THEORY & OBJECTIVE

MACHINE DESIGN

By
Team of
Engineers Academy

- State Engineering Services Examinations.
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CONTENTS

INTRODUCTION TO MACHINE DESIGN

THEORY

1. ENGINEERING DESIGN

(i) Mechanical Engineering Design

(ii) Civil Engineering Design

(iii) Electrical Engineering Design

(iv) Chemical Engineering Design etc.

Problem of Society → Engineering Design → Product, device or system.

Resources men,, material, machine, money → Engineering design → Product, device or system to satisfy human need.

Engineering design as iterative decision making activity to produce, a plan or drawing to convert resources optimally into a product or device or system to satisfy the human need.

- The ultimate aim of design is to develop a drawing [i.e. to select an appropriate shape, material, size and manufacturing process details) in such a way that the resulting machine component will perform given functionality satisfactorily (i.e. without fracture).

  A machine component is said to be failure when it doesn't perform given objective satisfactorily.

- A machine is defined as a combination of stationary and moving machine elements and they are assembled in such a way that either to produce or transform or utilize mesh energy. Ex. motor, engine turbine, generators, pump, compressor, automobile machine etc.

1.1 Steps used in design of a machine element:

(i) Specify function of machine element

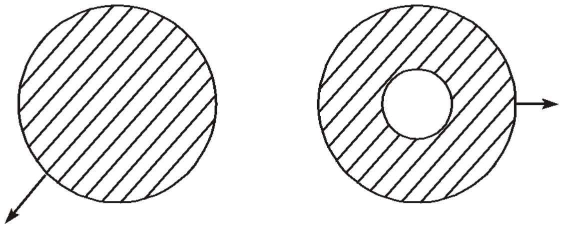
Example: Shaft load = kN at N = rpm

(ii) Analysis (determination of load acting of machine element]

Example: $T = \frac{P \times 60}{2\pi N} \times 10^6 = \_\_\_\_$ Nmm

(iii) Selection of appropriate shape for a given X s/c

Example: Circular X s/c



(iv) Selection of appropriate material. Here after selection of material mechanical properties are noted down.

Example: Low power transmission →M/S. [Low (Steel)]

High power transmission → HCS or Ni, Ni – (steel)

(v) Modes of failure

(a) Failure of material by yielding system

(b) Failure by fracture system.

(c) Failure by excessive deformation.

(vi) Calculation of dimension by using- stregth of material equation like strength criterion or rigidity criterion

(vii) Selection of manufacturing Process.

(viii) Preparation of drawing.

1.2 Basic Requirement of Machine Element :

High strength → High rigidity → Low weight → Low service life → Low cost → High wear resistant.

1.3 Design Criterion:

Strength criterion → maximum stress induce ≤ permissible, based on permissible stress → rigidity criterion or stiffness criterion-based on permissible deformation.

Example: Shaft, spring, beam, machine tool because deformation effects the functionality of member or performance of machine element hence designed by Rigidity criterion.

Maximum deformation ≤ permissible deformation.

1.4 Factor of Safety:

Used to determine permissible stress given by

$$N = \frac{\text{Failure stress}}{\text{permissible or safe or allowable stress}}$$

The failure stresses are :

Yield strength for Ductile material

Ultimate strength for Brittle material

Inductance limit for fatigue load

reserve strength = feature stress – permissible stress

Reason to Keep Reservic Strength :

(1) Unknown environmental and loading conditions.

(2) Imperfect workmanship.

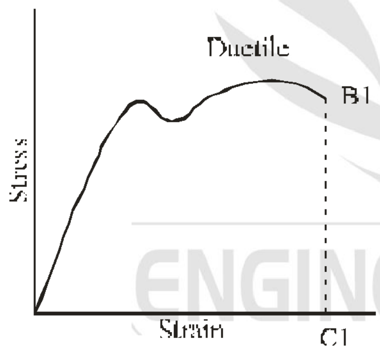
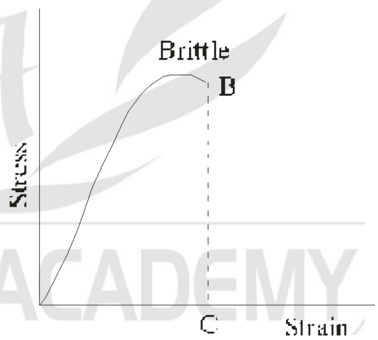
(3) Unreality of assumption made in basis some equations.

(4) Stress conc. effect.

FOS can also be called as Factor of Ignorance.

1.5 Machine Design:

Design is a decision making process which is used to satisfy human need and to create something with physical reality.

	Ductile Material		Brittle Material
1.	Resistance to yielding < Resistance to separation	**1.**	Resistance of separation < Resistance to yielding
2.	Failure takes place by yielding	**2.**	Failure takes place by separation
3.	$(\sigma_y)_{tension} = (\sigma_y)_{compression}$	**3.**	$(\sigma_{OTS})_{tension} \neq (\sigma_{ITS})_{comp}$
4.	A Material like copper is known as ductile i.e. It will flow and can be drawn out into a wire without fracture	**4.**	Material such as Glass that can be extended but do not show plastic deformation and will easily fracture
5.	In Failure theories Yield strength is used for Ductile material	**5.**	In Failure theories Ultimate strength is used for brittle material
6.		**6.**	

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STATIC LOADING

THEORY

1. STRESSES

The machine parts are subjected to various forces which are called as load. Due to load there is stress in machine elements.

