a part subjected to bending moment is done on the basis of safe tensile stress.

43. Explain reasons for using different theories of failures.

The problem of predicting the failure stresses for members subjected to bi axial or tri axial stresses is much complicated. Hence we are using different theories of failure.

44. What are the appropriate theories of failure for ductile and brittle materials?

For ductile materials – maximum distortion energy theory

For brittle materials – maximum principle stress theory

45. State St.Vanent theory of failure.

According to this theory, failure occurs when the maximum strain developed in the machine member is equal to maximum strain at yield point in a tension test.

46. What is eccentric load and eccentricity?

An external load, whose line of action is parallel but does not coincide with the censorial axis of the machine component, is known as an eccentric load. The distance between the censorial axis of the machine component and the ec centric load is called eccentricity. (e.g) c-clamps, punching machines, brackets, offset connecting links etc.

47. What are the assumptions made in torsion equation?

1. The material of the shaft is uniform throughout.
2. The twist along the shaft is uniform.
3. The normal cross section of the shaft, which were plane and circular before twist, remain plane and circular after twist.

48. Write the applications of curved beam.

Curved beams find applications in many machine members such as c – clampers, crane hooks, frames of presses, chains, links, rings.

49. Define Endurance limit.

Endurance limit is the maximum value of completing reversed stress that can sustain an infinite number (10^6) of cycles without failure.

50. Define factor of safety for fatigue loading.

Factor of safety for fatigue loading = endurance limit stress/Design stress

51. What are the factors that govern selection of materials while designing a machine component?

- Strength & stiffness
- Surface finish and tolerance
- Manufacturability
- Ergonomics and aesthetics
- Working atmosphere

52. What do you mean by optimum design?

Optimization is the process of maximizing a desired quantity or minimizing an undesired one.

53. State the difference between straight beams and curved beams.

Feature	Straight beam	Curved beam
Centroidal axis and neutral axis	Are coincident	Are not coincident. Neutral axis is shifted towards the centre of curvature.
Stress	Same throughout the section.	Different at inner and outer radii of the section.

UNIT –II

1. What are the advantages of flexible coupling over rigid coupling?(Nov/Dec-21)

Rigid coupling is used to connect two shafts which are perfectly aligned.Where as flexible coupling is used to connect two shafts having both lateral and angular misalignment.

2. List four required properties of good shaft materials. ?(Nov/Dec-21)

(i)High static strength
(ii)High fatigue strength
(iii)High resilence
(iv)Good machinability
(v)Ductilit

3. Define equivalent bending moment. ?(Nov/Dec-20)

A bending moment which,acting alone,would produce in a circular shaft a normal stress of the same magnitude as the maximum normal stress produced by a given bending moment and a given twisting moment acting simyultaneously

4.Distinguish rigid and flexible couplings. ?(Nov/Dec-19,20)

- **Rigid coupling** is used to connect two shafts which are perfectly aligned.
- **Flexible coupling** is used to connect two shafts having both lateral and angular misalignment.

5. Why generally,hollow shafts are preferred over solid shafts? ? (Nov/Dec-19)

- Hollow shafts are having more polar moment of inertia, thus they can transmit more torque compared to solid shafts.
- Hollow shafts do not transfer more power but power to weight ratio of hollow shafts is more as compare to solid shaft.

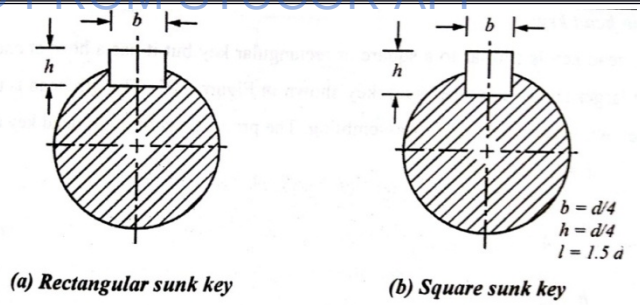
6.Write Rayleigh – Ritz equation to determine the critical speed of shaft subjected to point loads.

$$NC = \frac{30}{\pi}\sqrt{\frac{g}{\Delta st}}$$

Nc = Critical speed in rpm.
g=standard gravity =9.81 m/s^2
Δst = Total static deflection in m

7.List the different types of sunk keys and draw any one.

(i) Rectangular sunk key.
(ii) Square sunk key.



(a) Rectangular sunk key (b) Square sunk key

8.List the advantages of cotter joint over threaded joints.

This is used to connect rigidly two rods which transmit motion in the axial direction, without rotation. These joints may be subjected to tensile or compressive forces along the axes of the rods.

Advantages of cotter joint over threaded joints:

- This joint is the simplest cotter joint in existence.
- It is quit rigid and take both tensile and compressive loads.
- It can be easily assembled and dismantled.
- The joint can also be used to connect similar pipes, tubes.

9. State the reasons for which the couplings are located near the bearings.

Couplings tend to produce unbalanced forces due to misalignments of shafts which cause vibrations in rotating machinery.

10.Define the term critical speed of a shaft.

The speed, at which the shaft runs so that the additional deflection of the shaft from the axis of rotation becomes infinite, is known as critical or whirling speed.

11.What are the types of flexible coupling and rigid couplings?

Rigid couplings:	Flexible couplings:
(i) Sleeve couplings	(i) Universal couplings.
(ii) Flange couplings	(ii) Oldham's coupling
(iii) Clamp couplings	(iii) Pushed pin type couplings

12.What is the effect of key ways cut into the shaft?

A transmission shaft with key way is discontinuity. The reduction the cross sectional area of shaft and result in stress concentration at the corners at the shaft key way and reduce the load wearing capacity in other word torsinal shear strength is reduced.

13.Differentiate between rigid coupling and flexible coupling.

Rigid coupling is used to connect two shafts which are perfectly aligned.

Flexible coupling is used to connect two shafts having both lateral and angular misalignment.

14.What is meant by design of a shaft based on rigidity?

In designing shafts on the basis of strength and rigidity , the following cases may be considered :

(a) Shafts subjected to twisting moment or torque only,

(b) Shafts subjected to bending moment only,

(c) Shafts subjected to combined twisting and bending moments, and

(d) Shafts subjected to axial loads in addition to combined torsional and bending loads.

15.What are the possible modes of failure of the pin (belt) in a flexible coupling?

Direct shear stress failure due to torque transmission.

16.Write an equation for allowing shear stress for a shaft of diameter "d" which is subjected to a torque about its axis.

T=Π/16*J*D3

D – Diameter of the shaft

17.What type of stresses developed in the key?

Sunk keys are designed to fit is sunk keyway where is parallel to the axis of the shaft.

18.What is the difference between spindle and axle?

- Spindle is a rotating element.
- Axles combine with a key and shaft.

19.What is key?

A key is device which used for connecting two machine parts for preventing relative motion with respect to each other.

20. Discuss forces on keys.

Shear stress and crushing stress

21.What are the various stresses induced in the shafts?

Shear stress due to direct shear force, bending force, due to force over projected area.

22.Name any two of the rigid coupling.

Sleeve couplings, flange couplings

23. What is the material used for flange coupling.

Cast-iron

24.What is the main use of woodruff keys?

A woodruff key is used to transmit small value of torque to automotive and machine tool industries. The key way in the shaft is usually straight.

25. A hollow shaft has greater strength and stiffness than solid shaft of equal weight. Explain.

Stresses are maximum at the outer surface of a shaft. A hollow shaft has almost all material concentrated at the circumferential and has better strength and stiffness for equal weight.

26.What are the types of keys?

Saddle key
Tangent key
Sunk key
Round key and taper pins.

27.On what basis are the shafts designed?

When the shaft to decimal moment of shaft diameter can be formed from the torsional shear strength which is given by designed shaft.

28.What are the effects of introducing keyways in shafts?

Shearing and crushing stress

29.What is jack shaft?

The maximum permissible stress acting at the shaft connection jack shaft.

30.What is the critical speed of shaft?

The speed at which the shafts runs so that additional defection of the shaft from the axis of rotation.

31.In what situation is flexible coupling used?

They are used to join the ability ends of shaft when they are not exact alignment.

32.What is coupling?

The elements which joint two shafts are coupling .it is used to connect section of transmission shafts.

33.What is the significance of slenderness ratio in shaft design?

If slenderness ratio is increased the shaft derivates from its stub and its essential to buckling while disking shaft.

34.Under what circumstances flexible couplings are used.

They are used to permit an axial adjustment of the shaft without under absorption of the power, which shafts are transmits.

35.What types o stresses are developed in the key?

Shearing stress and crushing stress

36.What are the various factors involved in good shaft coupling?

i) It should be easy to connect or disconnect

ii) It transmit full power of the shaft

37.Define Preferred Numbers?

Preferred Numbers from a general basis for standardizing and grading a series of Simulator dimension characteristics or articles

38.What is knuckle joint?

Knuckle joint is used to connect two rods which are under the action of tensile loads.

39.Differentiate between a cotter joint and a knuckle joint.

Cotter joint is used to connect two rigid rods for transmitting motion without rotation. This joint is subjected to axial forces.

Knuckle joint is used for connecting two rods and transmitting axial force. This joint permits a small amount of flexibility.

40.How couplings are specified?

a) Diameter of shaft

b) Diameter of sleeve or muff c) Length of sleeve or muff

d) Outer diameter of hub

e) Nominal diameter or bolt f) PCD of bold circle

41.What is the mode of failure of the bolts in a flange coupling?

Direct shear stress failure due to torque transmission.

42.What is the difference between coupling and a clutch?

A coupling is a device used to make permanent or semi permanent connection where

As a clutch permits rapid connection or disconnection at will of the operator.

43.List any two methods used for manufacturing of shafts.

1. Cold rolling
2. Hot rolling
3. Turning or grinding from rough bars.

44.List out the requirements of a shaft coupling?

1. It should be easy to connect or disconnect.
2. It should transmit the full power of the shaft
3. It should hold the shafts in perfect alignment.

45.List the various purposes of shaft couplings?

1. To provide for the connection of shafts of units that is manufactured separately and to provide for disconnection for repairs or alternations.
2. To provide misalignment of the shafts or to introduce mechanical l flexibility.
3. To introduce protection against overloads.
4. To reduce the transmission of shock loads from one shaft to another.

46.What are advantages and disadvantages of a woodruff key?

1. It accommodates itself to any taper in the hub or boss of the mating piece.
2. It is useful on tapering shaft end. Its extra depth in the shaft prevents any tendency to turn over in its keyway.

47.What is column factor?

If a long shaft subjected to axial load (compressive load) in addition to torsion and bending, a factor must be introduced to take the column effect into account.

48.What are the ways of improving lateral rigidity of shafts?

1. Maintaining proper bearing clearances
2. Correct gear teeth alignment.

49.Define Torsional stiffness of shaft.

It is defined as the resisting strength of a shaft to torsional load. Mathematically it can be calculated by the formula.

50.Why rotating shaft are generally made with circular cross section?

Stress distribution pattern will be uniform throughout the circular cross section.

51.Differentiate the hollow shaft and solid shaft.

The hollow shafts are used in marine work.

These shafts are stronger per kg of material and they may be forged on a mandrel, thus making the material more homogenous than a solid shaft.

52.Differentiate between keys and splines.

S.No	KEYS	SPLINES
1.	A shaft which is having single keyway.	A shaft which is having multiple keyways.
2.	Keys are used in couplings.	Splines are used in automobiles and machine tools.

53.What are the materials used for crankshafts?

- For I.C engines C_{20} or C_{25} mild steel.
- Automobile & Aero plane engine chrome-nickel steel.

54.What are the different measures followed to control the lateral deflection?

- Reducing the span length.
- Increasing the number of supports
- Selecting the cross section in which the area moment of inertia is large as in case of tubular or hollow shaft.

55.Why is maximum shear theory used for shaft?

Since, the shaft is made of ductile material; maximum shear stress thus is used.

56.What is the advantage of gear coupling?

- Gear coupling is a rigid coupling with some flexibility because of using curved external teeth.
- Strength of gear coupling is very high.
- Most compact coupling for high power transmission.

57.What is the function of crankshafts?

Crankshafts are used to convent lottery motion into reciprocating motion.

PART B (Q& A)
UNIT-I

1.

