**B.E. (MECHANICAL ENGINEERING)**

**402048: MECHANICAL SYSTEM DESIGN**

# UNIT 01: DESIGN OF MACHINE TOOL DESIGN

Q.1 Justify the statement: The difference between number teeth of successive gears in change of gearbox must be greater than 4. 6

Q.2 State the law of geometric progression used in machine tool gearbox design. Discuss advantages and disadvantages. 6

Q.3 What do you understand by maximum loss economic cutting speed? 4

Q.4 The geometric progression ratio in a multispeed gearbox is selected in a range of 1 and 2. Explain its significance. 5

Q.5 Organize in a tabulated form comparison between different gearbox progressions. 5

Q.6 Describe the basic consideration in design of drives. 5

Q.7 Explain the following terms with reference to machine tool gearbox. How these parameters are decide while designing machine tool gearbox: Range ratio, Number of transmission groups or stages and Transmission range. 6

Q.8 Draw structure diagram for following structural formulae, find out optimum formula out of these and draw gearing diagram for optimum formula. 10

2(1) 3(2);

2(3) 3(1);

3(1) 2(3);

3(2) 2(1).

Q.9 Decide number of teeth of all gears from 9 speed gearboxes with speed starting from 100 rpm based on R5 series, to transmit 10 KW power from a motor running at 1440 rpm. (Assume that minimum number of teeth in all stages is 20 and that the design is based on symmetric structure diagram only.) 10

Q.10 Draw the suitable speed diagram for 14 speed machine tool gearbox having six speed high range operation with ceramics tools. The spindle speed between 160 rpm to 4200 rpm. The gearbox is driven by 5 KW, 1440 rpm electric motor. 10

Q.11 Multispeed sliding mesh gearbox is to be designed for tapping spindle speeds varying between 20 rpm and 3170 rpm. The recommended geometric progression ratio is as per $R_5$ series. The gearbox is driven by 720 rpm three phase A.C. electric motor. 10

1. Draw structure diagrams.
2. Select optimum structure diagram.

3. Draw optimum speed diagram.

4. Draw the gearing diagram.

| | | |
|---|---|---|
| Q.12 | Find the speed steps arranged in geometric progression for following conditions. $N_{min}$ = 100 rpm, $N_{max}$ = 1800 rpm, No. of spindle speed steps z = 8. Also, draw the best possible structure diagram for the same. | 10 |
| Q.13 | Draw a layout of a machine tool gearbox having following structural formula 3(1) 3(3). Assume input speed to the gearbox through belt drive. | 6 |
| Q.14 | Multispeed gearbox is to be designed for tapping spindle speeds varying between 200 rpm and 2000 rpm. The recommended geometric progression ratio is as per $R_5$ series. The gearbox is driven by 2880 rpm three phase A.C. electric motor. Design the optimum gearbox considering "Symmetric Structure Diagram". | 10 |
| Q.15 | Draw Symmetric Structure Diagrams for following structural formulae and find out optimum formula out of them along with justification.<br>2(1) 2(2) 3(4)<br>2(1) 2(6) 3(2)<br>2(2) 2(1) 3(4) | 10 |
| Q.16 | Draw the structure diagram and gear box arrangement for following equations of a six speed gear box:<br>i) Z = 2(1) 3(2)<br>ii) Z = 2(3) 3(1)<br>iii)Z = 3(1) 2(3)<br>iv) Z = 3(2) 2(1) | 6 |

# UNIT 02: STATISTICAL CONSIDERATION IN DESIGN

Q.1 Two populations X and Y are added together. Derive an expression to find the mean and standard deviation of resultant population. 6

Q.2 What are the causes of variation in dimension of component? 4

Q.3 Define 'Design tolerance' and ' Natural tolerance' and explain difference between them. 4

Q.4 What is standard variable? Explain concept of three sigma limits. 4

Q.5 Explain design based on factor of safety and design based on reliability. 5

Q.6 It is observed from a sample of 300 forging that the length are normally distributed with a mean of 150.5 mm and standard deviation of 0.02 mm. determine tolerance specified by desired if 15 jobs are rejected. 10

