Q.1.a) Modes of failure

– i) Yielding (Elastic failure)

When a mechanical compo. made of ductile material undergoes yielding or plastic deformation, its functional utility comes to an end & it is termed as a failure of the compo.

ii) Fracture

Sudden separation or a breakage of a material along the cross sections normal to the directⁿ of stress is fracture.

iii) Elastic deflection

In components (columns, beams etc), the lateral or torsion deflection, in a elastic range beyond a permissible limit is failure of component.

Q.1.b) Overhauling and self locking

We have,

$$T_t = \frac{W d_m}{2} \tan(\phi - \lambda) \quad \text{—(I)}$$

Self-locking screw –

if $\phi > \lambda$ (in eqⁿ (I)), the torque required to lower the load. T_t will be positive. Such screw is self locking screw.

– Friction angle 'ϕ' is greater than lead angle 'λ' & torque reqᵈ. to lower the load T_t will be always positive.

$$\phi > \lambda$$

$$\tan\phi > \tan\lambda$$

$$\mu > \tan\lambda$$

$$\mu > l/\pi d_m$$

(Used in screw-jack & C-clamps)

Over-hauling screw

In eqⁿ (I) if $\phi < \lambda$, the torque required to lower the load will be negative i.e. the load will start moving downward without the application of any torque, causing the screw to rotate. Such screw is over-hauling screw.

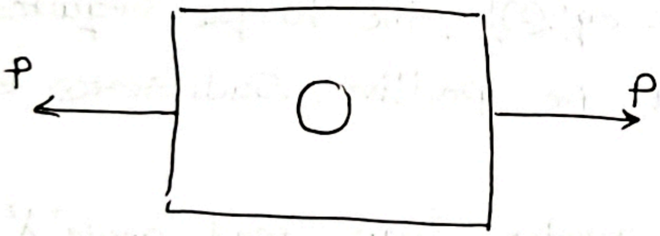
Q.1c]

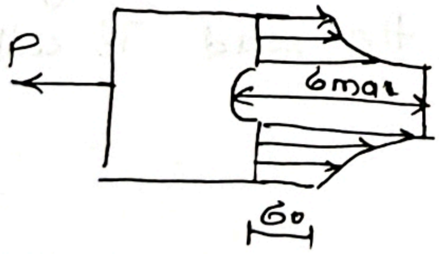
Stress concentration

It is defined as the localization of high stresses due to the irregularities present in the component and abrupt changes of the cross-section.
Stress concentration factor is denoted by Kt and defined as,

$$K_t = \frac{\text{Highest value of actual stress near discontinuity}}{\text{Nominal stress obtained by elementary equations for minimum c/s.}}$$

Or, $K_t = \frac{\sigma_{max}}{\sigma_0} = \frac{\tau_{max}}{\tau_0}$.





Methods of reducing stress concentration -

i) Avoid abrupt changes in c/s
The change in c/s should be gradual, as abrupt change in c/s results in stress concentration

ii) Place additional smaller discontinuities adjacent to discontinuity

This will make the change in stress lines gradual, thereby reducing the stress concentration

iii) Improve surface finish

Stress concentration effect can be reduced by improving the surface finish.

Q.1. e] i) Spring index -

Ratio of mean coil diameter to the wire diameter.

$C = D/d$

C = spring index

D = mean coil diameter (m)

d = wire diameter (mm)

Spring index 'C' is taken in the range of 6 to 12

ii) Spring constant (K)

It is denoted by K

It is defined as the load required per unit deflection of the spring.

$K = \frac{F}{\delta}$

F = axial force (N)

δ = deflection of spring (mm)

iii) Solid length of spring (Ls)

It is denoted by Ls

When spring is compressed until the coils touch each other, it is said to be solid. The length of such solid spring is known as solid length.

$L_s = n'd$

n' = total number of coils or turns.

d = diameter of wire.

Q.2 d] Preferred number/series -

— Preferred series are series of numbers obtained by geometric progression and rounded off.

Basic preferred series -

— Five basic preferred series designated as - R5, R10. R20, R40 and R80.