A hydraulic press exerts a total load of 3.5 MN. This load is carried by two steel rods, supporting the upper head of the press. If the safe stress is 85 MPa and E = 210 kN/mm², find : 1. diameter of the rods, and 2. extension in each rod in a length of 2.5 m.

Diameter of the rods

Let d = Diameter of the rods in mm.

$\therefore$ Area, $A = \frac{\pi}{4} \times d^2 = 0.7854\, d^2$

Since the load P is carried by two rods, therefore load carried by each rod,

$$P_1 = \frac{P}{2} = \frac{3.5 \times 10^6}{2} = 1.75 \times 10^6 \text{ N}$$

We know that load carried by each rod (P_1),

$$1.75 \times 10^6 = \sigma_t . A = 85 \times 0.7854\, d^2 = 66.76\, d^2$$

$\therefore$ $d^2 = 1.75 \times 10^6/66.76 = 26\,213$ or $d = 162$ mm **Ans.**

Extension in each rod

Let δl = Extension in each rod.

We know that Young's modulus (E),

$$210 \times 10^3 = \frac{P_1 \times l}{A \times \delta l} = \frac{\sigma_t \times l}{\delta l} = \frac{85 \times 2.5 \times 10^3}{\delta l} = \frac{212.5 \times 10^3}{\delta l} \quad \ldots \left(\because \frac{P_1}{A} = \sigma_t\right)$$

$\therefore$ $\delta l = 212.5 \times 10^3/(210 \times 10^3) = 1.012$ mm **Ans.**

2.

A mild steel rod of 12 mm diameter was tested for tensile strength with the gauge length of 60 mm. Following observations were recorded :

Final length = 80 mm; Final diameter = 7 mm; Yield load = 3.4 kN and Ultimate load = 6.1 kN.

Calculate : 1. yield stress, 2. ultimate tensile stress, 3. percentage reduction in area, and 4. percentage elongation.

1. *Yield stress*

We know that yield stress

$$= \frac{W_y}{A} = \frac{3400}{113} = 30.1 \text{ N/mm}^2 = 30.1 \text{ MPa} \quad \textbf{Ans.}$$

2. *Ultimate tensile stress*

We know the ultimate tensile stress

$$= \frac{W_u}{A} = \frac{6100}{113} = 54 \text{ N/mm}^2 = 54 \text{ MPa} \quad \textbf{Ans.}$$

3. *Percentage reduction in area*

We know that percentage reduction in area

$$= \frac{A - a}{A} = \frac{113 - 38.5}{113} = 0.66 \text{ or } 66\% \quad \textbf{Ans.}$$

3.

A thin steel tyre is shrunk on to a locomotive wheel of 1.2 m diameter. Find the internal diameter of the tyre if after shrinking on, the hoop stress in the tyre is 100 MPa. Assume $E = 200$ kN/mm^2. Find also the least temperature to which the tyre must be heated above that of the wheel before it could be slipped on. The coefficient of linear expansion for the tyre is 6.5×10^{-6} per °C.

Internal diameter of the tyre

Let d = Internal diameter of the tyre.

We know that hoop stress (σ),

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

$$\therefore \quad \frac{D-d}{d} = \frac{100}{200\times10^3} = \frac{1}{2\times10^3} \qquad \text{...}(i)$$

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

$$\therefore \quad d = \frac{D}{1.0005} = \frac{1200}{1.0005} = 1199.4 \text{ mm} = 1.1994 \text{ m}$$ **Ans.**

Least temperature to which the tyre must be heated

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

We know that

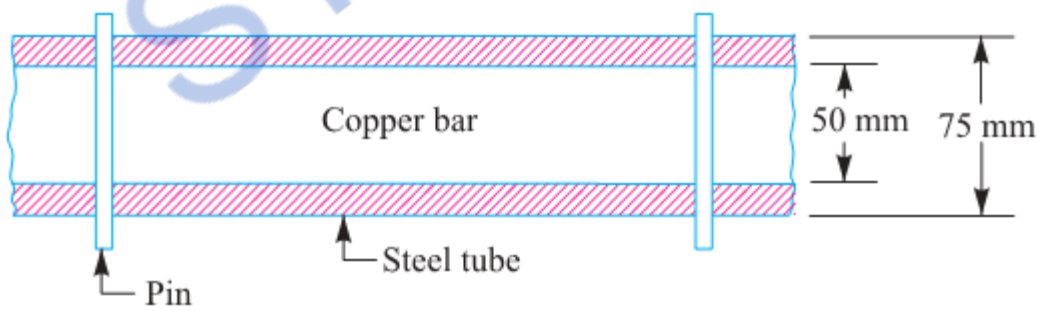
$$\pi D = \pi d + \pi d\,.\,\alpha.t = \pi d\,(1+\alpha.t)$$

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

$$\therefore \quad t = \frac{1}{\alpha\times2\times10^3} = \frac{1}{6.5\times10^{-6}\times2\times10^3} = 77°\text{C}$$ **Ans.**

4.

A copper bar 50 mm in diameter is placed within a steel tube 75 mm external diameter and 50 mm internal diameter of exactly the same length. The two pieces are rigidly fixed together by two pins 18 mm in diameter, one at each end passing through the bar and tube. Calculate the stress induced in the copper bar, steel tube and pins if the temperature of the combination is raised by 50°C. Take $E_s = 210$ GN/m^2; $E_c = 105$ GN/m^2; $\alpha_s = 11.5\times10^{-6}$/°C and $\alpha_c = 17\times10^{-6}$/°C.



We know that cross-sectional area of the copper bar,

$$A_c = \frac{\pi}{4}(d_c)^2 = \frac{\pi}{4}(50)^2 = 1964 \text{ mm}^2 = 1964 \times 10^{-6} \text{ m}^2$$

and cross-sectional area of the steel tube,

$$A_s = \frac{\pi}{4}\left[(d_{se})^2 - (d_{si})^2\right] = \frac{\pi}{4}\left[(75)^2 - (50)^2\right] = 2455 \text{ mm}^2$$

$$= 2455 \times 10^{-6} \text{ m}^2$$

Let l = Length of the copper bar and steel tube.

We know that free expansion of copper bar

$$= \alpha_c \,.\, l \,.\, t = 17 \times 10^{-6} \times l \times 50 = 850 \times 10^{-6}\, l$$

and free expansion of steel tube

$$= \alpha_s \,.\, l \,.\, t = 11.5 \times 10^{-6} \times l \times 50 = 575 \times 10^{-6}\, l$$

∴ Difference in free expansion

$$= 850 \times 10^{-6}\, l - 575 \times 10^{-6}\, l = 275 \times 10^{-6}\, l$$

5.

An unknown weight falls through 10 mm on a collar rigidly attached to the lower end of a vertical bar 3 m long and 600 mm² in section. If the maximum instantaneous extension is known to be 2 mm, what is the corresponding stress and the value of unknown weight? Take E = 200 kN/mm².

Value of the unknown weight

Let W = Value of the unknown weight.

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

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

$$\frac{400 \times 600}{3\,W} = 1 + \sqrt{1 + \frac{800\,000}{W}}$$

$$\frac{80\,000}{W} - 1 = \sqrt{1 + \frac{800\,000}{W}}$$

Squaring both sides,

$$\frac{6400 \times 10^6}{W^2} + 1 - \frac{160\,000}{W} = 1 + \frac{800\,000}{W}$$

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

$\therefore$ $W = 6400 \times 10^2 / 96 = 6666.7$ N **Ans.**

UNIT – II

1.

A steel spindle transmits 4 kW at 800 r.p.m. The angular deflection should not exceed 0.25° per metre of the spindle. If the modulus of rigidity for the material of the spindle is 84 GPa, find the diameter of the spindle and the shear stress induced in the spindle.

Diameter of the spindle

Let d = Diameter of the spindle in mm.

We know that the torque transmitted by the spindle,

$$T = \frac{P \times 60}{2\pi N} = \frac{4000 \times 60}{2\pi \times 800} = 47.74 \text{ N-m} = 47\,740 \text{ N-mm}$$

We also know that $\frac{T}{J} = \frac{G \times \theta}{L}$ or $J = \frac{T \times l}{G \times \theta}$

or $$\frac{\pi}{32} \times d^4 = \frac{47\,740 \times 1000}{84 \times 10^3 \times 0.0044} = 129\,167$$

$\therefore$ $d^4 = 129\,167 \times 32/\pi = 1.3 \times 10^6$ or $d = 33.87$ say 35 mm **Ans.**

Shear stress induced in the spindle

Let τ = Shear stress induced in the spindle.

We know that the torque transmitted by the spindle (T),

$$47\,740 = \frac{\pi}{16} \times \tau \times d^3 = \frac{\pi}{16} \times \tau\,(35)^3 = 8420\,\tau$$

$\therefore$ $\tau = 47\,740 / 8420 = 5.67 \text{ N/mm}^2 = 5.67 \text{ MPa}$ **Ans.**

2.

A steel spindle transmits 4 kW at 800 r.p.m. The angular deflection should not exceed 0.25° per metre of the spindle. If the modulus of rigidity for the material of the spindle is 84 GPa, find the diameter of the spindle and the shear stress induced in the spindle.

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3.

A hollow steel shaft is to transmit 20 kW at 300 r.p.m. The loading is such that the maximum bending moment is 1000 N-m, the maximum torsional moment is 500 N-m and axial compressive load is 15 kN. The shaft is supported on rigid bearings 1.5 m apart. The maximum permissible shear stress on the shaft is 40 MPa. The inside diameter is 0.8 times the outside diameter. The load is cyclic in nature and applied with shocks. The values for the shock factors are $K_t = 1.5$ and $K_m = 1.6$.

$$K = \sqrt{\frac{I}{A}} = \sqrt{\frac{\frac{\pi}{64}[(d_o)^4 - (d_i)^4]}{\frac{\pi}{4}[(d_o)^2 - (d_i)^2]}}$$

$$= \sqrt{\frac{[(d_o)^2 + (d_i)^2][(d_o)^2 - (d_i)^2]}{16[(d_o)^2 - (d_i)^2]}} = \sqrt{\frac{(d_o)^2 + (d_i)^2}{16}}$$

$$= \frac{d_o}{4}\sqrt{1 + \left(\frac{d_i}{d_o}\right)^2} = \frac{d_o}{4}\sqrt{1 + (0.8)^2} = 0.32\, d_o$$

nd column factor for compressive loads,

$$\alpha = \frac{1}{1 - 0.0044\,(L/K)} = \frac{1}{1 - 0.0044\,(1500/0.32 d_o)}$$

$$= \frac{1}{1 - 20.6/d_o} = \frac{d_o}{d_o - 20.6}$$

We know that equivalent twisting moment for a hollow shaft,

$$T_e = \sqrt{\left[K_m \times M + \frac{\alpha F d_o (1 + k^2)}{8}\right]^2 + (K_t \times T)^2}$$

$$= \sqrt{\left[1.6 \times 1000 \times 10^3 + \frac{\left(\frac{d_o}{d_o - 20.6}\right) 15000 \times d_o (1 + 0.8^2)}{8}\right]^2 + (1.5 \times 500 \times 10^3)^2}$$

$$= \sqrt{\left[1600 \times 10^3 + \frac{3075\,(d_o)^2}{d_o - 20.6}\right]^2 + (750 \times 10^3)^2} \qquad \text{...(i)}$$

4.

A solid steel shaft is supported on two bearings 1.8 m apart and rotates at 250 r.p.m. A 20° involute gear D, 300 mm diameter is keyed to the shaft at a distance of 150 mm to the left on the right hand bearing. Two pulleys B and C are located on the shaft at distances of 600 mm and 1350 mm respectively to the right of the left hand bearing. The diameters of the pulleys B and C are 750 mm and 600 mm respectively. 30 kW is supplied to the gear, out of which 18.75 kW is taken off at the pulley C and 11.25 kW from pulley B. The drive from B is vertically downward while from C the drive is downward at an angle of 60° to the horizontal. In both cases the belt tension ratio is 2 and the angle of lap is 180°. The combined fatigue and shock factors for torsion and bending may be taken as 1.5 and 2 respectively.

Design a suitable shaft taking working stress to be 42 MPa in shear and 84 MPa in tension.