Q.7 If device has failure rate of $40^{-6}$ failures / Hrs. what is its reliability in 250 hours? If there are 1000 items are in a test, how many failures are expected in 250 hours? 10

Q.8 Define the mechanical reliability find the reliability in operating period of 1000 hours, for a device having failure rate of $1 \times 10^{-6}$ failures/hour. If there are 1000 such items in a test, how many of failures are expected in 1000 hours? 8

Q.9 A shaft and baring assembly have following dimensions: Shaft: ϕ 40 ± 0.3 mm with standard deviation of 0.1mm.Bearing bore: ϕ 40.5 ± 0.3 mm with standard deviation of 0.1mm. 10

Find the percentage of assemblies with

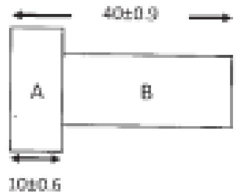
i) Clearance less than 0.25 mm and

ii) Clearance between 0.25 mm and 0.35mm. Areas under standardized normal distribution curves from -∞ to Z

Q.10 The diameters in a sample of 100 bolts are normally distributed with 10.5mm mean and 0.02 mm standard deviation. Determine the specified tolerances if the process is centered and only 95 bolts are accepted. Draw a neat figure and use Area under the normal curve from 0 to Z. 10

Q.11 A steel rod is subjected to axial stress within elastic limits. The strain in rod is normally distributed with mean of 0.001 mm/mm and a standard deviation of 0.00007 mm/mm. the modulus of elasticity is normally distributed with a mean of $2.07 \times 10^5$ N/mm$^2$. Determine the mean and standard deviation of corresponding stress variable, comment on analysis. 6

Q.12 Two components A and B are assembled with the overall dimension 40± 0.9mm as shown in Fig. Specify dimensions for component B if the overall dimensions as well as individual component dimensions are normally 10 distributed and natural tolerances are equal to design tolerances.




Q.13 A straight tensile bars of diameter 10±0.1 mm are made of plain carbon steel 40C8 having tensile yield strength of 300±30N/mm2. The load on the bars is 23.5±5kN. If the diameters, strength and loads are normally distributed, estimate the reliability of withstanding the load by the bars. The areas under the standard normal distribution curve from zero to Z. 10

Q.14 It is observed from a sample of 1000 bearings bushes that the internal diameters are normally distributed with mean of 50.015 mm and standard deviation of 0.008 mm. Dimension of this diameter specified on drawing is 50.01+0.1 mm. Calculate the approximate number of rejected bushes from that sample. 10

Q.15 Transmission shafts are manufactured on a machining center. The designer has specified the dimension of OD as 40+0.04mm. The natural tolerance is normally distributed with mean of 40mm but only 34% out of the manufactured shafts are found to be acceptable. So what is the standard deviation of this manufacturing process? 10

# UNIT 03: DESIGN BELT CONVEYOR

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|---|---|---|
| Q.1 | Differentiate between 'Angle of repose' and 'Angle of surcharge' in connection with the belt conveyor transporting bulk material. Explain the factors on which the surcharge angle depends. | 6 |
| Q.2 | Explain the procedure to estimate the power requirement for belt conveyors | 6 |
| Q.3 | "What are the design considerations in selecting the belt speed of a conveyor? | 6 |
| Q.4 | Explain in brief the system concept for material handling? | 5 |
| Q.5 | Draw and explain screw take up arrangement in belt conveyors? | 5 |
| Q.6 | Describe in detail belt conveyers and their types using neat sketches | 5 |
| Q.7 | Describe in detail using neat sketches loading and unloading methods in conveyer systems. | 5 |
| Q.8 | A Horizontal flat belt conveyor is to be used for transporting 500 metric ton of iron ore per hour at belt speed of 1.5 m/s. The mass density of iron ore is 1800 kg/m$^3$. If surcharge angle is 20°. Determine the required effective belt width | 10 |

Q.9 A triple ply belt conveyor is required to transport 2 ton of iron ore per hour through a distance of 1000m and a height of 300 m. The permissible belt speed is 90 m/min. if the mass density of iron ore is 2.5 ton per cubic meter, determine: — 10

(i) the belt width;

(ii) the diameter of drive pulley; and

(iii) the reduction ratio of gear reducer, if electric motor speed is 1440 r. p. m.