Their step ratios are $\sqrt[5]{10}$, $\sqrt[10]{10}$, $\sqrt[20]{10}$, $\sqrt[40]{10}$ and $\sqrt[50]{10}$ respectively.

— Each series is establised by taking the 1st no. 1 and multiplying it by a step ratio to get the 2nd no. The 2nd no. is then multiplied by a step ratio to get the 3rd no. The procedure is continued until the complete series is built up.

eg: Standard shaft diameter, power rating of coupling centre distances of standard gear boxes.

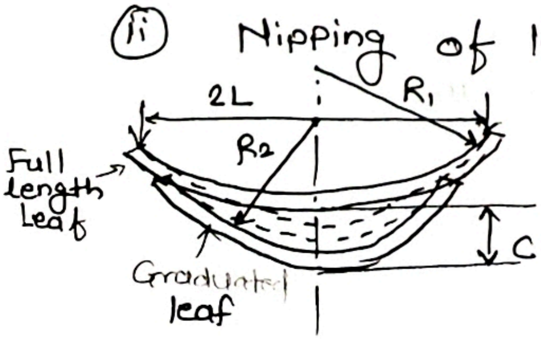
- If the product is to be manufactured in the minimum number of sizes, R5 series may be used. If no. of sizes required increases, then accordingly R10, R20, R40 or R80 series may be used.

Q.3. c] (i) Wahl factor (Kw)

The wahl shear stress factor is used to consider the effects of direct shear stress, torsional shear stress as well as curvature effect stress.

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

(ii) Nipping of leaf spring



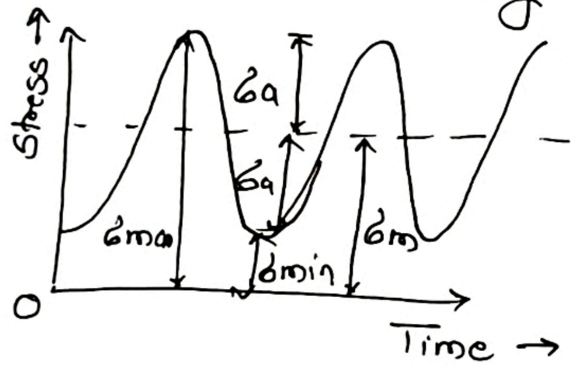
The stresses in full length leaves are 50% greater than the stresses in graduated leaves. In order to utilize the material to the best advantage all the leaves should be equally stressed. This may be achieved by pre-stressing the leaves.

Nipping- Process of pre-stressing the spring by giving, different radii of curvature before assembly is known as nipping.

The initial gap 'c' between full length leaf and graduated leaf before assembly is called 'nip'.

Q.4 d] Fatigue stress cycles -

(i) When the mechanical component is subjected to the fatigue or fluctuating load, the stress induced is known as fluctuating stress.