For gear D

We know that torque transmitted by the gear D,

$$T_D = \frac{P_D \times 60}{2\pi N} = \frac{30 \times 10^3 \times 60}{2\pi \times 250} = 1146 \text{ N-m}$$

∴ Tangential force acting on the gear D,

$$F_{tD} = \frac{T_D}{R_D} = \frac{1146}{0.15} = 7640 \text{ N}$$

and the normal load acting on the gear tooth,

$$W_D = \frac{F_{tD}}{\cos 20°} = \frac{7640}{0.9397} = 8130 \text{ N}$$

The normal load acts at 20° to the vertical as shown in Fig. 14.14. Resolving the normal load vertically and horizontally, we have

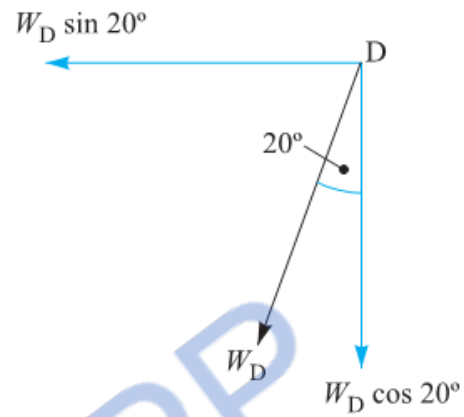


Fig. 14.14

Vertical component of W_D

$$= W_D \cos 20° = 8130 \times 0.9397 = 7640 \text{ N}$$

Horizontal component of W_D

$$= W_D \sin 20° = 8130 \times 0.342 = 2780 \text{ N}$$

Again, we know that equivalent bending moment,

$$M_e = \tfrac{1}{2}\left[K_m \times M + \sqrt{(K_m \times M)^2 + (K_t \times T)^2}\right] = \tfrac{1}{2}(K_m \times M + T_e)$$

$$= \tfrac{1}{2}(2 \times 3790 + 7772) = 7676 \text{ N-m} = 7676 \times 10^3 \text{ N-mm}$$

We also know that the equivalent bending moment (M_e),

$$7676 \times 10^3 = \frac{\pi}{32} \times \sigma_b \times d^3 = \frac{\pi}{32} \times 84 \times d^3 = 8.25\ d^3$$

∴ $$d^3 = 7676 \times 10^3 / 8.25 = 930 \times 10^3 \text{ or } d = 97.6 \text{ mm}$$

Taking the larger of the two values, we have

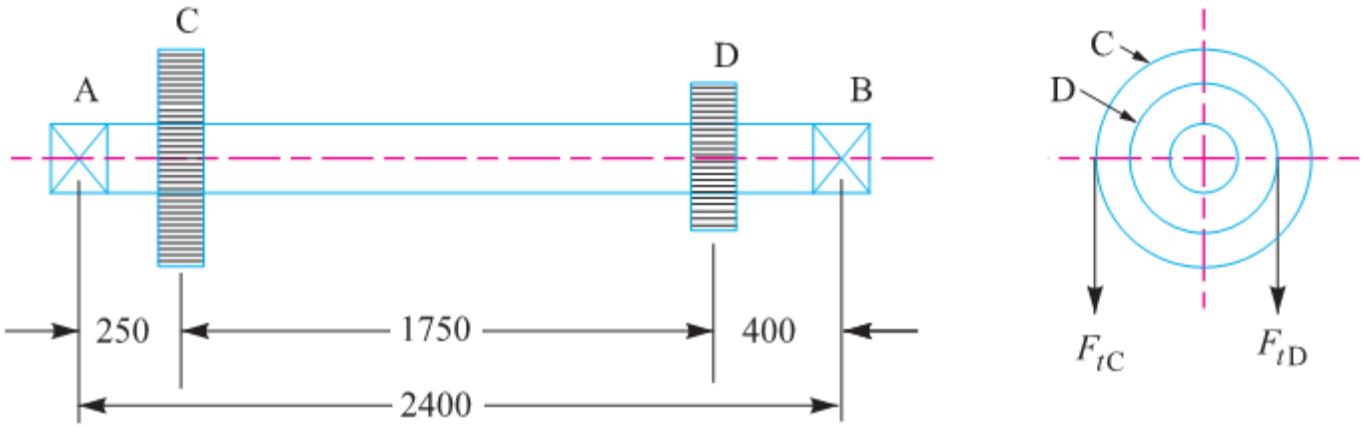
$$d = 98 \text{ say } 100 \text{ mm}$$ **Ans.**

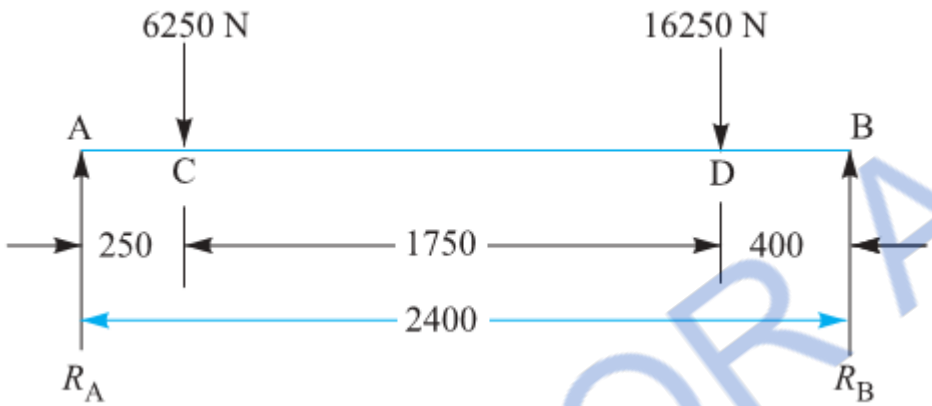
5.

transmits 20 kW at 120 r.p.m. The power is delivered to the shaft at gear C and is taken out at gear D in such a manner that the tooth pressure F_{tC} of the gear C and F_{tD} of the gear D act vertically downwards.

Find the diameter of the shaft, if the working stress is 100 MPa in tension and 56 MPa in shear. The gears C and D weighs 950 N and 350 N respectively. The combined shock and fatigue factors for bending and torsion may be taken as 1.5 and 1.2 respectively.

A horizontal nickel steel shaft rests on two bearings, A at the left and B at the right end and carries two gears C and D located at distances of 250 mm and 400 mm respectively from the centre line of the left and right bearings. The pitch diameter of the gear C is 600 mm and that of gear D is 200 mm. The distance between the centre line of the bearings is 2400 mm. The shaft





We also know that the equivalent twisting moment (T_e),

$$8725 \times 10^3 = \frac{\pi}{16} \times \tau \times d^3 = \frac{\pi}{16} \times 56 \times d^3 = 11\ d^3$$

$\therefore$ $$d^3 = 8725 \times 10^3 / 11 = 793 \times 10^3 \text{ or } d = 92.5 \text{ mm}$$

Again we know that the equivalent bending moment,

$$M_e = \tfrac{1}{2}\left[K_m \times M + \sqrt{(K_m \times M)^2 + (K_t \times T)^2}\right] = \tfrac{1}{2}(K_m \times M + T_e)$$

$$= \tfrac{1}{2}\left[1.5 \times 5676 \times 10^3 + 8725 \times 10^3\right] = 8620 \times 10^3 \text{ N-mm}$$

We also know that the equivalent bending moment (M_e),

$$8620 \times 10^3 = \frac{\pi}{32} \times \sigma_b \times d^3 = \frac{\pi}{32} \times 100 \times d^3 = 9.82\ d^3 \quad \text{...(Taking } \sigma_b = \sigma_t)$$

$\therefore$ $$d^3 = 8620 \times 10^3 / 9.82 = 878 \times 10^3 \text{ or } d = 95.7 \text{ mm}$$

Taking the larger of the two values, we have

$$d = 95.7 \text{ say } 100 \text{ mm}$$ **Ans.**

UNIT-III

1. Define equivalent torsional moment of a shaft. [AU –May/JUNE – 2017]

The equivalent twisting moment may be defined as that twisting moment or torsional moment may be defined as that twisting moment, which when acting alone, produces the same shear stress as the actual twisting moment. By limiting the maximum shear stress equal to the allowable shear stress for the material.

The expression $\sqrt{M^2 + T^2}$ Known as equivalent torsional moment**.**

2. Why throat is considered while calculating stresses in fillet welds? [AU –May/JUNE – 2017]

This shear stress occurs in a horizontal plane along a leg of the fillet weld. The maximum shear occurs on the throat of weld which is inclined at 45 degree to the horizontal plane.

∴ Length of throat, $t = s \sin 45° = 0.707\, s$

and maximum shear stress,

$$\tau_{max} = \frac{2T}{\pi \times 0.707\, s \times d^2} = \frac{2.83\, T}{\pi\, s\, d^2}$$

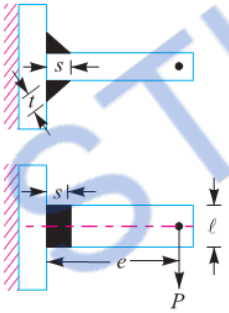
3. What are the different applications of screwed fasteners? [AU –Nov/Dec– 2015]

- Screwed joints are highly reliable in operation.
- Screwed joints are convenient to assemble and disassemble.
- A wide range of screwed joints may be adopted to various operating conditions.
- Screws are relatively cheap to produce due to standardization and highly, efficient manufacturing processes.

4. State the two types of eccentric welded connections? [AU –Nov/Dec– 2015]

An eccentric load may be imposed on welded joints in many ways.

- Welded connections subjected to moment in a plane of the weld.
- Welded connections subjected to moment in a plane normal to the plane of the weld.



5. What is the stresses act on screw fastenings due to static loading? [AU –May/JUNE – 2016]

Initial stresses due to screwing up
Stresses due to external forces
Combined stresses

6. What are the two types of fillet weld? [AU –May/JUNE – 2016]

Lap (or) fillet joint

a. Transverse fillet b. Parallel fillet c. Circular fillet

Butt joint

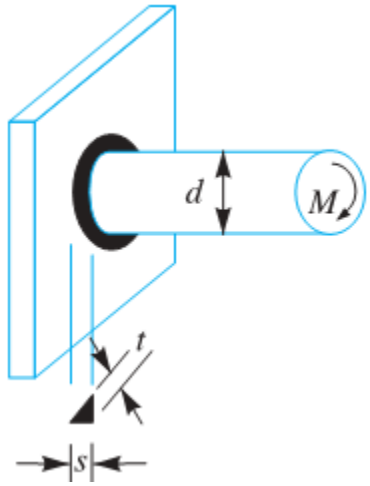
a. Square butt b. V butt c. U butt

7. What is the total shear in a double strap butt joint with equal length of straps? [AU –Nov/Dec– 2015]

. A double strap butt joint with equal length straps **always in double shear.**

8. What is the bending stress induced in the weld when a circular rod of diameter d, welded to a rigid plate by a circular fillet weld of size t, which is subjected to a bending moment m? [AU –Nov/Dec–

2015]



bending stress,

$$\sigma_b = \frac{M}{Z} = \frac{M}{\pi t d^2/4} = \frac{4M}{\pi t d^2}$$

9. What are the various forms of screw threads?

- British standard whitowrth (BSW) thread
- British Association thread
- Unified standard thread
- American national standard thread
- Square thread
- ACME threads
- Metric thread

10. What is stud?

A stud is a bolt in which the head is replaced by a threaded end. It passes through one of the parts to be connected and is crewed into the other part.

11. How is a bolt designated? Give examples.

A thread is designed with

- Letter 'M' followed by
- Nominal diameter in mm and
- Pitch in mm (for fine pitches only)

  It is given as,

  M d x p

  If coarse pitches are used, then p value is omitted thus m20 x 2.5 means

  - Nominal diameter is 20 mm
  - 2.5 mm pitch, fine thread.

    M20 means, 20 mm nominal diameter with coarse threads.

12. What is the meaning of bolt m24 x 2?

Bolt nominal diameter, d = 24mm and bolt pitch, p=2mm

13. State the advantages of threaded joints.

- High clamping
- Small tightening force requirement.
- Easy manufacturing
- Simple design

14. Define the term self-locking of power screws**.**

If the friction angle (Θ) is greater than helix angle (α) of the power screw, the torque required to lower the load will be positive, indicating that an effort is applied to lower the load. This type is screw is known as self-locking screw. The efficiency of the self-locking screw is less than 50%.