Tensile stress = Tensile load / resisting area.

Shear stress = tangential load / resisting area

It is state of stress where stress is parallel to the surface of material, complainer with material X s/c.

- **Thermal stress:** This occur due to temperature change and if the deformation occurring due to temperature change is opposed.
- **Bending stress:** There are tensile or comparative stress only.
- **Torsional stress:** These are shear stress only. shear stress Produced when we apply the twisting moment to the end of a shaft about its axis is known as Torsional stress.
- **Bearing stress:** Stress that result from contact of Two members.

2. TYPES OF LOAD

(i) **Static or dead load:** doesn't change its magnitude and direction.

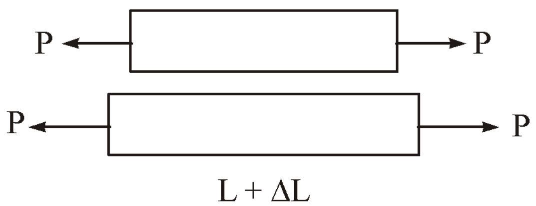
(ii) **Variable load:** Change in magnitude and direction of load occur.

(iii) **Sudden or shock load:** Their loads suddenly applied or removed.

(iv) **Impact load:** Sudden load when applied with some velocity.

3. STRESSES IN MACHINE PARTS

3.1 Tensile or Compressive Stresses :



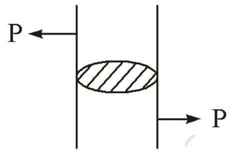
$$\text{Tensile stress} = \frac{P}{A}$$

$$\text{Strain} = \frac{\Delta L}{L}$$

$$\sigma = \varepsilon E$$

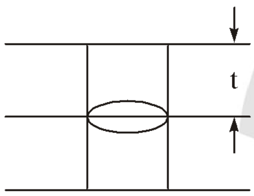
$$\Delta = \frac{PL}{AE}$$

3.2 Shear Stress (τ) :



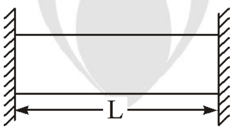
$$\tau = \frac{\text{tangential force}}{\text{resulting area}}$$

3.3 Bearing Stress :



$$\sigma_b = \frac{P}{dt}$$

3.4 Thermal Stresses :



t = Temperature change

α = Coefficient of thermal expression

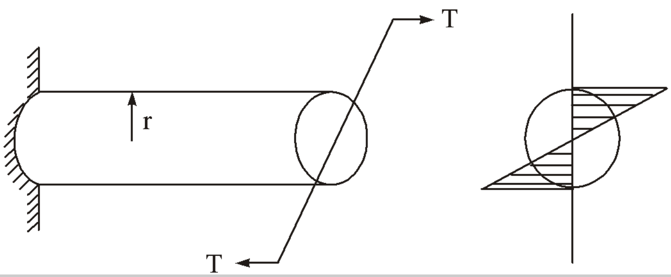
then $\delta L = L \alpha t$

$$\frac{\delta L}{L} = \alpha t \text{ (thermal strain)}$$

then $\sigma_t = E \in$

$$\boxed{\sigma_t = E \alpha t}$$

3.5 Torsional Stress: It is zero a centroids areas and maximum at outer surface.



Torsion equation

$$\frac{\tau_s}{r} = \frac{T}{J} = \frac{G\theta}{L}$$

where

τ_s = Shear stress

r = Radius of shaft

T = Twisiting moment

J = Polar moment of Inertia

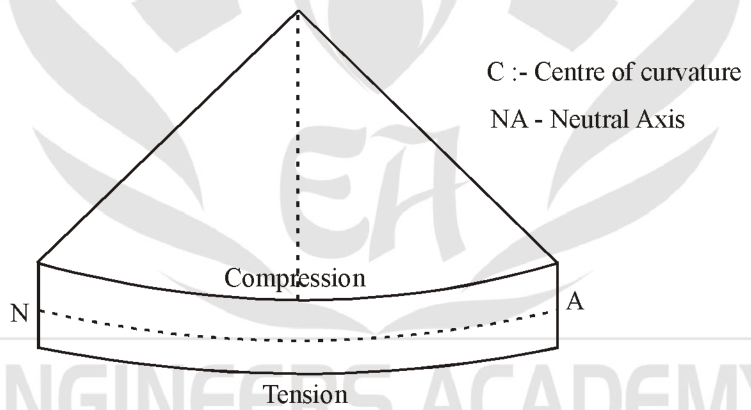
G = Modulus of rigidity of shaft material

$\frac{T}{J} = \frac{\tau_s}{R}$ is known as strength equation.