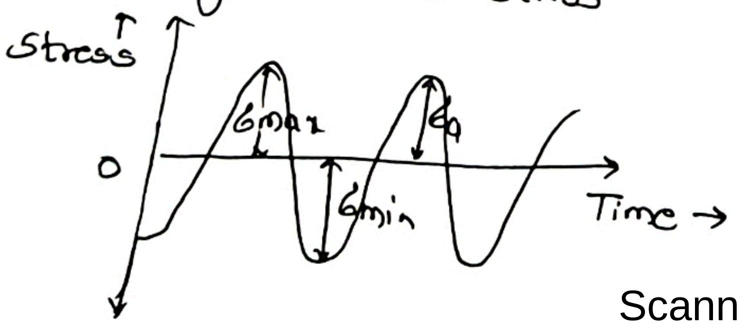
Mean stress

$$\sigma_m = \frac{\sigma_{max} + \sigma_{min}}{2}$$

Stress amplitude

$$\sigma_a = \frac{\sigma_{max} - \sigma_{min}}{2}$$

(ii) Completely reversed stress



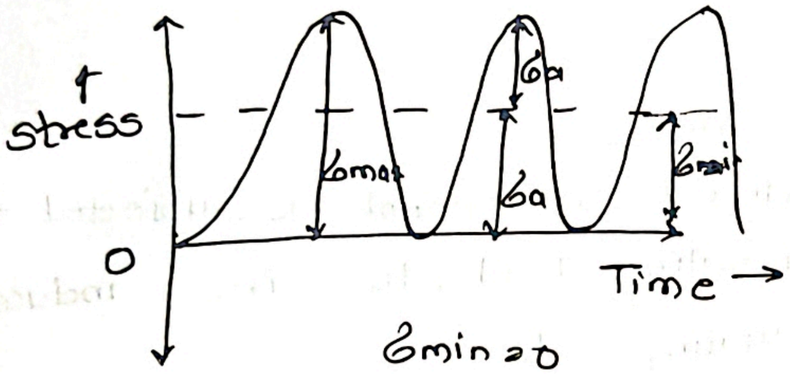
$$\sigma_m = \frac{\sigma_{max} + \sigma_{min}}{2} = \frac{\sigma_{max} + (-\sigma_{max})}{2} = 0$$

$$\sigma_a = \frac{\sigma_{max} - \sigma_{min}}{2} = \frac{\sigma_{max} - (-\sigma_{max})}{2} = \sigma_{max}$$

$\sigma_m = 0$

$\sigma_a = \sigma_{max}$.

(iii) Repeated stress

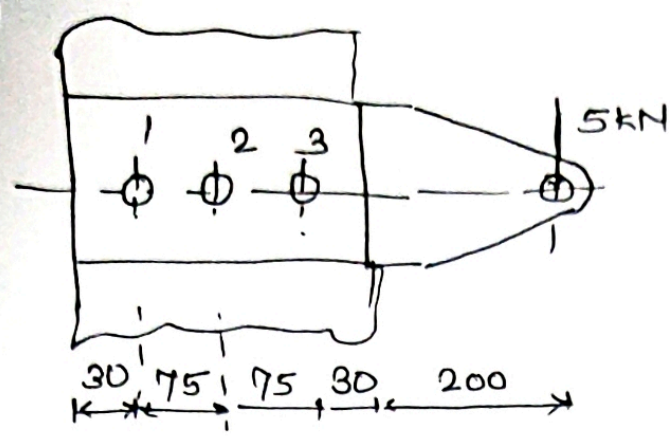


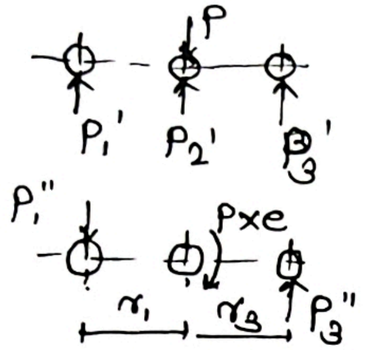
$\sigma_{min} = 0$

$$\sigma_m = \frac{\sigma_{max}}{2}$$

and $$\sigma_a = \frac{\sigma_{max}}{2}$$

Q.2 (a)





Given :-

$P = 5\,kN$

$S_{yt} = 380\,N/mm^2$

$fos = 3$

I] Permissible shear stress.

$$\tau = \frac{S_{yt} \times 0.5}{fos} = \frac{0.5 \times 380}{3} = 63.33\ N/mm^2$$

II] Primary & secondary shear forces.

Center of gravity of 3 bolts will be at center of bolt 2

$$P_1' = P_2' = P_3' = \frac{P}{3} = \frac{5000}{3} = 1666.67\,N.$$

$$P_1'' = P_3'' = \frac{(Pe)(r_1)}{(r_1^2 + r_3^2)} = \frac{5000 \times 305\ (75)}{75^2 + 75^2}$$

$$= 10166.67\,N$$

III] Resultant shear force

Resultant shear force on bolt 3 is max.