15. Why are welded joints preferred over riveted joints?

Materials are saved in welding joints and hence the machine element will be light if welded joints are used instead of riveted joints, leak proof joints can be easily obtained by welded joints compared riveted joints.

16. How is welding classified?

- Forge welding
- Electric resistance welding and
- Fusion welding

17. When will the edge preparation need?

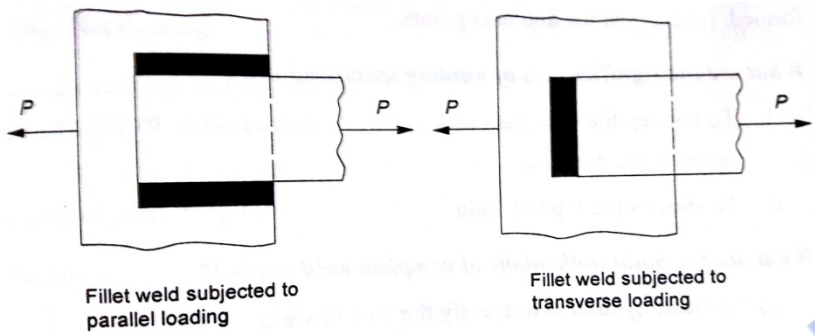
If the two plates to be welded have more than 6mm thickness, the edge preparation should be carried out.

18. What is the minimum size for fillet weld? If the required weld size from strength consideration is too small how will you fulfill the condition of minimum weld size?

It is defined as the minimum size of the weld for a given thickness of the thinner part joined or plate to avoid cold cracking by escaping the rapid cooling.

Size of fillet weld, h = √2 C X throat thickness (t)

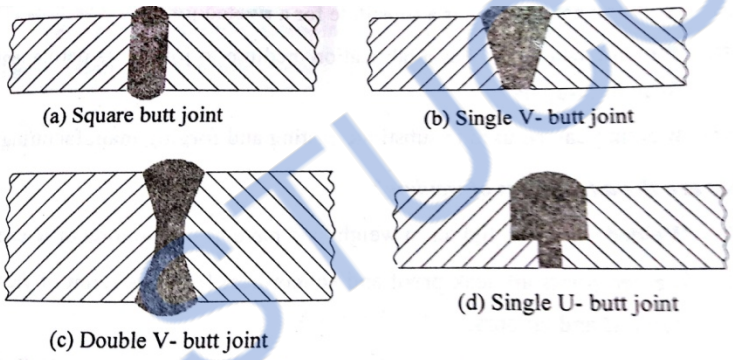
19. Differentiate with a neat sketch the fillet welds subjected to parallel loading and transverse loading.



20. Name the possible modes of failure of riveted joint.

- Crushing of rivets
- Shear of rivets
- Tearing of the plate at the edge
- Tearing of the plate between rivets.

21. Sketch at least two types of welded joints.



22. Define welding.

Welding can be defined as a process of joining two similar or dissimilar metals with or without application of pressure along with or without addition of filler material.

23. State the limitations of welding.

- It has poor vibration damping characteristics.
- Welding results in a thermal distortion of the parts, thereby including residual stresses. Therefore, it needs stress relieving heat treatment.
- The quality and strength of welded joints also depend upon the skill of the labours.

24. Define tee-joint and corner joint.

T – Joint:

The two plates are assigned in 'T' shape, which means the plates are located at right angles to Each other.

Corner weld:

Two plates are arranged at right angles such that it forms an angle.

25. State the types of forces involved while designing.

Tension and compressive forces.

26. Define eccentrically loaded welded joints.

The external loaded where applied may not pass through the geometric centre in structural joints called as eccentrically loaded joints.

27. What are the materials used for making rivets?

- Mild steel
- Wrought iron
- Copper
- Aluminum

28. What are the types of riveted butt joints according to the number of strap?

- Single strap
- Double strap
- Triple strap
- Quadruple strap

29. Differentiate between key and cotter.

- Key is driven parallel to the shaft whereas cotter is driven perpendicular to the shaft axis.
- Key is subjected to torsionally stress. Cotter is subjected to axial and bending forces.
- Key resists shear in longitudinal direction whereas cotter resists shear in transverse direction.

30. What are the advantages and limitations of cotter joints?

Advantages

- Simple design
- Easy assembly
- Disassembly

Limitations

- Weakening of parts due to holes for cotter
- Sometimes, cotter joints need locking devices

31. What are the main indications of complete weld symbol?

- A basis symbol is to specify the type of weld
- An arrow and a reference line to indicate the location of the weld.
- Supplementary symbols to indicate special instructions.
- Dimensions of the weld in cross section and length.

32. What is the stress concentration factor? Where does it occur?

Due to abrupt change in cross section, some stress concentration will be formed. it occurs at toe and heel points.

33. What are the advantages of welding?

- Welded joints are lighter in weight and have higher joining efficiency.
- Welded joints are leak proof and economical from the point of view of cost of material and labors.
- The design of welded assemblies can be easily and economically modified to meet the changing product requirement.
- The production time is less for welded assemblies.

34. How is forged welding performed?

The parts to be welded are heated to reach the plastic stage and the joint is prepared by applying impact force.

35. Give some examples for temporary joints and permanent joints?

Some examples for temporary joints and permanent joints are,
Permanent joints – Riveted joints,
Welded joints, bonded joints.
Temporary joints,
Threaded joints, cotter joints, knuckle joints

36. In what way coarse thread is different from fine thread?

Fine and coarse threads are having same major and minor diameters except their pitch value as Fine threads having smaller pitches than coarse threads.

37. What are methods of minimizing welding distortion?

- Use of rugged jigs and fixtures
- Intermittent welding
- Back-step welding
- Welding on alternate sides.

38. What are uncertainties to be considered in design of welds?

- Stress concentration
- Metallurgical change
- Residual stresses

39. Why are welded joints preferred over riveted joints?

Riveted Joints	Welded Joints
1. Metal plates are to be drilled And Joined by rivets.	1. Drilling work is eliminated, plates Can be directly welded.
2. It may require covering plates	2. No covering plate is required.

40. What are the types of eccentrically loaded welded joints?

- Welded joint subjected to moment in the plane of the weld.
- Welded joint subjected to moment in a plane normal to the plane of weld.

41. State the limitation of welding.

- It has poor vibration damping characteristics.
- Welding results distortion of parts which induces residual stresses.

42. What are the main indications of complete weld symbol?

- Reference line
- Arrow
- Basic weld symbol
- Dimensions
- Tail
- Supplementary symbol
- Finish symbol
- Specification
- Process

43. Enumerate the demerits of screw joints.

- Stress concentration is available in threaded portions and hence lowering of their life.
- Self loosening properties and hence air tight joints cannot be maintained unless providing some locking devices.

44. What is a turn buckle and where it is used?

A turn buckle is a type of connecting element for connecting two tie rods. In this type of joint, one of tie rods is having right hand thread and the other is having left hand thread. These rods are screwed into the threaded hold of the turn buckle. It is also called as coupler nut.

45. What are the advantages of preloading?

- Stops leakages
- Improves fatigue strength

46. What is bolt of uniform strength?

A bolt of uniform strength has equal strength at the thread and shank position.

47. What do you mean by single start threads?

When a nut is turned on a bolt by one full turn which is having a single continuous thread cut on it, it advances axially through a distance equal to pitch h. Hence in a single Continuous thread (single start thread) the lead is equal to pitch.

48. What is the difference between a stud and a bolt?

- Stud is a round bar threaded at both ends.
- Bolt is a cylindrical bar with threads for nut at one end and heat at the other end.

49. Define longitudinal joint.

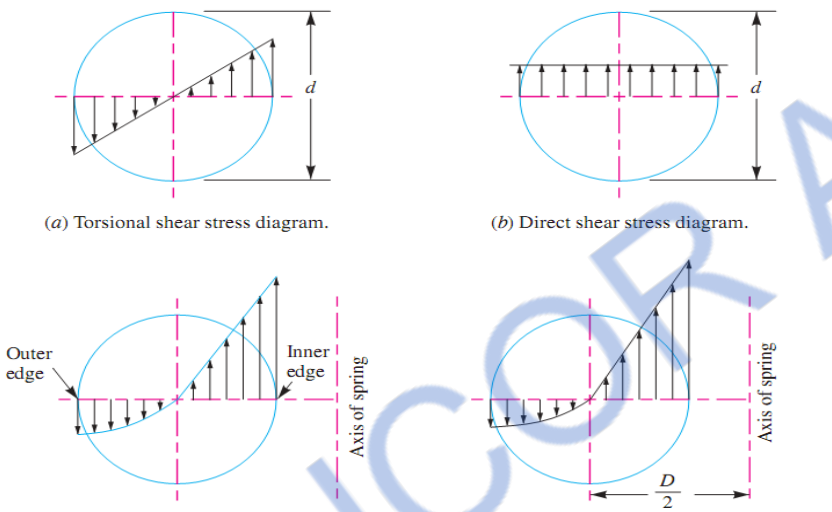
The ends of the plate are joined to get the required diameter of a boiler.

50. Name the possible modes of failure of riveted joint.

- Crushing of rivets
- Shear of rivets
- Tearing of the plate at the edge
- Tearing of the plate between rivets

UNIT-IV

1. Sketch the stresses induced in the cross section of a helical spring, considering Wahl's effect.[AU-MAY/JUNE -2017]



(*a*) Torsional shear stress diagram.

(*b*) Direct shear stress diagram.

(*c*) Resultant torsional shear and direct shear stress diagram.

(*d*) Resultant torsional shear, direct shear and curvature shear stress diagram.

Wahl's effect,

∴ Maximum shear stress induced in the wire,

$$\tau = K \times \frac{8\,W.D}{\pi\,d^3} = K \times \frac{8\,W.C}{\pi\,d^2}$$

where $$K = \frac{4C-1}{4C-4} + \frac{0.615}{C}$$

2. What are the forces acting on connecting rod? .[AU-MAY/JUNE -2017]

The combined effect of a) load on the piston due to the gas pressure and due to inertia of the reciprocating parts, and b) the friction of piston rings, piston, piston rod and cross head.

1. Inertia of the connecting rod
2. The friction force in the gudgeon and crank pin bearings.

3. State any two functions of springs. [AU-NOV/DEC -2016]

- To provide cushioning effect or reduce the effect of shock or impact loading.
  Example: automobile springs, aircraft landing gears, railway buffers and shock absorbers.

- To measure forces in spring balance, meters and engine indicators.
- To store energy such as in clocks, toys, circuit breakers and starters.
- To apply forces and to control the motion as in brakes and clutches.

4. How does the function of flywheel differ from that of governor? [AU-NOV/DEC -2016]

- A governor regulates the mean speed of an engine or machine when there are vibrations in the mean loads. It automatically controls the speed of the engine with the varying load conditions and keeps the mean speed within the limits.

- Flywheels does not control the speed variation caused by the varying load. it acts as an " energy accumulator". It will absorb energy when the demand is less than the supply of energy and it will release it when the demand is more than the energy being supplied.

5. Define spring rate. [AU-MAY/JUNE-2016]

Spring rate is defined as the amount of weight needed to compress a spring for one inch.

6. Define the term 'fluctuation of speed' and 'fluctuation of energy'. [AU-MAY/JUNE-2016]

Fluctuation of speed:

The difference between the maximum and minimum speeds during a cycle is called fluctuation of speed.

Fluctuation of energy:

The difference between maximum and minimum energy during the cycle is called fluctuation of energy.

7. What is the purpose of the flywheel? [AU-NOV/DEC-2015]

A flywheel is a machine member serves a reservoir which stores energy during the period when the supply of energy is more than the requirement and releases it during the period when the requirement of energy is more than the supply.

8. What type of spring is used to maintain an effective contact between a cam and a reciprocating roller or flat faced follower? [AU-NOV/DEC-2015]

An open coil helical compression spring is used to maintain an effective contact between a cam and a reciprocating roller or flat faced follower.

9. Why are springs used in the machines?

Springs are used in the machines to provide cushioning effect or reduce the effect of shock or impact loading.

10. State any two functions of springs.

- To measure forces in spring balance, meters and engine indicators.
- To store energy.