Use following data: Standard belt widths:400, 450, 500, 600, 650, 750, 800, 900,1000, 1200, 1400, 1600, 1800, 2000 mm material factor for plies for Capron belt: $K_1$ = 2.0; belt tension and arc of contact factor: $K_2$ = 80.

| Belt inclination, δ° | 10°-15° | 16°-20 | 21°-25° | 26°-30° | 31°-35° |
|---|---|---|---|---|---|
| Flow ability factor 'k' | $2.65\times10^{-4}$ | $2.5\times10^{-4}$ | $2.35\times10^{-4}$ | $2.20\times10^{-4}$ | $2.05\times10^{-4}$ |

Q.10 A belt conveyor is to be designed to carry bulk material at the rate 300x10$^3$ kg/hour with the following details: Bulk density of the material = 800 kg/m; Angle of surcharge of bulk material = 15$^0$; Belt speed = 10 km/hour; Material factor for plies, $k_1$= 2.0; Belt tension and arc of contact factor, $k_2$ = 63; — 10

Number of plies for the belt = 4.

Suggest:

i) Suitable width for the belt.

ii) Diameter and length of the drive pulley.

Q.11 A triple ply belt conveyor is required to transport 4 Ton of iron ore per hour at a conveyor speed of 3 m/s. If the mass density of iron ore is 2.5 Ton/m3, suggest: 10

i) The maximum suitable inclination for the conveyor which can be given.

ii) The diameter of the drive pulley.

iii) The gear box reduction ratio, if motor speed is 1440rpm. Material factor for plies for belt: $K_1$ = 2.0 and Belt tension and arc of contact factor: $K_2$ = 80

| Belt inclination, á° | $10^0$-$15^0$ | $16^0$-20 | $21^0$-$25^0$ | $26^0$-$30^0$ | $31^0$-$35^0$ |
|---|---|---|---|---|---|
| Flow ability factor 'k' | $2.65\times10^{-4}$ | $2.5\times10^{-4}$ | $2.35\times10^{-4}$ | $2.20\times10^{-4}$ | $2.05\times10^{-4}$ |

Q.12 A horizontal belt conveyor transports material of mass density 1200 kg/$m^3$. The surcharge factor for the flat belt drive is 0.16 and the belt width is 650 mm. Determine the capacity of the conveyor if the belt speed is 1.75 m/s and the effective width b (in meters) of the material carried by the belt safely is given by the equation: **b=0.9B-0.05**; where B is the belt width in meters. 8

Q.13 Design a belt conveyor to carry material at the rate of $30\times10^3$ kg/hr. with the following details. Bulk density of material is 800 kg/$m^3$, angle of bulk material surcharge is 15°, belt speed is 10 km/hr. belt has 4 plies, material factor $k_1$ for plies is 2.0, belt tension and arc of contact factor $k_2$ is 63. Determine: 8

i) Suitable belt width

ii) Drive pulley diameter and length

Q.14 A horizontal belt conveyor is to be used for transporting 450 tons of iron ore with mass density 1750kg/$m^3$. If surcharge factor is 0.06. Determine belt width. 6

Q.15 A flat horizontal belt conveyor is to be used for transporting material with mass density 2.5 ton/$m^3$. The belt is 800mm wide and has speed of 1.75 m/s. Determine capacity of conveyor if surcharge angle is $25^0$. 8