$$P_3 = P_3' + P_3''$$

$$= 1666.67 + 10166.67$$

$$= 11833.34\,N$$

III]

$$\tau = \frac{P_3}{A}$$

$$63.23 = \frac{11833.34}{\pi/4 \, d_c^2}$$

$\therefore$ $d_c = 15.42$

$\therefore$ $\boxed{d_c = 15.42 \text{ mm}}$

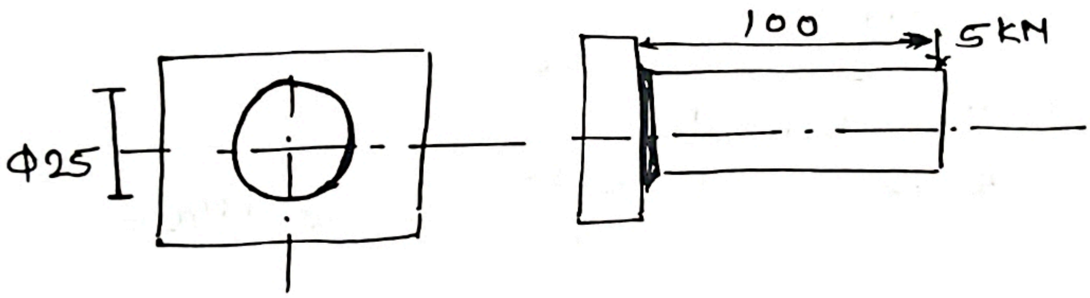
$$d = \frac{d_c}{0.8} = \frac{15.42}{0.8} = 19.28$$

$d = 19.28 \simeq 20$

$\therefore$ $\boxed{d = 20 \text{ mm}}$

Std. bolt size = M20

c]



Given :-

$P = 5 \text{ kN}$

$\tau = 95 \text{ N/mm}^2$

I] Prim. shear stress.

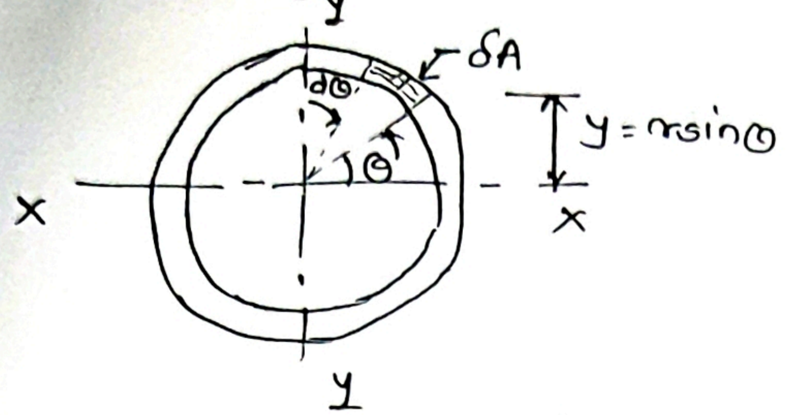
Prim. shear stress in weld is given by.

$$\tau_1 = \frac{P}{A} = \frac{P}{\pi D t}$$

$$\tau \cancel{95} = \frac{5000}{\pi (25) t}$$

$$\therefore \tau = \frac{63.66}{t} \text{ N/mm}^2 \quad \text{—— (1)}$$

II] Bending stress



$$\delta A = r \cdot d\theta \cdot t$$

$$\delta(I_{xx}) = (\delta A)(y^2)$$
$$= (r\,d\theta\,t)(r\sin\theta)^2$$
$$= t r^3 \sin^2\theta \cdot d\theta$$

The moment of Inertia of an annular fillet weld is obtained by integrating above eqn.

$$I_{xx} = 2\int_0^{\pi} t r^3 \cdot \sin^2\theta \cdot d\theta$$
$$= 2tr^3 \int_0^{\pi} \sin^2\theta \cdot d\theta$$
$$= 2tr^3 \int_0^{\pi} \left[\frac{1-\cos 2\theta}{2}\right] d\theta$$
$$= 2tr^3 \left(\frac{\pi}{2}\right)$$

$$\therefore I_{xx} = \pi t r^3$$
$$= \pi (t) (25/2)^3 \text{ mm}^4$$

We have,

$$\sigma_b = \frac{M_b \cdot y}{I}$$
$$= \frac{(5000 \times 100)(25/2)}{\pi t\,(25/2)^3} = \frac{\cancel{5000}^{200} \times \cancel{50}^{2} \times \cancel{25} \times 8}{\pi t \times \cancel{25} \times \cancel{25} \times \cancel{25}}$$
$$= \frac{200 \times 16}{\pi t}$$

$$\doteq \frac{3200}{\pi t}$$

$$\therefore \sigma_b = \frac{1018.59}{t} \ N/mm^2$$

III] Max. shear stress.