$\frac{T}{J} = \frac{G\theta}{l}$ is known as stiffness equation.

and Power = Torque × ω

3.6 Bending Stress: It occurs when a beam is subjected to bending moment.



Bending equation $\frac{E}{R} = \frac{M}{I} = \frac{\sigma}{y}$

E = Young's modulus

M = Bending moment acting at a given s/c

σ = Bending stress

I = MOI about neutral axis

y = Distance from neutral axis to extreme fibre

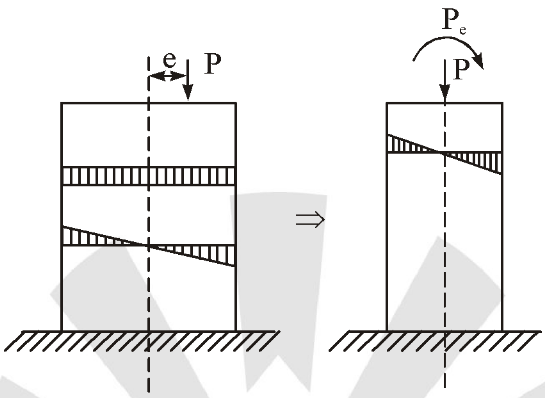
R = Radius of curvature of beam.

4. TYPE OF LOADING

4.1 Combined Bending and Torsion Stress:

Then we would calculate maximum shear and principle stress.

4.2 Eccentric Loading:



Maximum compressive stress

$$= \frac{-(P.e)\, y_c}{I} - \frac{P}{A}$$

and maximum tensile stress

$$= \frac{(P.e)\, y_t}{I} - \frac{P}{A}$$

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PRACTICE SHEET

OBJECTIVE QUESTIONS

1. In a multiple disc clutch in n_1 and n_2 are the number of discs on the driving and driven shafts, respectively, the number of pairs of contact surfaces will be

(a) $n_1 + n_2$ (b) $n_1 + n_2 - 1$

(c) $n_1 + n_2 + 1$ (d) $\frac{n_1 + n_2}{2}$

2. In a plate clutch axial force is 4 kN. The inside radius of contact surface is 50 mm and the outside radius is 100 mm. For uniform pressure the mean radius of friction surface will be

(a) 78 mm (b) 60 mm

(c) 75 mm (d) 80 mm

3. In the multiple disc clutch, if there are 6 discs on the driving shaft and 5 discs on the driven shaft, then the number of pairs of contact surfaces will be equal to

(a) 11 (b) 12

(c) 10 (d) 22

4. In the formulation of Lewis equation for toothed gearing, it is assumed that tangential tooth load F_T acts on the

(a) Pitch point

(b) Tip of the tooth

(c) root of the tooth

(d) Whole face of the tooth

5. Consider the following statements are correct :

The form factor of a spur gear tooth depends upon the:

1. Number of teeth

2. Pressure angle

3. Addedum modification

4. Circular pitch

(a) 1 and 3 (b) 2 and 4

(c) 1, 2 and 3 (d) 1 and 4

6. A sliding contact bearing is operating under stable condition. The pressure developed in oil film is p when the journal rotates at N r.p.m. The dynamic viscosity of lubricant is μ and effective coefficient of friction between bearing and journal of diameter D is f. Which of the following statements is correct for the bearing?

(a) f is directly proportional to μ and p

(b) f is directly proportional to μ and N

(c) f is inversely proportional to P and D

(d) f is directly proportional to μ and inversely proportional to N

7. A 6 × 19 rope implies that there are

(a) 6 wires in each strand and 19 strands in the rope.

(b) 6 strands and 19 wires in each strand.

(c) 6 large diameter wires and 19 small diameter wires.

(d) 19 large diameter wires and 6 small diameter wires

8. A full journal bearing having clearance to radius ratio of $\frac{1}{100}$, using a lubricant with $\mu = 28 \times 10^{-3}$ Pas supports the shaft journal running at N = 2400 r.p.m. If bearing pressure is 1.4 MPa, the Sommerfeld number is

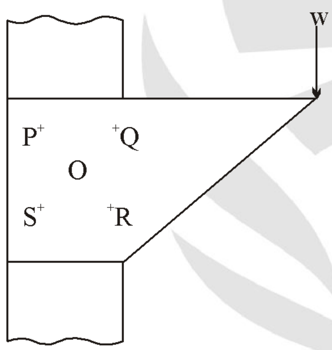
(a) 8×10^{-3} (b) 8×10^{-5}

(c) 0.48 (d) 0.48×10^{-2}

9. The creep in a belt drive is due to the
(a) material of the pulleys
(b) material of the belt
(c) unequal size of the pulleys
(d) unequal tension on tight and slack sides of the belt

10. Which of the following stresses are associated with the tightening of nut on a bolt.
1. Tensile stress due to streching of bolt.
2. Bending stress due to the bending of bolt
3. Crushing and shear stress in thread.
4. Torsional shear stress due to frictional resistance between the nut and the bolt.
(a) 1, 2 and 4 (b) 1, 2 and 3
(c) 2, 3 and 4 (d) 1, 3 and 4 only

11. An eccentrically load riveted joint is shown with 4 rivets at P, Q, R and S.



Which of the rivets are the most loaded?
(a) P and Q (b) Q and R
(c) R and S (d) S and P

12. In a fillet welded joint, the weakest area of the weld is
(a) Toe (b) root
(c) throat (d) face

13. A shaft can safely transmit 90 kW while rotating at a given speed. If this shaft is replaced by a shaft of diameter double of the previous one and rotated at half the speed of the previous, the power that can be transmitted by the new shaft is
(a) 90 kW (b) 180 kW
(c) 360 kW (d) 720 kW