# UNIT 04: DESIGN OF CYLINDER AND PRESSURE VESSEL

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|---|---|---|
| Q.1 | What are types of end closure for cylindrical vessel? State the design procedure of conical head. | 4 |
| Q.2 | Describe various types of supports used in vertical pressure vessel. | 4 |
| Q.3 | What is autofrettage? Explain any one method of pre-stressing the cylinders? | 4 |
| Q.4 | Explain with the help of neat sketches, the different types of formed heads used as end closures in cylindrical pressure vessels. State their advantages, disadvantages and applications. | 6 |
| Q.5 | "Explain the design of openings in pressure vessels by' area for method of compensation" | 5 |
| Q.6 | Derive Clavarino's equation for thick cylinder subjected to internal pressure. | 6 |
| Q.7 | State and explain various categories of welded joint used in unfired pressure vessel. Draw neat sketch. | 6 |
| Q.8 | A cylindrical pressure vessel is made up of stainless steel. Assuming the following data, determine thickness of the vessel shell: Internal diameter of vessel, Di =1500 mm, Design Pressure = 0.44 Mpa, Permissible stress for a material = 130 Mpa, Welded joint efficiency = 85%. Assuming both ends as closed and external forces as well as corresponding stresses as negligible, determine the resultant stress in the shell. | 8 |
| Q.9 | A tube of inner and outer diameters 50 mm and 75 mm respectively is reinforced by shrink fitting another tube of 100 mm diameter. This assembly is to withstand an internal pressure of 35 Mpa. The shrinkage is such that the maximum tangential stress in both the tubes is the same. Calculate the shrinkage pressure and the original dimensions of the tube. Also plot the distribution tangential stresses. Assume E =207 $KN/mm^2$ | 12 |
| Q.10 | A $10^3$ capacity cylindrical pressure vessel with torispherical heads is to be used to store water at a temperature of $160^o$ C (Water vapour pressure 6.4 bar absolute). The crown and knuckle radii for the torispherical heads are taken as 0.75 $d_i$ and 0.125 $d_i$ respectively. The shell as well as heads is made of plain carbon steel with allowable tensile stress of 85 $N/mm^2$. The single welded butt joints with backing strips are used to fabricate the vessel. The total length of the vessel is limited to 5m. | 12 |

i) Which class vessel is to be used for this purpose?

ii) Determine minimum vessel diameter and the corresponding thickness of the vessel shell.

iii) Determine dimensions of the torispherical head. Assume weld joint efficiency or shell & head = 0.9

Q.11 The following data refers to single acting hydraulic cylinder. Pressure of hydraulic fluid = 10 MPa, Operating force available at the piston rod = 10 KN, Friction due to piston ring and stuffing box = 10% of operating force Thickness of cylinder flange = 10 mm, Thickness of cylinder head = 8 mm, Cylinder and cylinder head material = FG200, Modulus of elasticity for FG200 = 100 GPa, Thickness of Zinc gasket = 3 mm, Modulus of elasticity for zinc = 83 GPa, Number of bolts = 4, Preload in each bolt = 2.8 KN, Bolt material = FeE 400, Modulus of elasticity for FeE 400 = 207 GPa, Factor of safety for cylinder = 5, Factor of safety for bolts = 6, Standard diameter of cylinder = 20, 30, 40, 50, 60 mm, Standard Thickness of cylinder = 2, 4, 5, 6, 7, 8, 10 mm, Standard diameter of bolts = 8, 10, 12, 14 mm. Determine: 12

i) Inner diameter of cylinder

ii) Thickness of cylinder

iii) Diameter of bolts.

Q.12 The cylindrical pressure vessel shell of inside diameter 1500mm is subjected to an internal pressure of 2 MPa. The shell as well as head are made of low alloy steel with an ultimate tensile strength of 450 $N/mm^2$.The double welded butt joint which are spot radiographed are used to fabricate the vessel. The corrosion allowance is 3 mm. Determine the thickness of cylindrical shell and the thickness of head if the heads are: 12

i) Flat

ii) Plain formed

iii) Torispherical with crown radius of 1125 mm

iv) Semi elliptical with ratio of major axis to minor axis as 2.

v) Hemispherical

vi) Conical with semi cone angle 30 0.