We have,

$$\tau = \sqrt{\left(\frac{\sigma_b}{2}\right)^2 + (\tau_1)^2}$$

$$= \sqrt{\left(\frac{1018.59}{2t}\right)^2 + \left(\frac{63.66}{t}\right)^2}$$

$$= \frac{513.26}{t} \ N/mm^2.$$

IV] Size of weld

Permissible shear stress in weld is $95 N/mm^2$

$$\therefore \frac{513.26}{t} = 95$$

$$\therefore \boxed{t = 5.402 \ mm}$$

$$h = \frac{t}{0.707}$$

$$= \frac{5.402}{0.707} = 7.640 \simeq 8$$

$$\therefore \boxed{h = 8 mm}$$

Q.3. b).

Given :

$n = 320$ rpm

$kW = 22$

$d = 40mm$

$b = 22mm$

$h = 14mm$

$S_{yc} = S_{yt} = 300\ N/mm^2$

$fos = 2.8$

$S_{sy} = 0.577 S_{yt}$

Step I. Permissible compressive and shear stresses

$$\sigma_c = \frac{S_{yc}}{fos} = \frac{300}{2.8} = 107.14\ N/mm^2$$

According to max. shear stress theory of failure,

$$S_{sy} = 0.577 S_{yt}$$

$$= 0.577 (300)$$

$$= 173.1\ N/mm^2$$

$$\tau = \frac{S_{sy}}{fos} = \frac{173.1}{2.8}$$

$$\therefore \tau = 61.82\ N/mm^2$$

II] Key length.

We have,

$$l = \frac{2M_t}{\tau d b}$$

$$= 2\left(\frac{60\times10^6 \times kW}{2\pi n \times \tau \times 40 \times 22}\right)$$

$$= 2\left(\frac{60\times10^6 \times 22}{61.82\times 40\times 22}\right)$$

$$= 485279.84\ N\text{-}mm$$

$$M_t = \frac{60\times10^6 \times 22}{2\pi\, 320}$$

$M_t = 656514.14$

$$l = \frac{2 M_t}{\tau d b}$$

$$= \frac{2 \times 656514.14}{\tau \times 40 \times 22}$$

$$l = 24.13$$

$$\therefore \boxed{l = 24.13\,mm} \quad \text{--- (a)}$$

Or

$$l = \frac{4 M_t}{\sigma_c d h}$$

$$= \frac{4 \times 656514.14}{107.14 \times 40 \times 14}$$

$$= 43.76\,mm$$

$$\boxed{l = 43.76\,mm} \quad \text{--- (b)}$$

from (a) & (b), select max. value

$$\therefore \quad l = 43.76 \simeq 44$$

$$\therefore \boxed{l = 44\,mm}$$

Q3. d]

Given:

Semi-elliptical leaf spring

$n_f = 2$

$n_g = 6$

$b = 50mm$

$t = 7.5mm$

$2L = 1 m$ $\quad L = 500mm$

$\sigma_b = 350 N/mm^2$

$n = n_f + n_g$

$= 2 + 6$

$\therefore n = 8$

$$\sigma_b = \frac{6PL}{nbt^2}$$

$$350 = \frac{6P \times 500}{8 \times 50 \times (7.5)^2}$$

$$\therefore P = \frac{350 \times 8 \times 50 \times (7.5)^2}{500 \times 6}$$

$$= \frac{35 \times 8 \times (7.5)^2}{6}$$

$\therefore P = 2625 N$

Initial preload

$$P_i = \frac{2 n_g n_f P}{n(3n_f + 2n_g)}$$

$$= \frac{2(6)(2)(2625)}{8(3 \times 2 + 2 \times 6)}$$

$$= \frac{2 \times 12 \times 2625}{8(6 + 12)} = \frac{3 \times 2625}{18} = 437.5$$