11. Mention any four types of springs.

- Helical spring
- Spiral spring
- Leaf spring
- Conical spring
- Disc spring or Belleville springs

12. How will you find whether the given helical spring is a compression spring or tension spring?

Ends of compression springs are flat whereas for tension springs, hooks will be provided at the ends. Coils will be slightly opened to facilitate compression in compression springs whereas in tension springs. Coils are Very close.

13. Why leaf springs are made in layers instead of single plate?

To have equal stress and to achieve economical design, leaf springs are made in layers.

14. Under what circumstances Belleville springs are preferred?

- When large force is applied and deflection must be small
- When space availability is small.

15. What is spring index? Or define the term spring rate.

The ratio of mean or pitch diameter to the diameter of wire for the spring is called spring index.

16. What is the effect of increase in wire diameter on the allowable stress value?

Increase in wire diameter will increase the spring rate but it reduces the spring index.

17. What are the different styles of end for helical compression spring?

Plain end, plain and ground, squared, squared and ground.

18. Define surging of springs.

Consider a helical spring resting on a rigid support at one end. When a compressive load is applied suddenly to a helical spring, the coil at the contact end gets deflected and sends a compression wave that travels along the spring up to the supported end where it gets deflected and travels back to the deflected end. If there is no damping present, this wave travels along the spring indefinitely. The material is subjected to higher stresses which may cause early fatigue failure. This effect is called spring surge.

19. What is surge in springs?

The material is subjected to higher stresses, which may cause early fatigue failure. This effect is called as spring surge.

20. For springs in serious, the spring rates (stiffness) ad reciprocally. – prove.

When the springs are connected in series then total deflection produced by the spring is equal to the sum of the deflections of the individual springs.

$Y_{equ} = y_1 + y_2$

$p/q_{equ} = P/q_1 + p/q_2$

$1/q_{equ} = 1/q_1 + 1/q_2$

21. Give some of the materials used for springs.

Material	Safe shear stress, N/mm^2	Modulus of rigidity, N/mm^2
High carbon steel	480	0.8×10^5
Oil tempered carbon steels	400	0.8×10^5
Stainless steel	325	0.7×10^5
Music wire	460	0.8×10^5
Phosphor bronze	225	0.48×10^5
Monel	250	0.67×10^5
Brass spring	160	0.4×10^5
Chromium vanadium alloy steel	405	0.8×10^5
Nickel silver	250	0.39×10^5

22. Where are Belleville springs used?

- Stiffness required is very large
- Space availability is limited

23. State any two important applications of leaf spring.

- Structural members
- Energy absorbing devices.

24. What is meant by semi elliptical leaf spring?

The spring consists of number of leaves, which are held together by U – clips. The long leaf fastened to the supported is called master leaf. Remaining leaves are called graduated leaves.

25. What is nipping of laminated leaf spring? Discuss its role in spring design.

For the economical use of materials, designing all leaves should be equally stressed; otherwise the master leaf will fail. This condition can be obtained if the full-length leaves are given a greater radius of curvature than that used in the graduated leaves before the leaves are assembled to form a spring. It will create an initial gap (x) between the leaves called the nip. When the central bolt is tightened, the full –length leaf will bend back and have an initial stress in a direction opposite to that of the normal the load. When the load is gradually applied to the spring, the full length leaf is first relieved of this initial stress and then stressed in opposite direction. Such a pre – stressing obtained by a difference of radii of curvature is known as nipping.

26. Why Wahl's factor is to be considered in the design of helical compression springs?

When a wire is wound in the form of helix, the length of inner fiber of wire is reduced in comparison to the length of outer fiber. It results in stress concentration at the inner fiber. Wahl's factor takes into account the effect of curvature as well as shear stress correction factor.

27. How does the function of flywheel differ from that of governor?

A governor regulates the mean speed of an engine when there are variations in the mean loads. It automatically controls the supply of working fluid to engine with the varying load condition and keeps the mean speed within the limits. It does not control the speed variation caused by the varying load. A flywheel does not maintain constant speed.

28. Define the term "fluctuation of energy".

The difference between maximum and minimum energy during the cycle is called fluctuation of energy (ΔE)

$$\Delta E = E_{max} - E_{min}$$

29. Define coefficient of fluctuation of speed in case of flywheels.

Coefficient of fluctuation of speed is the ratio of the maximum change of speed to mean speed of the flywheel.

$$Ks = W_{max} - W_{min} / W_{mean}$$

(OR)

$$2(W_{max} - W_{min}) / W_{max} + W_{min}$$

30. Define coefficient of fluctuation of speed and energy.

The difference between maximum speed and minimum speed during a cycle is called maximum fluctuation of speed. The ratio of maximum fluctuation of speed to the mean speed is called coefficient of Fluctuation speed, Ks.

The difference between maximum and minimum energy during the cycle is called fluctuation of energy (ΔE).

$$\Delta E = E_{max} - E_{min}$$

The ratio of fluctuation of energy to the mean energy is called coefficient of fluctuation of energy.

$$K_E = E_{max} - E_{min} / E = \Delta E/E$$

31. Define 'coefficient of fluctuation of speed' and 'coefficient of steadiness'.

Coefficient of fluctuation of speed is the ratio of the maximum change of speed to mean speed of the flywheel.

$$Ks = W_{max} - W_{min} / W_{mean}$$

(OR)

$$2(W_{max} - W_{min}) / W_{max} + W_{min}$$

Co-efficient of steadiness is the reciprocal of the co-efficient of fluctuation of energy.

32. What type of stresses is produced in a disc flywheel?

- Radial stress
- Tangential stress

33. Why I- section is chosen for the connecting rod?

The I section of the connecting rod is used due to its lightness and to keep the inertia forces as low as possible. It can also with stand high gas pressure.

34. Why is piston end of a connecting rod kept smaller than the crank pin end?

The piston end of the connecting rod experiences less bending moment than the crack end. Hence, on the basic of 'beam of uniform strength', the piston end of the connecting rod is smaller.

35. Define the mechanical advantage of the lever.

Mechanical advantage = Load/ Effort

36. At what angle of the crank the twisting moment is maximum in the crank shaft?

The crank angle for maximum twisting moment usually lies between 25° and 35° from TDC for petrol engines and between 30° and 40° for diesel engines.

37. What are the stresses involved in crank web?

- Direct stress due to radial force,
- Bending stress due to radial force
- Shear stress due to tangential force
- Bending stress due to tangential force

38. What are the materials used for crankshafts?

- For I.C engines C 20 or C 25 mild steel
- Automobile & Aero plane chrome –nickel steel

39. Classify crankshaft.

- Single –throw crankshafts
- Multi-throw crankshafts

40. What is the method of manufactures of connecting rod?

The method of manufactures of connecting rod is forging.

41. What are the materials used for connecting rod?

Mild steel and alloy of aluminum for light duty, alloy steels of molybdenum and chromium are used for heavy duty.

42. What are the stresses induced in flywheel arms?

- Tensile stress due to centrifugal force
- Bending stress due to torque
- Stress due to belt tension

43. What are the stresses set up in an IC engine connecting rod?

- Tensile stress
- Compressive stress
- Bending stress due to inertia force.

44. What is flywheel effect?

The mass moment of inertia required for the flywheel is termed as flywheel effect.

45. How concentric springs are obtained?

Two or more springs are joint to from a nest.

46. What are the various spring materials?

- High carbon steels.
- Medium carbon alloy steel.
- Phosphor bronze and
- Brass

47. What is buckling of springs?

The helical compression spring behaves like a column and buckles at a comparative small load when the length of the spring is more 4 times the mean coil diameter.

48. What are the disadvantages of springs?

- The wire is generally not uniform in cross-section.
- The quality of the material is not good; it is produced in smaller quantities than the round wire.
- The stress distribution is not as favorable as that for the round wire.
- The shape of the wire does not remain rectangular or square while forming the coil, resulting in trapezoidal cross section.
- The charge in cross-section reduces the energy absorbing capacity.

49. What is stiffness of spring (q)?

Stiffness is the ratio of load to deflection.

Stiffness, q = Load/Deflection = P/y

50. What is pitch?

The axial distance between adjacent coils in uncompressed state is called pitch.

51. Define: Leaf Springs.

A leaf spring consists of flat bars of varying lengths clamped together and supported at both ends , thus acting as a simply supported beam.

UNIT-V

1. What are anti – friction bearings? [AU-MAY/JUNE-2017]

The contact between the bearing elements is rolling this type has very small friction.

2. Plot the friction induced in various bearings based on shaft speed. [AU-MAY/JUNE-2017]

3. Classify the types of bearings. [AU-NOV/DEC-2016]

Depending upon the type of contact

- Rolling element bearing, and
- Sliding contact bearing

Depending upon the type of rolling element

- Ball bearing , and
- Roller bearing

Depending upon the load to be carried

- Radial
- Angular contact, and
- Thrust bearing

4. Define the term reliability of a bearing. [AU-NOV/DEC-2016]

The reliability ® is defined as the ratio of the number of bearings which have successfully completed L million revolutions to the total number of bearings under test. Sometimes, it becomes necessary to select a bearing having a reliability of more than 90%. The relation between the bearing life and the reliability is given as

$$\log_e\left(\frac{1}{R}\right) = \left(\frac{L}{a}\right)^b \qquad \text{or} \qquad \frac{L}{a} = \left[\log_e\left(\frac{1}{R}\right)\right]^{1/b}$$

Reliability is defined as the probability that a system or product will successfully operate for a

- Given range of operating conditions
- Specific environmental condition
- Prescribed economic survival tune.

5. What is meant by hydrodynamic lubrication?[AU-MAY/JUNE-2016]

In hydrodynamic lubrication, thin film of lubrication is created between shaft and bearing two sliding surfaces to separate them.

6. What are the advantages of rolling contact bearings over sliding contact bearings? [AU-MAY/JUNE-2016]

- They produce low starting and running friction except at very high speeds.
- It can withstand momentary shock loads.
- Accuracy of shaft alignment is high.
- Low cost of maintenance is sufficient as no lubrication is required while in service.
- The bearings have small overall dimensions.
- They provide good reliability of service.
- They are easy to mount and erect.
- They provide more cleanliness.

7. What is meant by square journal bearing? [AU-NOV/DEC-2015]

When the length of journal (l) is equal to the diameter of the journal (d).then the bearing is called square bearing.

8. Give an example for anti-friction bearing. [AU-NOV/DEC-2015]

- Ball bearing
- Roller bearing

5. What is babbit?

Babbit is the alloy of tin, lead, copper and antimony.

Types

Tin based babbit - Tin 90%, copper – 4.5%
Antimony 5%, lead - 0.5%

Lead based babbit – Lead 84%, tin – 6%
copper – 0.5%, Antimony 9.5%.

6. Give the compassion of gun metal & phosphor bronze.

Gun metal – copper 88%, Tin – 10% Zinc 2%

Phosphor bronze – copper 80%, Tin 10% Lead 9% phosphorus 1%.

7. List the desirable properties of learning materials.

1. High compressive strength
2. Sufficient fatigue strength
3. Conformability
4. Embeddability
5. Bondability
6. Corrosion resistance
7. Thermal Conductivity
8. Thermal Expansion

8. Define the terms Conformability and Embeddability.

Comformability is the ability of the bearing material to accommodate shaft deflections and bearing in accuracies by plastic deformation without excessive wear and heating. Embeddability is the ability of the bearing material to accommodate small particles of dust, grit etc, without scoring the material of the journal.

9. What is meant by journal bearing?

A sliding contact bearing that supports load in a radial direction and there is sliding action along the circumference of circle is called as circle journal bearing. It consists of two parts. 1. Shaft. 2. Sleeve (or) Bearing.

10. Differentiate between full journal bearing and partial journal bearing.

In full journal bearing, the Shaft (journal) is fully covered by bearing where as in partial journal bearing, the shaft is partly covered by the bearing.

11. Define filled bearing.

When a partial journal bearing has no clearance ie., the diameter of journal and bearing are equal, then the bearings is called fitted bearing.

12. Differentiate between thin film and thick film bearings. [NOV/DEC2011]

	Thick film bearing	Thin film bearing
1.	Working surfaces are completely separated from each other by lubricant.	Working surfaces are having partially contact each other atleast part of time.
2.	Also called as hydrodynamic lubricated bearings.	Also called as boundary lubricated bearing.

13. What is Hydro static bearing?

Bearings which can support steady loads without any relative motion between the journal and the bearing is called as hydro static (or) externally pressurized lubricated bearing. This is achieved by forcing externally pressurized lubricant between the members.