Q.13 Determine the inside diameter of shell and the crown radius of the torispherical heads if the thickness of the shell and the torispherical heads of a cylindrical pressure vessel are 12mm and 16mm respectively. The vessel operating at 2.0 MPa pressure is entirely made of 270$N/mm^2$ yield strength material with weld joint efficiency 0.7 and corrosion allowance of 2 mm. 10

Q.14 The maximum tensile stress induced in a pressure cylinder consisting of an inner cylinder of 300mm ID and 400mm OD is $100N/mm^2$. The vessel is jacketed by outer cylinder of 500mm OD. Calculate the shrinkage pressure and the difference between the inner cylinder OD and the jacket ID before assembly assuming $E = 210kN/mm^2$. 10

Q.15 A hydraulic cylinder, made of gray cast iron FG 300, is subjected to an internal pressure of 15 MPa. If the inner and outer diameters of the cylinder are 200 mm and 240 mm respectively, determine the factor of safety. If the cylinder pressure is further increased by 30 %, What will be the factor of safety? 10

# UNIT 05: DESIGN OF INTERNAL COMBUSTION ENGINE

Q.1 Explain design procedure of Connecting Rod. 4

Q.2 What is a desirable property of I.C. engine piston material? State the materials used for I.C. engine piston. 4

Q.3 What are the types of piston rings? State their functions. 4

Q.4 Explain with neat sketches procedure for design of center crankshaft at top dead center position. 6

Q.5 Draw a neat sketch of the connecting rod and explain its constructional details. 5

Q.6 Explain whipping stress in connecting rod. 4

Q.7 Explain with sketch construction of Piston. 4

Q.8 The cylinder of 4-stroke diesel engine has the following specifications: Brake Power = 7.5 kW, Speed= 1400 RPM, Indicated mean effective pressure = 0.35 Mpa, Mechanical Efficiency = 80% and Maximum gas pressure = 3.5 Mpa. The liner and head are made of gray cast iron with $S_{ut}$ = 250 Mpa and μ = 0.25. The stud are made of plain carbon steel with $S_{yt}$ = 380 Mpa. Factor of safety for all parts is 6. Calculate: 10

i) Bore and length of cylinder liner

ii) Thickness of cylinder liner

iii) Thickness of cylinder head

iv) Size, number and pitch of stud.

Q.9 "Design cast iron Piston for a single acting 4-stroke diesel engine with the following data: Cylinder bore = 300 mm, Length of stroke: 450 mm, Speed: 300 RPM, Indicated mean effective pressure = 0.85 Mpa, Maximum gas pressure: 5 Mpa, Fuel consumption 0.3 kg per BP per hour, higher calorific value of fuel: 44000 kJ/kg. Clearly state the assumptions of suitable data. 16

Q.10 The following data is given for a four- stroke diesel engine: Cylinder bore = 250 mm, Length of stroke = 300 mm, Speed = 600 rpm, Indicated mean effective pressure = 0.6 MPa, Mechanical efficiency = 80 %, Maximum gas pressure = 4 MPa, Fuel consumption = 0.25 kg per BP per hr. Higher calorific value of fuel = 44000 KJ/kg Assume that 5% of total heat developed in the cylinder is transmitted by the piston. The piston is made of gray C.I. FG 200 (Sut = 200 N/mm2 and K = 46.6 W/m/$^{o}$ C) and the factor of safety is 5. The 12 temperature difference between the center and the edge of the piston head is 220$^{o}$C.

i) Determine the thickness of piston head by strength consideration and thermal consideration.

ii) State whether the ribs are required, IF so calculate the number and thickness of ribs.

iii) State whether a cup is required in the top of piston head, If so calculate the radius of the cup.

Q.11 " The following data is given for the connecting rod of a diesel engine : Cylinder bore = 85 mm, Length of connecting rod = 350mm, Maximum gas pressure = 3 MPa, Factor of safety against buckling failure = 5, (l/d) ratio for piston pin bearing = (1.5), (l/d) ratio for crank pin bearing = (1.25), Allowable bearing pressure for piston pin bearing = 13MPa, Allowable bearing pressure for crank pin bearing = 11 MPa, length of stroke = 140 mm, Mass of reciprocating parts = 1.5 kg, Engine speed = 2000 rpm, Thickness of bearing bush = 3 mm, Material of cap = 40 C8 (Syt = 380 N/mm$^2$), Material of bolts = Alloy steel (Syt = 450N/mm$^2$), Factor of safety for cap and bolts = 4 and 5 respectively. Density of connecting rod = 7800 kg/m$^3$ Determine: 16

i) Dimensions of the cross-section of connection rod.

ii) Dimensions of small and big and of bearings.

iii) Nominal diameters of bolts for the cap

iv) Thickness of cap; and v) Magnitude of whipping stress.