14. The length of the belt in the case of a crossbelt drive is given in terms of centre distance between pulleys (C), diameters of the pulley D and d as
(a) $2C + \frac{\pi}{2}(D + d) + \frac{(D + d)^2}{4C}$
(b) $2C + \frac{\pi}{2}(D - d) + \frac{(D + d)^2}{4C}$
(c) $2C + \frac{\pi}{2}(D + d) + \frac{(D - d)^2}{4C}$
(d) $2C + \frac{\pi}{2}(D - d) + \frac{(D - d)^2}{4C}$

15. A cold rolled steel shaft is designed on the basis of maximum shear stress theory. The principal stresses induced at its critical principal stresses induced at its critical section are 60 MPa and -60 MPa respectively. If the yield stress for the shaft material is 360 MPa, the factor of safety of the design is
(a) 2 (b) 3
(c) 4 (d) 6

16. Match List-I (Coupling) with List-II (Purpose) and select the correct answer using the codes given below the lists :

List-I
A. Muff coupling
B. Flange coupling
C. Oldham's coupling
D. Hooke's joint

List-II
1. To transmit power between two parallel shafts
2. To transmit power between two intersecting shafts with flexibility
3. For rigid connection between two aligned shafts for power transmission
4. For flexible connection between two shafts with some misalignment for transmitting power

Codes :	A	B	C	D
(a)	1	4	3	2
(b)	3	4	2	1
(c)	3	1	4	2
(d)	1	2	3	4

71. Considering the effect of centrifugal tension in a flat belt drive with T_1 = tight side tension and Tc = centrifugal tension and m = mass per unit length of the belt, the velocity of the belt for maximum power transmission is given by :

(a) $V=\sqrt{\frac{T_1}{3m}}$ (b) $V=\sqrt{\frac{T_c}{3m}}$

(c) $V=\sqrt{\frac{(T_1-T_c)}{3m}}$ (d) $V=\sqrt{\frac{(T_1+T_c)}{3m}}$

72. If the load on a ball bearing is reduced to one third, then its life would increse by :

(a) 3 times (b) 9 times

(c) 27 times (d) 81 times

73. Removal of metal particles from the race-way of a rolling contact bearing is a kind of failure of bearing, known is

(a) Pitting (b) Wearing

(c) Spalling (d) Scuffing

74. In a power screw square threads, the torque required to raise the given load is found to be 8800 N-m. The core diameter of the screw is 40 mm. The shear stress due to this torque in the power screw is :

(a) 350 N/mm^2 (b) 700 N/mm^2

(c) 175 N/mm^2 (d) 525 N/mm^2

75. A helical coil spring of stiffness k is cut to two equal halves and then these are connected in parallel to support a vibratin mass m. The angular frequency of vibration, ωis

(a) $\sqrt{\frac{k}{m}}$ (b) $\sqrt{\frac{2k}{m}}$

(c) $\sqrt{\frac{4k}{m}}$ (d) $\sqrt{\frac{k}{4m}}$

76. A close -coiled helical spring of 10 active turns is made of 8 mm diameter steel. The mean coil diameter is 10 cm. If G = 80 GPa for the material of spring, the extension of spring under a tensile load of 200 N will be nearly.

(a) 40 mm (b) 45 mm

(c) 49 mm (d) 53 mm

77. Two concentric springs,having same number of turns and free axial length, are made of same materia. One spring has mean coil diameter of 12 cm and its wire diameter is 1.0 cm. The other one has mean coil diameter of 0.6 cm. If the set of springs is compressed by an axial load of 2000 N, the loads shared by the springs will be

(a) 1245.5 N and 754.5 N

(b) 1391.4 N and 608.6 N

(c) 1100.0 N and 900.0 N

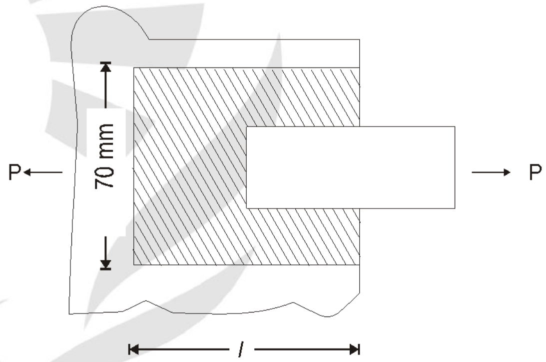
(d) 1472.8 N and 527.2 N

78. The load on a gear tooth is 50 kN. If the gear is transmitting a torque of 6000 Nm, the diameter of the gear is approximately (consider pressure angle as 20° and cos 20° = 0.94)

(a) 0.5 m (b) 0.75 m

(c) 1 m (d) 0.25 m

79. Two plates are jointed as shown in the Figure



The maximum tensile and shear stresses are 70 N/mm^2 and 56 N/mm^2 respectively. The plate is 70 mm wide and 12.5 mm thick. What will be value of l if the total load carried by the joint is 85 kN ?