14. What are the assumptions made in the theory of hydrodynamic lubricated bearings. [NOV/DEC2011]

1. The lubricant obeys Newton's law of viscous flow.
2. The pressure is assumed to be constant through out the film thickness.
3. The lubricant is assumed to be incompressible.
4. The viscosity is assumed to be constant throughout the film.
5. The flow in one dimensional ie., side leakage is neglected.

15. What are the important factors to be considered for the formation of thick oil film in hydrodynamic bearing?

1. A continuous supply of oil.
2. A relative motion between the two surfaces in a direction approximately tangential is the surfaces.
3. The ability of one of the surfaces to take up a small inclination to the other surface in the direction of the relative motion.
4. the line of action of resultant oil pressure must coincide with the line of action of the external load between the surfaces.

16. What is the preferred angle of contact for partial journal bearing?

120°.

17. What is lubricant and why is it employed?

Lubricants are used in bearings to reduce friction between the rubbing surfaces and to carry away the heat generated by friction. It also protects the bearing against corrosion.

18. Specify the types of lubricant with example. [NOV/ DEC 2009]

1. Liquid lubricants - Mineral and synthetic oils.
2. Semisolid lubricants - Grease ,
3. Solid lubricants - Graphite

19. What are the desirable properties of lubricant?

Viscosity, Oiliness, Density, Viscosity index, Flash point, Fire point, Power point (or) Freezing point.

20. Define viscosity and Viscosity Index.

viscosity is the property of fluid which resists the flow of one layer of fluid from its adjacent layer.It is defined as force required to resists the layer of unit area running with unit velocity relative with its adjacent layer, when these two layers are separated by unit distance.

Viscosity Index is the term used to denote the degree of variation of viscosity with temperature.

21. What will happen if the velocity of lubricant is very low?

If the viscosity is very low, then it will not separate the relative rotating members, and hence metal to metal contact will occur which results wear of contacting members.

22. What are the materials for non metallic hearing?

Carbon-graphite, rubber, wood and plastics.

23. What is say bolt universal second?

The viscosity of the lubricant is measured key say bolt viscometer. If determines the time required for a standard volume of oil at a certain temperature to flow under a certain head through a tube of standard diameter and length. The time so determined in seconds is the say bolt universal viscosity.

24. List the terms used in journal bearing.

Diametral clearance, clearance ratio, Eccentricity, Minimum oil film thickness, Attitude (or) eccentricity ratio.

25. Define Diametral clearance and Diametral clearance ratio.

Diametral clearance is the difference between diameters of bearing and journal.

Diametral clearance ratio is the ratio of diametral clearance to the diameter of the journal.

26. Define eccentricity and attitude.

Eccentricity is the radial distance between centre of the bearing and the displaced centre of bearing under load.

Attitude (or) eccentricity ratio is the ratio of the eccentricity to the radial clearance.

27. What is minimum oil film thickness?

It is the minimum distance between the bearing and the journal under complete lubrication condition.

28. What is long and short bearing.

It the ratio of length to diameter of journal is less than 1, then it is short bearing, on the other hand, if l/d is greater than 1 then the bearing is known as long bearing.

29. What is meant by square bearing?

When the length of the journal (l) is equal to the diameter of the journal (d), then the bearing is called square bearing.

30. Expand the following: SAE, AFBMA and SKF.

SAE - Society of Automotive Engineers
AFBMA - Anti Friction Bearing Manufacturing Association
SKF - SKEFKO

31. Define bearing characteristic number.

The term ZN/P is called as bearing characteristic number. Where,

Z = Absolute viscosity
N = Speed of journal
P = Bearing pressure.

32. Define Bearing modulus.

The value of co-efficient of friction varies with the variation of bearing characteristic number (ZN/P). The value (ZN/P) for which the value of μ is minimum is identified as bearing modulus.

33. How lubricant oil is designated?

SAE followed by grade number.

34. Define Summerfield number.

It is the dimensionless parameter used is design of journal bearing.

$S = (ZN/P)\ (D/C)^2$

35. Write the formula used to calculate the amount of heat generated and heat dissipated in journal bearing.

Heat generated

$Hg = \mu\ WV$

Heat dissipated

$Hd = ((\Delta t+18)^2\ LD) / K$

36. Define kinematic viscosity

Kinematic viscosity = (Absolute viscosity / Density)

37. What is critical pressure of the journal bearing?

The pressure at which the oil film breaks down so that metal to metal contact begins, is known as critical pressure or minimum operating pressure of the bearing.

38. What is the nature of contact involved in bearing element? [NOV/DEC2012]

Rolling.

39. Define Anti friction bearing.

The contact between the bearing surfaces is rolling and it has a very low friction, then the bearing is called as rolling contact bearing (or) Anti friction bearing.

40. Name a few applications of rolling Contact bearing.

Automobiles, Agricultural machineries, Fans, Motors, Machine tools etc.

41. Specify the materials by which the rolling contact bearings are made.

High carbon chromium steel.

42. What are the types of rolling contact bearings.

i. Based on type of rolling element.
   a. Ball bearing b. Roller bearing.

ii. Based on load to be carried.
   a. Radial bearing. b. Angular contact bearing c. Thrust bearing.

43. What are the components of rolling contact bearings?

1. Outer race 2. Inner race 3. Rolling element 4. Cage or Seperator

44. Name various ball bearings.

1. Deep groove ball bearing 2. Self aligning bearing 3. Angular contact bearing
4. Filling notch bearing 5. Double row bearing.

45. What are the types of roller bearings?

1. Cylindrical roller bearing 2. Spherical roller bearing
3. Needle roller bearing 4. Tapered roller bearing

46. List the factors should be considered when selecting roller bearing.

1. Space availability 2. Type and amount of load
3. Speed 4. Alignment 5. Environmental conditions.

47. Enumerate the advantages of rolling contact bearing over sliding contact bearing.

1. Low starting and running friction except at very high speeds.
2. Ability to withstand momentary shock loads.
3. Accuracy of shaft alignment.
4. Low cost of maintenance as no lubrication is required while in service.
5. Small overall dimensions.
6. Reliability of service.
7. Cleanliness
8. Easy to mount and erect.

48. List the disadvantages of rolling contact bearing.

1. More noisy at very high speeds. 2. Low resistance to shock loading.
3. More initial cost. 4. Design of bearing housing complicated.
4.

49. What is nominal life and average life of rolling contact bearing?

The nominal life of rolling contact bearing is defined as the number of revolutions which the bearing is capable of enduring before the first evidence of fatigue, that is developed in the bearing material of either rings or rolling element. The average life of bearing is defined as the summation of all bearing lives in a series of life tests and is divided by the number of life tests. Usually this average life is approximately equal to five times the nominal life.

50. Indicate the influence of operating temperature on rolling bearing materials.

At elevated temperatures, the hardness of the bearing materials is reduced and thus their dynamic load carrying capacity is also reduced.

51. Define basic static load rating.

The basic static load rating is defined as the static radial load or axial load which corresponds to a total permanent deformation of the ball and race, at the most heavily stressed contact equal to 0.0001 times the ball diameter.

52. Define Equivalent load.

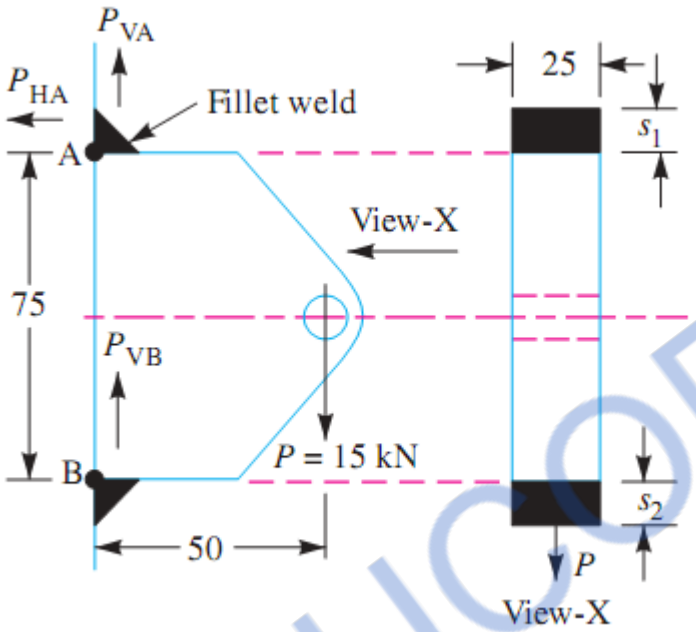
Equivalent load is defined as that constant stationary radial or axial load which, if applied to a bearing with rotating inner ring and stationary outer ring, would give the

UNEXPECTED QUESTIONS
UNIT – III

1.

The bracket, as shown in Fig. 10.34, is designed to carry a dead weight of P = 15 kN.

What sizes of the fillet welds are required at the top and bottom of the bracket? Assume the forces act through the points A and B. The welds are produced by shielded arc welding process with a permissible strength of 150 MPa.



All dimensions in mm.

Size of the fillet weld at the top of the bracket

Let s_1 = Size of the fillet weld at the top of the bracket in mm.

We know that the resultant force at A,

$$P_A = \sqrt{(P_{VA})^2 + (P_{HA})^2} = \sqrt{(7.5)^2 + (10)^2} = 12.5 \text{ kN} = 12\,500 \text{ N} \quad ...(i)$$

We also know that the resultant force at A,

$$P_A = \text{Throat area} \times \text{Permissible stress}$$
$$= 0.707\, s_1 \times l \times \tau = 0.707\, s_1 \times 25 \times 150 = 2650\, s_1 \quad ...(ii)$$

From equations **(*i*)** and **(*ii*)**, we get

$$s_1 = 12\,500 / 2650 = 4.7 \text{ mm} \quad \textbf{Ans.}$$

Size of fillet weld at the bottom of the bracket

Let s_2 = Size of the fillet weld at the bottom of the bracket.

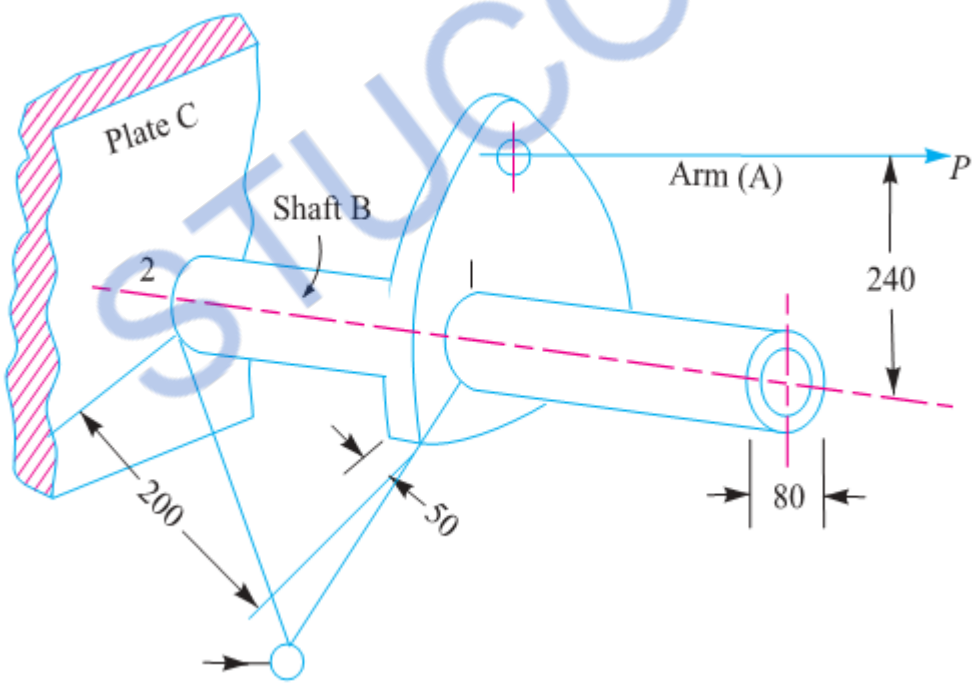
The fillet weld at the bottom of the bracket is designed for the vertical force (P_{VB}) only. We know that

$$P_{VB} = 0.707\, s_2 \times l \times \tau$$
$$7500 = 0.707\, s_2 \times 25 \times 150 = 2650\, s_2$$
$$\therefore \quad s_2 = 7500 / 2650 = 2.83 \text{ mm} \quad \textbf{Ans.}$$

2.