Q.12 "Determine the cross section of I section of connecting rod for single cylinder IC engine. Use the following data for engine: Piston diameter = 100 mm, Mass of reciprocating parts = 2.25 Kg, Length of connecting rod = 300 mm, Stroke length = 125 mm, Speed = 1500 rpm, Maximum explosion pressure = 3.5 N/mm$^2$, Factor of safety = 7, Density of rod material = 8000 Kg/m3 Yield stress in compression = 330 MPa, Assume width of section as 4 x t and depth as 5 x t where t is the web thickness of I section. 12

Q.13 "Following data is given for a single cylinder four stroke diesel engine: Cylinder bore = 100mm, Length of stroke = 125 mm, Speed = 2000 rpm, Brake mean effective pressure = 0.65MPa, Maximum gas pressure = 5 Mpa, Fuel consumption = 0.25 kg per BP per hour, Higher calorific value of fuel = 42000 KJ/kg. Assume that piston transmits 5% of total heat developed in cylinder. Permissible stress of piston material is 37.5 N/mm$^2$ (k = 46.6 W/m/$^0$C). Temperature difference between center and the edge of piston head is 12

$220^0$C.

i) Calculate thickness of piston head by strength consideration

ii) Calculate thickness of piston head by thermal consideration

iii) Decide on the criteria that decides piston head thickness

iv) Decide if ribs are required

v) If yes, calculate number and thickness of piston ribs

vi) Decide whether a cup is required at the top of piston head vii) If yes, calculate radius of cup.

Q.14 A two stroke engine is to be designed for a brake power of 7 kW at a speed of 800 rpm. The indicated mean effective pressure may be assumed as 0.5 MPa. Design: 12

i) The bore and length of the cylinder liner.

ii) The thickness of the liner.

iii) The cylinder head thickness.

iv) The size, number and pitch of the studs. Also calculate the apparent and net stresses in the liner, if the Poisson's ratio is 0.25.

Q.15 Design a cast iron piston for a single acting four stroke diesel engine with the following data: Cylinder bore = 200 mm, length of the stroke = 250 mm, Speed = 600 rpm, Brake mean effective pressure = 0.60 MPa, Maximum gas pressure = 4 MPa, Fuel consumption = 0.25 kg per BP per hour, l/d ratio for bush in small end of connecting rod =1.5. 16

Assume suitable data if required and state the assumptions you make.

# UNIT 06: OPTIMUM DESIGN AND DFMA

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|---|---|---|
| Q.1 | Explain with examples, what are desirable and undesirable effects in a design of a mechanical system. | 4 |
| Q.2 | What do you understand by optimum and adequate design? | 4 |
| Q.3 | Explain the Johnson's method of optimum design. | 4 |
| Q.4 | Differentiate between optimum design problems with normal specifications and redundant specifications | 4 |
| Q.5 | With suitable sketches, explain the DFM principals in the Design of Castings and Forgings. | 8 |
| Q.6 | Explain the factors to be considered while designing the components for castings. | 6 |
| Q.7 | Explain the basic principles of DFMA. | 6 |
| Q.8 | Design a shaft with minimum weight. It transmits a torque 900 N-m. Required torsional stiffness (rigidity) is 90 N-m /degree. Use maximums hear stress theory of failure for this design. Assume a Factor of safety of 1.5 based on Yield strength. What will be the change in design for minimum cost? | 14 |