(a) 126.39 mm (b) 84.25 mm

(c) 70.00 mm (d) 42.125 mm

80. If a rectangular key of 8 mm witdth and 6 mm height and a shaft of diameter 32 mm are made of same material, then the necessary length of the key for equal shear strength of shaft and key willl be (neglecting stress concentration on the shaft)

(a) 50.24 mm (b) 55 mm

(c) 45 mm (d) 60.24 mm

ANSWERS AND EXPLANATIONS

1. ***Ans. (b)***

Number of pair of contacting surface

$$n_1 + n_2 - 1$$

2. ***Ans. (a)***

$$r_m = \frac{2}{3}\left[\frac{r_0^3 - r_i^3}{r_0^2 - r_i^2}\right]$$

$$= \frac{2}{3}\left[\frac{100^3 - 50^3}{100^2 - 50^2}\right]$$

$$= 77.77 \approx 78\text{mm}$$

3. ***Ans. (c)***

$$n = n_1 + n_2 - 1$$

$$= 6 + 5 - 1 = 10$$

4. ***Ans. (d)***

Lewis equation is based on the following assumptions.

The tangential component is uniformly distributed over the face width of the gear.

5. ***Ans. (c)***

The form factor of (Lewis) depends upon

1. Number of teeth
2. Tooth system (pressure angle)
3. Point of application of load addendum modification as length of assumed cantilever keeps on increasing.

6. ***Ans. (b)***

Petroff equation correlates

$$f = 2\pi^2\left(\frac{\mu n_s}{p}\right)\left(\frac{r}{c}\right)$$

$$f \propto \mu,\ n_s$$

$$f \propto \frac{1}{p}$$

Where, n_s = Revolution per second.

7. ***Ans. (b)***

35	× 6	× 19
↓	↓	↓
dia. of rope wire	No. of strand	No. of wire in each strand.

8. ***Ans. (a)***

$$S = \left(\frac{r}{c}\right)^2 \cdot \frac{\mu n_s}{p}$$

$$= \frac{(100)^2 \times 28 \times 10^{-3} \times 2400}{1.4 \times 10^6 \times 60} = 8 \times 10^{-3}$$

9. ***Ans. (d)***

Creep is apermanent increase in length of the belt due to alternate tension and compression during the motion. So, it depends on only material.

10. ***Ans. (d)***

Bending stress will be absent as there is no eccentricity associated with load from bolt axis. All the other stresses arises.

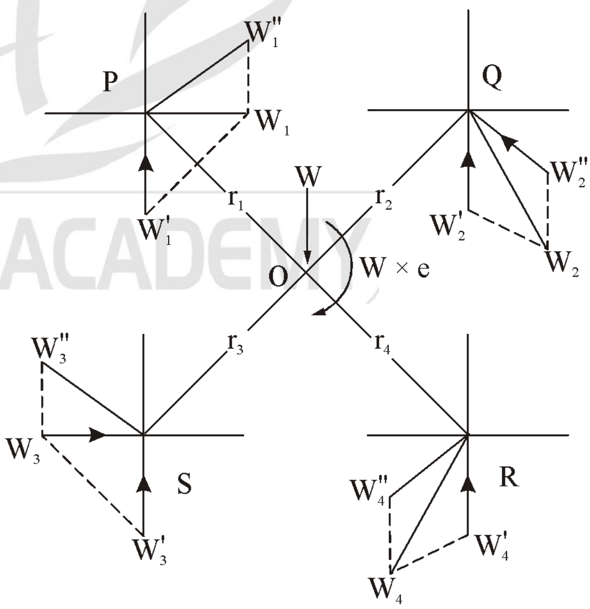
11. ***Ans. (b)***

W_1' = Primary shear load

$= W_2' = W_3' = W_4'$

W_1'' = Secondary shear load

$$= \frac{Wer_1}{r_1^2 + r_2^2 + r_3^2 + r_4^2}$$



Resultant shear stress at

$$Q = \sqrt{(W_2')^2 + (W_2'')^2 + 2(W_2')(W_2'')\cos\theta}$$

As q decreases, cos q increases and resultant shear stress increases.

Resultant shear stress is maximum at rivets Q and R because between primary shear force and secondary shear force have minimum angle at 'Q' and 'R' only.

12. ***Ans. (c)***

The troat is the minimum cross section of the weld located at 45° to the leg dimension. So, maximum shear stresses will develop at throat.

13. ***Ans. (c)***

$$d_2 = 2d_1$$

$$\text{Power (P)} = \frac{2\pi NT}{60}$$

$$T = \frac{\pi}{16}\tau d^3$$

$$P \propto N$$

$$P \propto T$$

$$P \propto d^3$$

$$P \propto Nd^3$$

$$\frac{P_2}{P_1} = \frac{N_d d_2^3}{N_1 d_1^3}$$

$$= \frac{N_1}{2} \times \frac{8d_1^3}{N_1 d_1^3} = 4$$

$$P_2 = 4P_1$$

14. ***Ans. (a)***

$$L_{open} = 2c + \frac{\pi}{2}(D+d) + \frac{(D-d)^2}{4c}$$

$$L_{cross} = 2c + \frac{\pi}{2}(D+d) + \frac{(D+d)^2}{4c}$$

15. ***Ans. (b)***

$$t_{max} = \frac{\sigma_1 - \sigma_2}{2}$$

$$= \frac{60-(-60)}{2}$$

$$\frac{S_{sy}}{F.S.} = \frac{S_{yt}}{2 \times F.S.}$$

$$F.S. = \frac{360}{60 \times 2} = 3$$

Where, S_{sy} = Yield strength at shear

S_{yt} = Yield strength at tension

16. ***Ans. (c)***

Muff coupling → For rigid connection between two aligned shafts for power transmission