An arm A is welded to a hollow shaft at section '1'. The hollow shaft is welded to a plate C at section '2'. The arrangement is shown in Fig. 10.27, along with dimensions. A force P = 15 kN acts at arm A perpendicular to the axis of the arm.

Calculate the size of weld at section '1' and '2'. The permissible shear stress in the weld is 120 MPa.



The welded joint, as shown in Fig. 10.27, is subjected to twisting moment or torque (T) as well as bending moment (M).

We know that the torque acting on the shaft,

$$T = 15 \times 10^3 \times 240 = 3600 \times 10^3 \text{ N-mm}$$

$\therefore$ Shear stress, $$\tau = \frac{2.83\,T}{\pi s d^2} = \frac{2.83 \times 3600 \times 10^3}{\pi \times s\,(80)^2} = \frac{506.6}{s} \text{ N/mm}^2$$

Bending moment, $$M = 15 \times 10^3 \left(200 - \frac{50}{2}\right) = 2625 \times 10^3 \text{ N-mm}$$

$\therefore$ Bending stress, $$\sigma_b = \frac{5.66\,M}{\pi s\,d^2} = \frac{5.66 \times 26.25 \times 10^3}{\pi s\,(80)^2} = \frac{738.8}{s} \text{ N/mm}^2$$

We know that maximum shear stress (τ_{max}),

$$120 = \frac{1}{2}\sqrt{(\sigma_b)^2 + 4\,\tau^2} = \frac{1}{2}\sqrt{\left(\frac{738.8}{s}\right)^2 + 4\left(\frac{506.6}{s}\right)^2} = \frac{627}{s}$$

$\therefore$ $$s = 627/120 = 5.2 \text{ mm}$$ **Ans.**

3.

A steam engine cylinder has an effective diameter of 350 mm and the maximum steam pressure acting on the cylinder cover is 1.25 N/mm². Calculate the number and size of studs required to fix the cylinder cover, assuming the permissible stress in the studs as 33 MPa.

$\therefore$ *Circumferential pitch of the studs

$$= \frac{\pi \times D_p}{n} = \frac{\pi \times 445}{12} = 116.5 \text{ mm}$$

We know that for a leak-proof joint, the circumferential pitch of the studs should be between $20\sqrt{d_1}$ to $30\sqrt{d_1}$, where d_1 is the diameter of stud hole in mm.

$\therefore$ Minimum circumferential pitch of the studs

$$= 20\sqrt{d_1} = 20\sqrt{25} = 100 \text{ mm}$$

and maximum circumferential pitch of the studs

$$= 30\sqrt{d_1} = 30\sqrt{25} = 150 \text{ mm}$$

Since the circumferential pitch of the studs obtained above lies within 100 mm to 150 mm, therefore the size of the bolt chosen is satisfactory.

$\therefore$ Size of the bolt = M 24 **Ans.**

4.

A mild steel cover plate is to be designed for an inspection hole in the shell of a pressure vessel. The hole is 120 mm in diameter and the pressure inside the vessel is 6 N/mm². Design the cover plate along with the bolts. Assume allowable tensile stress for mild steel as 60 MPa and for bolt material as 40 MPa.

Since the circumferential pitch of the bolts obtained above is within 100 mm and 150 mm, therefore size of the bolt chosen is satisfactory.

∴ Size of the bolt = M 24 **Ans.**

Design of cover plate

Let t_1 = Thickness of the cover plate.

The semi-cover plate is shown in Fig. 11.27.

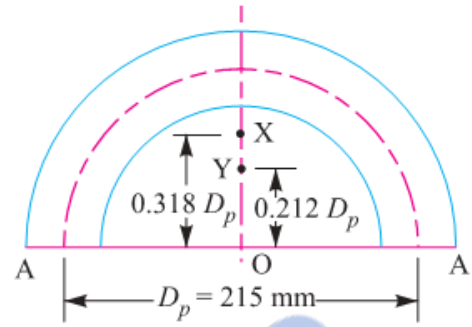


Fig. 11.27

We know that the bending moment at *A-A*,

$$M = 0.053\ P \times D_p$$
$$= 0.053 \times 67\ 860 \times 215$$
$$= 773\ 265 \text{ N-mm}$$

Outside diameter of the cover plate,

$$D_o = D_p + 3d_1 = 215 + 3 \times 25 = 290 \text{ mm}$$

Width of the plate,

$$w = D_o - 2d_1 = 290 - 2 \times 25 = 240 \text{ mm}$$

∴ Section modulus,

$$Z = \frac{1}{6}\, w(t_1)^2 = \frac{1}{6} \times 240\ (t_1)^2 = 40\ (t_1)^2 \text{ mm}^3$$

We know that bending (tensile) stress,

$$\sigma_t = M/Z \quad \text{or} \quad 60 = 773\ 265 / 40\ (t_1)^2$$

∴ $(t_1)^2 = 773\ 265 / 40 \times 60 = 322$ or $t_1 = 18$ mm **Ans.**

5.

A steam engine of effective diameter 300 mm is subjected to a steam pressure of 1.5 N/mm². The cylinder head is connected by 8 bolts having yield point 330 MPa and endurance limit at 240 MPa. The bolts are tightened with an initial preload of 1.5 times the steam load. A soft copper gasket is used to make the joint leak-proof. Assuming a factor of safety 2, find the size of bolt required. The stiffness factor for copper gasket may be taken as 0.5.

We know that mean or average stress on the bolt,

$$\sigma_m = \frac{P_m}{A_s} = \frac{23\,196}{0.7854\,(d_c)^2} = \frac{29\,534}{(d_c)^2}\ \text{N/mm}^2$$

and variable stress on the bolt,

$$\sigma_v = \frac{P_v}{A_s} = \frac{3314}{0.7854\,(d_c)^2} = \frac{4220}{(d_c)^2}\ \text{N/mm}^2$$

According to *Soderberg's formula, the variable stress,

$$\sigma_v = \sigma_e \left(\frac{1}{F.S} - \frac{\sigma_m}{\sigma_y} \right)$$

$$\frac{4220}{(d_c)^2} = 240 \left(\frac{1}{2} - \frac{29\,534}{(d_c)^2\ 330} \right) = 120 - \frac{21\,480}{(d_c)^2}$$

or $\dfrac{4220}{(d_c)^2} + \dfrac{21\,480}{(d_c)^2} = 120$ or $\dfrac{25\,700}{(d_c)^2} = 120$

$\therefore$ $(d_c)^2 = 25\,700 / 120 = 214$ or $d_c = 14.6$ mm

UNIT-IV

1.

A helical torsion spring of mean diameter 60 mm is made of a round wire of 6 mm diameter. If a torque of 6 N-m is applied on the spring, find the bending stress induced and the angular deflection of the spring in degrees. The spring index is 10 and modulus of elasticity for the spring material is 200 kN/mm². The number of effective turns may be taken as 5.5.

Bending stress induced

We know that Wahl's stress factor for a spring made of round wire,

$$K = \frac{4C^2 - C - 1}{4C^2 - 4C} = \frac{4 \times 10^2 - 10 - 1}{4 \times 10^2 - 4 \times 10} = 1.08$$

∴ Bending stress induced,

$$\sigma_b = K \times \frac{32\ M}{\pi\ d^3} = 1.08 \times \frac{32 \times 6000}{\pi \times 6^3} = 305.5 \text{ N/mm}^2 \text{ or MPa} \quad \textbf{Ans.}$$

Angular deflection of the spring

We know that the angular deflection of the spring (in radians),

$$\theta = \frac{64\ M.D.n}{E.d^4} = \frac{64 \times 6000 \times 60 \times 5.5}{200 \times 10^3 \times 6^4} = 0.49 \text{ rad}$$

$$= 0.49 \times \frac{180}{\pi} = 28° \quad \textbf{Ans.}$$

2.

A composite spring has two closed coil helical springs as shown in Fig. 23.22 (b). The outer spring is 15 mm larger than the inner spring. The outer spring has 10 coils of mean diameter 40 mm and wire diameter 5mm. The inner spring has 8 coils of mean diameter 30 mm and wire diameter 4 mm. When the spring is subjected to an axial load of 400 N, find 1. compression of each spring, 2. load shared by each spring, and 3. shear stress induced in each spring. The modulus of rigidity may be taken as 84 kN/mm².

$$P_2 = \frac{P_1}{\delta_1} \times \delta_2 = \frac{154}{15} \times \delta_2 = 10.27\ \delta_2$$

Let W_2 = Load taken by the inner spring to compress it by δ_2 mm.

We know that $$\delta_2 = \frac{8\ W_2\ (D_2)^3\ n_2}{G\ (d_2)^4} = \frac{8\ W_2\ (30)^3\ 8}{84 \times 10^3 \times 4^4} = 0.08\ W_2$$

∴ $W_2 = \delta_2 / 0.08 = 12.5\ \delta_2$

and $P_2 + W_2 = W - P_1 = 400 - 154 = 246$ N

or $10.27\ \delta_2 + 12.5\ \delta_2 = 246$ or $\delta_2 = 246 / 22.77 = 10.8$ mm **Ans.**

∴ Total compression of the outer spring

$= \delta_1 + \delta_2 = 15 + 10.8 = 25.8$ mm **Ans.**

3.

A concentric spring for an aircraft engine valve is to exert a maximum force of 5000 N under an axial deflection of 40 mm. Both the springs have same free length, same solid length and are subjected to equal maximum shear stress of 850 MPa. If the spring index for both the springs is 6, find (a) the load shared by each spring, (b) the main dimensions of both the springs, and (c) the number of active coils in each spring.

Assume G = 80 kN/mm² and diametral clearance to be equal to the difference between the wire diameters.

We know that Wahl's stress factor for both the springs,

$$K_1 = K_2 = \frac{4C-1}{4C-4} + \frac{0.615}{C} = \frac{4\times 6-1}{4\times 6-4} + \frac{0.615}{6} = 1.2525$$

and maximum shear stress induced in the outer spring (τ_1),

$$850 = K_1 \times \frac{8\,W_1.C}{\pi(d_1)^2} = 1.2525 \times \frac{8\times 3462\times 6}{\pi(d_1)^2} = \frac{66\,243}{(d_1)^2}$$

$\therefore$ $(d_1)^2 = 66\,243 / 850 = 78$ or $d_1 = 8.83$ say 10 mm **Ans.**

and $D_1 = C.d_1 = 6\,d_1 = 6\times 10 = 60$ mm **Ans.**

Similarly, maximum shear stress induced in the inner spring (τ_2),

$$850 = K_2 \times \frac{8W_2.C}{\pi(d_2)^2} = 1.2525 \times \frac{8\times 1538\times 6}{\pi(d_2)^2} = \frac{29\,428}{(d_2)^2}$$

$\therefore$ $(d_2)^2 = 29\,428 / 850 = 34.6$ or $*d_2 = 5.88$ say 6 mm **Ans.**

and $D_2 = C.d_2 = 6\times 6 = 36$ mm **Ans.**

4.

A split type flywheel has outside diameter of the rim 1.80 m, inside diameter 1.35 m and the width 300 mm. the two halves of the wheel are connected by four bolts through the hub and near the rim joining the split arms and also by four shrink links on the rim. The speed is 250 r.p.m. and a turning moment of 15 kN-m is to be transmitted by the rim. Determine:

1. *The diameter of the bolts at the hub and near the rim, σ_{tb} = 35 MPa.*
2. *The cross-sectional dimensions of the rectangular shrink links at the rim, σ_{tl} = 40 MPa ; w = 1.25 h.*
3. *The cross-sectional dimensions of the elliptical arms at the hub and rim if the wheel has six arms, σ_{ta} = 15 MPa, minor axis being 0.5 times the major axis and the diameter of shaft being 150 mm.*

Assume density of the material of the flywheel as 7200 kg / m³.