$P_i = 437.5 N$

Q.4 a)

Given :-

$D_o = 160mm$

$D_i = 95mm$

$N = 6$

$P_i = 10kN$

$\mu = 0.15$

$n = 100 rpm$

I)

$$R_f = \frac{2}{3}\frac{(R_o^3 - R_i^3)}{(R_o^2 - R_i^2)}$$

$$= \frac{2}{3}\frac{(80^3 - 47.5^3)}{(80^2 - 47.5^2)}$$

$$= \frac{2}{3}\ 0.666 \times \frac{404828.125}{4148.75}$$

$$R_f = 65.065\ mm$$

We have,

$$P_i = \frac{M_t}{\mu N R_f}$$

$$10\times10^3 = \frac{M_t}{0.15\times6\times65.065}$$

$$\therefore \quad M_t = 585585\ Nmm$$

Also,

$$M_t = \frac{60\times10^6 (kW)}{2\pi n}$$

$$585585 = \frac{60\times10^6 (kW)}{2\pi\times100}$$

$$\frac{367933906.8}{60\times10^6} = kW$$

$$kW = 6.13$$

9.4 c] Given:

Helical compression spring

$P = 600N$

$\delta = 22mm$

$C = 6$

$S_{ut} = 1000\ N/mm^2$

$G = 81370\ N/mm^2$

$\tau = 0.5\ S_{ut}$.

I] Wire dia.

$\tau = 0.5 S_{ut}$

$= 0.5(1000)$

$\therefore \tau = 500\ N/mm^2$

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

$$= \frac{4(6)-1}{4(6)-4} + \frac{0.615}{6}$$

$K = 1.2525$

$$\tau = K\left(\frac{8PC}{\pi d^2}\right)$$

$$500 = 1.2525\left(\frac{8 \times 600 \times 6}{\pi d^2}\right)$$

$$d^2 = \frac{1.2525 \times 8 \times 600 \times 6}{\pi \times 500}$$

$d^2 = 22.964$

$d = 4.7920$

d = 5mm

II] Mean coil dia.

$D = Cd$

$= 6(5)$

D = 30mm

III] No. of active coils

$$\delta = \frac{8PD^3N}{Gd^4}$$

$$22 = \frac{8 \times 600 \times 30^3 \times N}{81370 \times 5^4}$$

$$N = 8.633$$

$$N = 9 \text{ coils}$$

IV] Total no. of coils.

assumptn - spring has sq. & ground ends.

No. of inactive coils is 2

$$N_t = N + 2$$

$$\therefore N_t = 11 \text{ coils.}$$

V] Free length of spring

actual deflection,

$$\delta = \frac{8PD^3N}{Gd^4}$$

$$= \frac{8 \times 600 \times (30)^3 \times 9}{81370 \times 5^4}$$

$$\therefore \delta = 22.93 \text{ mm}$$

Solid length of spring $= N_t . d$

$= 11 \times 5 = 55$ mm

Total axial gap $= 1\cancel{0} - 1 \times 1 = 10$ mm

Free length = solid length + Total axial gap + δ

$= 55 + 10 + 22.93$

$= 87.93$ mm

VI] Pitch of coil

$$\text{Pitch} = \frac{\text{Free length}}{N_t - 1} = \frac{87.93}{10} = 8.79 \text{ mm}$$

Q.4 (b)

Given :-

Spur gear pair.

$z_p = 20$

$z_g = 100$

$m = 6$

I] Center distance

$$a = \frac{m(z_p + z_g)}{2}$$

$$a = \frac{6(20+100)}{2}$$

$$a = 3(120)$$

$$\boxed{a = 360 mm}$$

II] Pitch circle diameter.

i) Pitch circle diameter of pinion

$$d_p' = m \cdot z_p$$
$$= 6 \times 20$$
$$\boxed{d_p' = 120 mm}$$

ii) Pitch circle diameter of gear

$$d_g' = m \cdot z_g$$
$$= 6 \times 100$$
$$\boxed{d_g' = 600 mm}$$