Flange coupling → To transmit power between two parallel shafts

Oldham's coupling → For flexible connection between two shafts with some misalignment for transmitting power

Hooke's joint → To transmit power between two intersecting shafts with flexibility

17. ***Ans. (b)***

$$P = (T_1 - T_2)V$$

$$= \left[T_1 - \frac{T_1}{e^{\mu\theta}}\right]V \qquad \left[\because \frac{T_1}{T_2} = e^{\mu\theta}\right]$$

Where, T_1 = Tight side tension

T_2 = Slack side tension

T_C = Centrifugal tension

Let $\left[1 - \frac{1}{e^{\mu\theta}}\right] = K$

$$P = T_1.V.K = (T_{max} - T_c).V.K$$

$$= (T_{max} - mV^2).VK$$

$$= (T_{max}\,V - mV^3)K$$

Power transmitted will be maximum when

$$\frac{\partial}{\partial V}(\text{Power}) = 0$$

$$T_{max} - 3mV^2 = 0$$

The optimum velocity of the belt for maximum power transmission is given by

$$V = \sqrt{\frac{T_{max}}{3m}}$$

$$T_{max} - 3T_C = 0$$

or $T_{max} = 3T_C$

18. ***Ans. (d)***

Jaw clutch is example of positive clutch whereas others are example of friction clutches.

Jaw clutch has no slip, so no heat generation but accompanied with shock. It is very difficult to engage them at high speed.

19. ***Ans. (a)***

For self locking $\phi > \alpha$

Where, α = Helix angle

ϕ = friction angle

The efficiency of screw jack is given by

$$\eta = \frac{\tan\alpha}{\tan(\phi+\alpha)}$$

By substituting the limiting value

f = a

$$\eta \le \frac{\tan\phi}{\tan(\phi+\alpha)}$$

or $$\eta \le \frac{\tan\phi}{\tan(2\phi)}$$

$$\eta \le \frac{\tan(1-\tan^2\phi)}{2\tan\phi}$$

$$\eta \le \left[\frac{1}{2}-\frac{\tan^2\phi}{2}\right]$$

Therefore, efficiency of a self-locking screw jack is less than 50%.

20. ***Ans. (d)***

Unwin's formula

$$d = 6.1\sqrt{t} \text{ for rivets.}$$

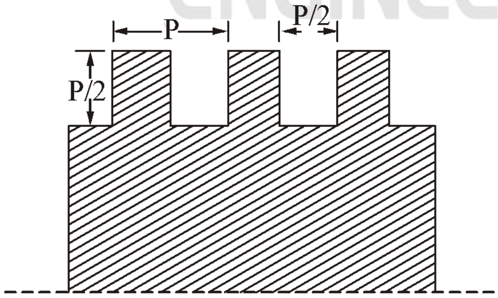
Wahls factor,

$$Kw = \frac{4c-1}{4c-4}+\frac{0.615}{c}$$

For spring to take in account of stress concentration Reynold equation for Journal bearing.

21. ***Ans. (a)***

The depth of thread d is given by 0.5 P. Where P is the pitch of a square thread.



22. ***Ans. (d)***

Number of rivets = 2

Secondary shear load,

F_1 = 4 kN

Direct shear load,

F_2 = 3 kN

A = 500 mm^2

Resultant shear force on each rivet,

$$F = \sqrt{F_1^2+F_2^2+2F_1F_2\cos 90^\circ}$$

$$= \sqrt{4^2+3^2} = 5 \text{ kN}$$

The resultant stress in each rivet

$$\frac{F}{A} = \frac{5\times10^3}{500} = 10 \text{ N/mm}^2$$

Direct shear load on each rivet

$$F_2 = \left(\frac{P}{2}\right)$$

$$P = 2 \times F_2 = 2 \times 3 = 6 \text{ kN}$$

23. ***Ans. (b)***

24. ***Ans. (b)***

$$\frac{T}{J} = \frac{\pi}{r}$$

Polar moment of inertia,

$$J = I_{xx} + I_{yy}$$

$$= \pi r\ r^3 + \pi r\ r^3 = 2\pi r\ r^3$$

$$\tau = \frac{T_x}{J} = \frac{T}{2\pi t r^2}$$

$$= \frac{4T}{2\pi\times t\times d^2} = \frac{2T}{\pi t d^2}$$

Where, t = Thickness of weld

25. ***Ans. (c)***

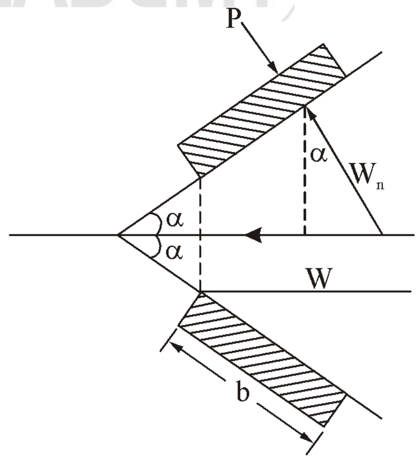
$\sin\alpha = W/W_n$

$W_n = W/\sin\alpha$

Frictional force,

$F_t = \mu W_n$

Where, μ = Coefficient of friction



For uniform pressure

Torque, $T = \frac{2}{3} \times \mu \times W_n \times \left(\frac{R^3 - r^3}{R^2 - r^2}\right)$

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

26. ***Ans. (a)***

The dynamic load between the meshing teeth arises due to following factors:

(i) Inaccuracies of tooth profile.