Let a_1 = Major axis,

b_1 = Minor axis = 0.5 a_1 ...(Given)

n = Number of arms = 6 ...(Given)

Since the diameter of shaft (d_1) is 150 mm and the diameter of hub (d) is taken equal to twice the diameter of shaft, therefore

$$d = 2\,d_1 = 2 \times 150 = 300 \text{ mm} = 0.3 \text{ m}$$

We know that maximum bending moment on arms at the hub end,

$$M = \frac{T}{R.n}(R - r) = \frac{T}{D.n}(D - d) = \frac{15000}{1.575 \times 6}(1.575 - 0.3)$$

$$= 2024 \text{ N-m} = 2024 \times 10^3 \text{ N-mm}$$

Section modulus, $Z = \frac{\pi}{32} \times b_1 (a_1)^2 = \frac{\pi}{32} \times 0.5\, a_1 (a_1)^2 = 0.05\,(a_1)^3$

We know that bending stress for arms (σ_{ta}),

$$15 = \frac{M}{Z} = \frac{2024 \times 10^3}{0.05\,(a_1)^3} = \frac{40.5 \times 10^6}{(a_1)^3}$$

$\therefore$ $(a_1)^3 = 40.5 \times 10^6 / 15 = 2.7 \times 10^6$ or $a_1 = 139.3$ say 140 mm **Ans.**

and $b_1 = 0.5\, a_1 = 0.5 \times 140 = 70$ mm **Ans.**

5.

A punching press pierces 35 holes per minute in a plate using 10 kN-m of energy per hole during each revolution. Each piercing takes 40 per cent of the time needed to make one revolution. The punch receives power through a gear reduction unit which in turn is fed by a motor driven belt pulley 800 mm diameter and turning at 210 r.p.m. Find the power of the electric motor if overall efficiency of the transmission unit is 80 per cent. Design a cast iron flywheel to be used with the punching machine for a coefficient of steadiness of 5, if the space considerations limit the maximum diameter to 1.3 m.

Allowable shear stress in the shaft material = 50 *MPa*

Allowable tensile stress for cast iron = 4 *MPa*

Density of cast iron = 7200 *kg / m*^{3}

Design of cast iron flywheel

First of all, let us find the maximum fluctuation of energy.

Since the overall efficiency of the transmission unit is 80%, therefore total energy to be supplied during each revolution,

$$E_T = \frac{10\ 000}{0.8} = 12\ 500 \text{ N-m}$$

We know that velocity of the belt,

$$v = \pi\, d.N = \pi \times 0.8 \times 210 = 528 \text{ m/min}$$

∴ Net tension or pull acting on the belt

$$= \frac{P \times 60}{v} = \frac{7292 \times 60}{528} = 828.6 \text{ N}$$

Since each piercing takes 40 per cent of the time needed to make one revolution, therefore time required to punch a hole

$$= 0.4 / 35 = 0.0114 \text{ min}$$

and the distance moved by the belt during punching a hole

= Velocity of the belt × Time required to punch a hole

$$= 528 \times 0.0114 = 6.03 \text{ m}$$

UNIT-V

1.

Design a journal bearing for a centrifugal pump from the following data :

Load on the journal = 20 000 N; Speed of the journal = 900 r.p.m.; Type of oil is SAE 10, for which the absolute viscosity at 55°C = 0.017 kg / m-s; Ambient temperature of oil = 15.5°C ; Maximum bearing pressure for the pump = 1.5 N / mm².

Calculate also mass of the lubricating oil required for artificial cooling, if rise of temperature of oil be limited to 10°C. Heat dissipation coefficient = 1232 W/m²/°C.

$$Q_g = \mu W V = \mu W \left(\frac{\pi d.N}{60}\right) \text{W} \qquad \ldots\left(\because V = \frac{\pi d.N}{60}\right)$$

$$= 0.0051 \times 20\,000 \left(\frac{\pi \times 0.1 \times 900}{60}\right) = 480.7 \text{ W}$$

... (d is taken in metres)

7. Heat dissipated,

$$Q_d = C.A\,(t_b - t_a) = C.l.d\,(t_b - t_a) \text{ W} \qquad \ldots (\because A = l \times d)$$

We know that

$$(t_b - t_a) = \tfrac{1}{2}\,(t_0 - t_a) = \tfrac{1}{2}\,(55° - 15.5°) = 19.75°\text{C}$$

$$\therefore \qquad Q_d = 1232 \times 0.16 \times 0.1 \times 19.75 = 389.3 \text{ W}$$

2.

A full journal bearing of 50 mm diameter and 100 mm long has a bearing pressure of 1.4 N/mm². The speed of the journal is 900 r.p.m. and the ratio of journal diameter to the diametral clearance is 1000. The bearing is lubricated with oil whose absolute viscosity at the operating temperature of 75°C may be taken as 0.011 kg/m-s. The room temperature is 35°C. Find : 1. The amount of artificial cooling required, and 2. The mass of the lubricating oil required, if the difference between the outlet and inlet temperature of the oil is 10°C. Take specific heat of the oil as 1850 J / kg / °C.

Since the value of heat dissipation coefficient (C) for unventilated bearing varies from 140 to 420 W/m^2/°C, therefore let us take

$$C = 280 \text{ W/m}^2/^\circ\text{C}$$

We know that heat dissipated,

$$Q_d = C.A\,(t_b - t_a) = C.l.d\,(t_b - t_a)$$
$$= 280 \times 0.05 \times 0.1 \times 20 = 28 \text{ W} = 28 \text{ J/s}$$

∴ Amount of artificial cooling required

$$= \text{Heat generated} - \text{Heat dissipated} = Q_g - Q_d$$
$$= 71.5 - 28 = 43.5 \text{ J/s or W}$$ **Ans.**

2. Mass of the lubricating oil required

Let m = Mass of the lubricating oil required in kg / s.

We know that heat taken away by the oil,

$$Q_t = m.S.t = m \times 1850 \times 10 = 18\,500\, m \text{ J/s}$$

Since the heat generated at the bearing is taken away by the lubricating oil, therefore equating

$$Q_g = Q_t,\ 71.5 = 18\,500\, m$$

3.

A footstep bearing supports a shaft of 150 mm diameter which is counter-bored at the end with a hole diameter of 50 mm. If the bearing pressure is limited to 0.8 N/mm^2 and the speed is 100 r.p.m.; find : 1. The load to be supported; 2. The power lost in friction; and 3. The heat generated at the bearing.

Assume coefficient of friction = 0.015.

We know that total frictional torque,

$$T = \frac{2}{3}\mu W\left(\frac{R^3 - r^3}{R^2 - r^2}\right)$$

$$= \frac{2}{3} \times 0.015 \times 12\,568\left[\frac{(75)^3 - (25)^3}{(75)^2 - (25)^2}\right] \text{ N-mm}$$

... (Assuming $\mu = 0.015$)

$$= 125.68 \times 81.25 = 10\,212 \text{ N-mm} = 10.212 \text{ N-m}$$

∴ Power lost in friction,

$$P = \frac{2\pi N T}{60} = \frac{2\pi \times 100 \times 10.212}{60} = 107 \text{ W} = 0.107 \text{ kW}$$ **Ans.**

4.

Design a self-aligning ball bearing for a radial load of 7000 N and a thrust load of 2100 N. The desired life of the bearing is 160 millions of revolutions at 300 r.p.m. Assume uniform and steady load,

From Table 27.4, we find that for a self-aligning ball bearing, the values of radial factor (X) and thrust factor (Y) for $W_A / W_R = 2100 / 7000 = 0.3$, are as follows :

$$X = 0.65 \quad \text{and} \quad Y = 3.5$$

Since the rotational factor (V) for most of the bearings is 1, therefore dynamic equivalent load,

$$W = X.V.W_R + Y.W_A = 0.65 \times 1 \times 7000 + 3.5 \times 2100 = 11\,900 \text{ N}$$

From Table 27.5, we find that for uniform and steady load, the service factor K_S for ball bearings is 1. Therefore the bearing should be selected for $W = 11\,900$ N.

We know that the basic dynamic load rating,

$$C = W\left(\frac{L}{10^6}\right)^{1/k} = 11\,900\left(\frac{160 \times 10^6}{10^6}\right)^{1/3} = 64\,600 \text{ N} = 64.6 \text{ kN}$$

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

5.

Select a single row deep groove ball bearing with the operating cycle listed below, which will have a life of 15 000 hours.

Fraction of cycle	*Type of load*	*Radial (N)*	*Thrust (N)*	*Speed (R.P.M.)*	*Service factor*
1/10	*Heavy shocks*	*2000*	*1200*	*400*	*3.0*
1/10	*Light shocks*	*1500*	*1000*	*500*	*1.5*
1/5	*Moderate shocks*	*1000*	*1500*	*600*	*2.0*
3/5	*No shock*	*1200*	*2000*	*800*	*1.0*

Assume radial and axial load factors to be 1.0 and 1.5 respectively and inner race rotates.

It is given that radial load factor (X) = 1 and axial load factor (Y) = 1.5. Since the rotational factor (V) for most of the bearings is 1, therefore equation (*i*) may be written as

$$W = (W_R + 1.5\, W_A)\, K_S$$

Now, substituting the values of W_R, W_A and K_S for different operating cycle, we have

$$W_1 = (W_{R1} + 1.5\, W_{A1})\, K_{S1} = (2000 + 1.5 \times 1200)\, 3 = 11\,400 \text{ N}$$

$$W_2 = (W_{R2} + 1.5\, W_{A2})\, K_{S2} = (1500 + 1.5 \times 1000)\, 1.5 = 4500 \text{ N}$$

$$W_3 = (W_{R3} + 1.5\, W_{A3})\, K_{S3} = (1000 + 1.5 \times 1500)\, 2 = 6500 \text{ N}$$

and

$$W_4 = (W_{R4} + 1.5\, W_{A4})\, K_{S4} = (1200 + 1.5 \times 2000)\, 1 = 4200 \text{ N}$$

We know that life of the bearing in revolutions

$$L = 60\, N.L_H = 60\, N \times 15\,000 = 0.9 \times 10^6\, N \text{ rev}$$

$\therefore$ Life of the bearing for 1/10 of a cycle,

$$L_1 = \frac{1}{10} \times 0.9 \times 10^6\, N_1 = \frac{1}{10} \times 0.9 \times 10^6 \times 400 = 36 \times 10^6 \text{ rev}$$

Similarly, life of the bearing for the next 1/10 of a cycle,

$$L_2 = \frac{1}{10} \times 0.9 \times 10^6 N_2 = \frac{1}{10} \times 0.9 \times 10^6 \times 500 = 45 \times 10^6 \text{ rev}$$

Life of the bearing for the next 1/5 of a cycle,

$$L_3 = \frac{1}{5} \times 0.9 \times 10^6 N_3 = \frac{1}{5} \times 0.9 \times 10^6 \times 600 = 108 \times 10^6 \text{ rev}$$

and life of the bearing for the next 3/5 of a cycle,

$$L_4 = \frac{3}{5} \times 0.9 \times 10^6 N_4 = \frac{3}{5} \times 0.9 \times 10^6 \times 800 = 432 \times 10^6 \text{ rev}$$

We know that equivalent dynamic load,

$$W = \left[\frac{L_1 (W_1)^3 + L_2 (W_2)^3 + L_3 (W_3)^3 + L_4 (W_4)^3}{L_1 + L_2 + L_3 + L_4}\right]^{1/3}$$

$$= \left[\frac{36 \times 10^6 (11\,400)^3 + 45 \times 10^6 (4500)^3 + 108 \times 10^6 (6500)^3 + 432 \times 10^6 (4200)^3}{36 \times 10^6 + 45 \times 10^6 + 108 \times 10^6 + 423 \times 10^6}\right]^{1/3}$$

$$= \left[\frac{1.191 \times 10^8 \times 10^{12}}{621 \times 10^6}\right]^{1/3} = (0.1918 \times 10^{12})^{1/3} = 5767 \text{ N}$$

and $$L = L_1 + L_2 + L_3 + L_4$$

$$= 36 \times 10^6 + 45 \times 10^6 + 108 \times 10^6 + 432 \times 10^6 = 621 \times 10^6 \text{ rev}$$

We know that dynamic load rating,

$$C = W \left(\frac{L}{10^6}\right)^{1/k} = 5767 \left(\frac{621 \times 10^6}{10^6}\right)^{1/3}$$

$$= 5767 \times 8.53 = 49\,193 \text{ N} = 49.193 \text{ kN}$$

From Table 27.6, the single row deep groove ball bearing number 215 having $C = 52$ kN may be selected. **Ans.**