| Material | Mass Density ( $Kg/m^3$) | Modulus of rigidity (GPa) | Yield strength (MPa) | Material Cost (Rs/N weight) |
|---|---|---|---|---|
| Mat 1 | 8500 | 80 | 130 | 16 |
| Mat.2 | 3000 | 26.5 | 50 | 32 |
| Mat 3 | 4800 | 40 | 90 | 480 |
| Mat 4 | 2100 | 16 | 20 | 32 |

| | | |
|---|---|---|
| Q.9 | Design a tensile bar for minimum cost of the following materials. Assume a Factor of safety of 2. Area of bar should be at least 85 $mm^2$. Length of bar is 200 mm. A constant tensile load on bar is of 5000 N. | 14 |

| Material | Mass Density $\frac{kg}{m^3}$ | Yield Strength (MPa) | Material Cost (Rs/ N weight) |
|---|---|---|---|
| Steel | 7500 | 16 | 130 |
| Aluminum alloy | 3000 | 32 | 50 |
| Magnesium Alloy | 2100 | 32 | 20 |

Q.10 A cantilever beam of the length 250 mm & rectangular cross section is subjected to varying load ± 100N. The width to depth ratio of the beam is 5:1; If the factor of safety is; design the beam for optimum material cost and find required dimensions of beam. Use following materials. 14

| Material | Mass density 'ρ' $kg/m^3$ | Material cost/ unit weight 'C' Rs/N | Endurance limit 'Se' $N/mm^2$ |
|---|---|---|---|
| M 1 | 8450 | 100 | 17 |
| M 2 | 8020 | 100 | 37.5 |
| M 3 | 7830 | 60 | 32 |

Q.11 A tensile bar of cross- sectional area at least 85 $mm^2$ and length of 200 mm is subjected to a constant load of 500 N. Design a bar for minimum cost, of the following materials. Assume factor of safety as 2. 14

| Material | Mass Density ($kg/m^3$) | Material cost (Rs / N) | Yield strength MPa |
|---|---|---|---|
| M 1 | 7500 | 16 | 130 |
| M2 | 3000 | 32 | 50 |
| M3 | 2100 | 32 | 20 |

Q.12 In light weight equipment a shaft is required to transmit 40 KW power at 425 rpm. The required stiffness of shaft is 90 N-m /degree. The factor of safety based on yield strength in shear is 1 .5.Using the maximum shear stress theory; design the shaft with the objective of minimizing the weight out of the following materials. What will be the change in design for minimum cost? 14

| Material | Mass density ρ, $Kg/m^3$ | Material cost per unit weight c, Rs/N | Tensile yield strength Syt, $N/mm^2$ | Modulus of rigidity G, $N/mm^2$ |
|---|---|---|---|---|
| Alloy steel | 7800 | 7.5 | 450 | $82 \times 10^3$ |
| Aluminum alloy | 2800 | 9 | 150 | $27 \times 10^3$ |
| Titanium alloy | 4500 | 150 | 800 | $41 \times 10^3$ |
| Magnesium alloy | 1800 | 10 | 100 | $17 \times 10^3$ |

Q.13 A tensile bar of circular cross section made of plain carbon steel 40 C8 (Sut = 580 $N/mm^2$, Syt = 330 $N/mm^2$; E = 207 x 103 $N/mm^2$ and density = 7750 kg / $m^3$) is subjected to the cyclic tensile force which varies from zero to 90 kN. The required stiffness of bar is 3.5 x $10^5$ N/mm. The surface finish and size factors are 0.76 and 0.6 respectively. Using the Soderberg criterion, design the bar with the objective of optimizing the factor of safety. The following 14 limitations are used in the design.

$d \le 30$ mm, $350mm \le L \le 500$ mm, $M \le 3kg$.

Q.14 An exhaust valve mechanism helical coiled spring is initially compressed with a preload of 500N and the valve lift is 40mm. Design the spring with modulus of rigidity 90GPa and Wahl's shear stress factor as 1.14 such that the torsional shear stress in spring will not exceed 700 MPa. The spring would weigh minimum with the condition $P_{max}$ = 2Pmin and the outside diameter fixed at 60mm when optimized. 12