(ii) Error in tooth spacing

(iii) Runout of gear

(iv) Gear mesh stiffness variation

(v) Inertia of rotating masses

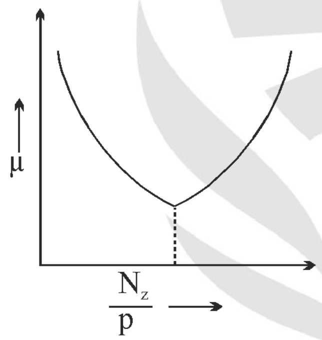
(vi) Deflection of teeth

(vii) Stiffness of rotating parts

But dynamic factor mainly depends upon tooth error and pitch line velocity.

27. ***Ans. (c)***

Mckee Number



28. ***Ans. (c)***

$$\eta = \frac{\tan\alpha}{\tan(\alpha+\phi)}$$

$$\Rightarrow \quad \frac{d\eta}{d\alpha} = 0$$

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

$$h_{max} = \frac{1-\sin\phi}{1+\sin\phi}$$

29. ***Ans. (c)***

The main advantage of journal bearing is that they carry very high load at higher speed due to hydrodynamic pressure developed by the film.

30. ***Ans. (c)***

η less than 50% so statement 1 correct $\alpha > \phi$ statements 2 incorrect

$$\therefore \quad \eta \geq \frac{1}{2} - \frac{\tan^2\alpha}{2}$$

31. ***Ans. (d)***

The load on a ball bearing is halved, its life increases eight times

For ball bearing $L \propto 1/P^3$

$$\frac{L_1}{L_2} = \frac{P_2^3}{P_1^3}$$

$$= \left(\frac{1}{2}\right)^3 = \frac{1}{8}$$

$$L_2 = 8L_1$$

32. ***Ans. (b)***

Total length of the weld = $2l + 100$

Allowable shear per mm is 300 N

Let L is the total length of weld required for joint. Since the allowable shear load per mm length of weld is 300 N, the required length of weld.

$$300 \times (2l + 100) = 150 \times 10^3$$

$$\Rightarrow 2l + 100 = 500$$

$$\Rightarrow l = 200 \text{ mm}$$

33. ***Ans. (d)***

$$T = \frac{GJ\theta}{L}, P\alpha T$$

$$\frac{T_1}{J_1} = \frac{T_2}{2J_1}$$

$$2T_1 = T_2$$

When J is doubled T will be doubled so power will be doubled and torque will be halved.

34. ***Ans. (c)***

The pertaining to the basic Lewis-equation for the strength design of spur gear teeth single pair of teeth participates in power transmission at any instant. The tooth is considered as a cantilever beam of uniform strength. Loading on the teeth is static in nature.

35. ***Ans. (c)***

Power transmitted

$$P = (T_1 - T_2).V$$

If the effect of centrifugal tension is taken into consideration.

Total tension on slack side,

$$T_{t_1} = T_1 + T_C$$

Total tension on slack side

$$T_{t_2} = T_2 + T_C$$

Thus the belt is to be design to carry a maximum permissible tension of $T_{t_1} = T_1 + T_C$ when centrifugal tension is considered as compared to T_1 for the same power transmitted.

Within the permissible limit of tension in the belt, the centrifugal tension has no effect power transmitted.

But since the maximum tension is increased, in effect the driving power or capacity of belt is reduced.

36. ***Ans. (b)***

Steel-screw, Phosphor Bronze-nut, cast iron also used for nut in case of low speed.

37. ***Ans. (b)***

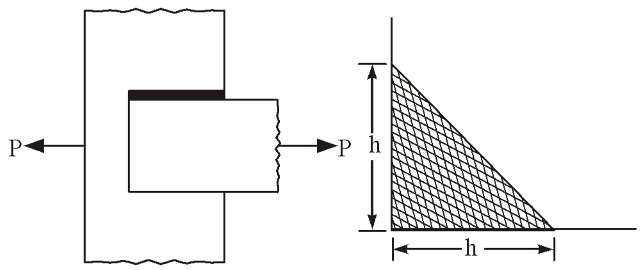
Length of crossed belt

$$= \pi(r_1 + r_2) + 2C + \frac{(r_1 + r_2)^2}{C}$$

Hence length of the crossed belt increases as the sum of the diameters of the pulleys increases.

38. ***Ans. (c)***

The parallel fillet welded joints are designed for shear strength. The throat is the minimum cross section at the weld located at 45° to the leg dimension.



$$t = h \cos 45$$

$$t = \text{throat thickness} = 0.707\ h$$

$$\text{Throat area} = 0.707 \times h \times l$$

$$\text{Shear stress } \tau = \frac{P}{0.707hl}$$

39. ***Ans. (b)***

Petroff's equation

$$\mu = 2\pi^2\left(\frac{r}{c}\right)\left(\frac{ZN_s}{P}\right)$$

40. ***Ans. (d)***

If the shank of the bolt is turned down to a diameter equal to even slightly less than the core diameter of the thread, then the shank of the bolt will undergo a higher stress. This means that the shank will absorb a large portion of the energy thus reliveving the material at the section near the thread. The bolt in this way becomes stronger and lighter and it increase the shock absorbing capcity of the bolt.

41. ***Ans. (b)***

35	× 6	× 19
↓	↓	↓
dia. of rope	No. of strand	No. of wire in each strand.

42. ***Ans. (c)***

Efficiency of screw Jack

$$\eta = \frac{\tan\alpha}{\tan(\varphi+\alpha)}$$

Where, α = Helis angle

φ = friction angle

$$\eta = \frac{(\sin\alpha/\cos\alpha)}{\sin(\varphi+\alpha)/\cos(\varphi+\alpha)}$$

$$= \frac{\sin\alpha\cos(\varphi+\alpha)}{\cos\alpha\sin(\varphi+\alpha)}$$

$$= \frac{2\sin\alpha\cos(\varphi+\alpha)}{2\cos\alpha\sin(\varphi+\alpha)}$$

$$= \frac{\sin(\alpha+(\alpha+\varphi))+\sin(\alpha-(\alpha+\varphi))}{\sin(\alpha+(\alpha+\varphi))-\sin(\alpha-(\alpha+\varphi))}$$

$$= \frac{\sin(2\alpha+\varphi)-\sin\varphi}{\sin(2\alpha+\varphi)+\sin\varphi} \quad ...(1)$$

In this Equation co-efficient of friction 'μ' is constant and 'α' is variable. For h is to be maximum, sin (2α + φ) should be maximu.

sin (2α + φ) = 1

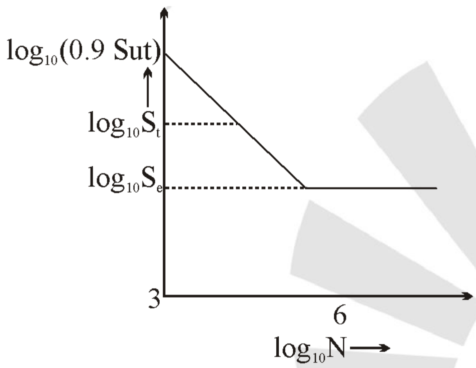
⇒ 2α + φ = 90°

$$\alpha = 45 - \frac{\varphi}{2}$$

By substituting in (1)

$$\eta_{max} = \frac{\sin(90) - \sin\varphi}{\sin(90) + \sin\varphi} = \frac{1 - \sin\varphi}{1 + \sin\varphi}$$

43. ***Ans. (b)***



S-N Curve for finite life

44. ***Ans. (b)***

The gears in 20° stube tooth system have shorter addendum and shorter dedendum. The interfering portion of the tooth, that is, a part of the addendum, is thus removed therefore, these teeth have still smaller interference. This also, reduces the undercutting. In this system, reduces the undercutting. In this system, the minimum number of theeth on the pinion, to avoid interference is 14. Since the pinion is small the drive becomes more compact. Stub teeth are stronger than full depth teeth because of the smaller moment arm of the bending force. Therefore, the stub system transmits very high load.

45. ***Ans. (b)***

Worm gear → To transmit power between two non-intersecting shafts which are perpendicular to each other

Spur gear → To transmit power when the shafts are parallel

Herringbone gear → Impose no thrust load on the shaft

Spiral bevel gear → To transmit power when the shafts are at right angle to one another

46. ***Ans. (c)***

Hollow shaft,

$$\tau_{max} = \frac{16 d_1 T}{\pi(d_1^4 - d_2^4)}$$

Solid shaft,

$$\tau_{max} = \frac{16T}{\pi D^3}$$

For same torque and same maximum shear stress

$$D^3 = \frac{d_1^4 - d_2^4}{d_1}$$

$$= \frac{(40)^4 - (20)^4}{(40)} = \frac{(20)^4[(2)^4 - 1}{40}$$

$$D^3 = 1000 \times 4 \times 15$$

$$= 10 \times (60)^{1/3} \text{ mm}$$

47. ***Ans. (b)***

Z_p and Z_g are the number of teeth of pinion and gear respectively.

Given, $Z_g = 2.3Z_p$ ...(1)

and $Z_g + Z_p = 99$ ...(2)

from (1) and (2)

$Z_p = 30$

$Z_g = 69$

48. ***Ans. (c)***

Tensile force oneach bolt

$$= \frac{\text{Total force}}{\text{Number of bolts}}$$

$$= \frac{980.175 \times 10^3 N}{8}$$

Design of Bolt,

$$s = \frac{F}{A} = \frac{F}{(\pi/4)\, d^2}$$

$$\Rightarrow 315 \text{ N/mm}^2 = \frac{980.175 \times 10^3 N}{(\pi/4) d^2}$$

$$d = 22.25 \text{ mm} \approx 30 \text{ mm}$$

49. ***Ans. (d)***

$$\text{Power (P)} = (T_1 - T_2)V$$

$$T_1/T_2 = e^{\mu\theta}$$

$$P = (T_{max} - T_c)\left(1 - \frac{1}{e^{\mu\theta}}\right).V$$

$$= (T_{max}.V - mV^3)\left(1 - \frac{1}{e^{\mu\theta}}\right)$$

$$dP/dv = 0$$