UNIT-4

DESIGN OF SPRINGS

Spring:-

Spring is defined as elastic or resilient body whose function is to deflect or deform when load is applied and recover is original position when load is removed

To apply force
- Spring is clutches, brakes
- Spring loaded valves.

To measure force
- Spring balance.

To store energy
- Spring in toys, watches.

To absorb shocks and vibrations.

Types of Springs.
- Helical compression and tension
- Disc spring (or) Bellevel spring
- Leaf (or) Laminated spring.
- Torsion spring.

Buckling of Springs:-

Free length of helical compression spring is too large compared to mean coil diameter. The spring act as a flexible column, and buckle under the action of axial load.

In order to avoid the buckling of spring must satisfy the following conditions

$$\frac{L}{D} < \frac{\pi}{\alpha}\left[\frac{2(E-G)}{2G+E}\right]^{1/2}$$ (Slenderness ratio)

α – n condition constant for helical compression spring

1 It is required to design a helical compression spring made of oil harden & tempered steel spring carrying a maximum static load of 1000 N Maximum deflection is 25 mm. The ultimate ~~tensile strength~~ shear stress and modulus of rigidity of springs are 420 N/mm^2 & 84 kN/mm^2 respectively. Spring index is 5. Determine wire diameter, Mean coil diameter. Total number of coils. Total no. of active coils, free length, solid length & pitch. Draw the neat sketch of spring and give the necessary dimension

Given:

$P = 1000\ N$

$G = 84\ kN/mm^2$

$\tau = 420\ N/mm^2$

$C = 5$

$Y_{max} = \delta = 25\ mm$

$$q = \frac{P_{max}}{\delta_{max}}$$

$$= \frac{1000}{25}$$

$$= 40 \text{ N/mm}.$$

PSG data book pg. No 7.100

Wahl's stress factor,

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

$$= \frac{19}{16} + \frac{0.615}{5}$$

$$= 1.3105$$

$$\tau = \frac{8PC}{\pi d^2} K_s$$

$$420 = \frac{8 \times 1000 \times 5}{\pi d^2} \times 1.3105$$

$$d^2 = \frac{8 \times 1000 \times 5 \times 1.3105}{\pi \times 420}$$

$$d = 7 \text{ mm}$$

$$C = D/d$$

$$D = C \times d$$

$$= 5 \times 7$$

$$= 35 \text{ mm}.$$

$$q = \frac{Gd}{8C^3 n}$$

$$n = \frac{Gd}{q8C^3}$$

$$= \frac{84 \times 10^3 \times 7}{40 \times 8 \times 5^3}$$

$n = 15$

End - Plain and Ground.

Total coils $n' = n$

$= 15$

Solid ~~height~~ $L_s = dn$

$= 7 \times 15$

$= 105 mm$

$L_f = L_s + y + (n'-1) \times$ gap btwn two coils

$= 105 + 25 + (15-1) \times 1$

$= 144$ mm

$L_f = pn$

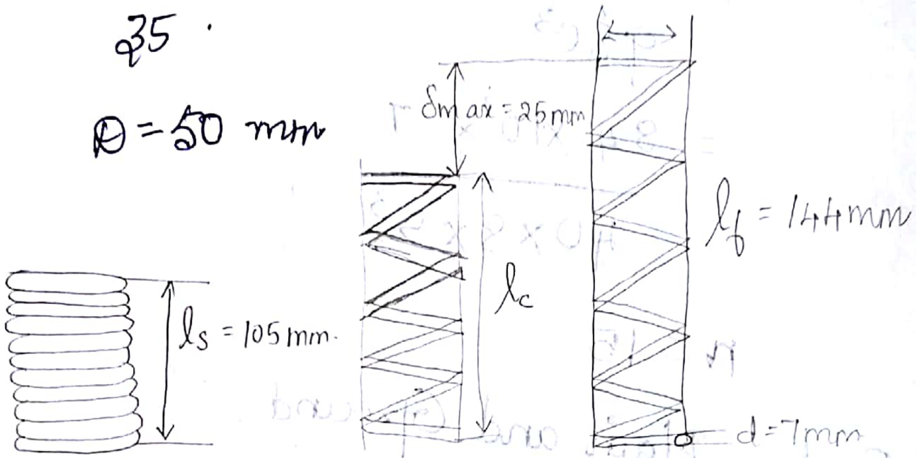
$144 = p \times 15$

$p = 9.6$ mm.

$$\frac{l_f}{D} < 3$$

$$\frac{144}{35} \cong 4.114$$

$D = 50$ mm



1. Spring loaded safety valves is required to blow off at the pressure of 1.5 N/mm². Diameter of valve is 60 mm. Maximum lift of the valve is 15 mm. Design a suitable helical spring for the safety valve for the following data. Initial compression of spring is 25 mm.

Given

$P_1 = 1.5$ N/mm²

$d_v = 60$ mm.

$P = W/A$

$W = P \times A$

$\delta_{max} = 25 + 15$
$= 40$ mm

$$A_v = \frac{\pi d_v^2}{4}$$
$$= \frac{\pi\, 60^2}{4}$$
$$= 2827.4 \text{ mm}^2.$$

$$W = A_v \cdot P_1$$
$$= 4241.1 \text{ N}$$

Spring index = 6

Modulus of rigidity = 0.84×10^5 MPa

Allowable shear stress = 450 N/mm²

$$\tau = K_s \frac{8PC}{\pi d^2}$$

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

$$= \frac{23}{20} + \frac{0.615}{6}$$

$$= 1.2525$$

$$450 = \frac{1.25 \times 8 \times 4241 \times 6}{\pi d^2}$$

$$d^2 = 179.9$$

$$d = 13.4 \text{ mm}$$

$$C = D/d.$$

$$D = 80 \text{ mm}$$

$$q = \frac{P_{max}}{\delta_{max}}$$

$$= \frac{4241}{40}$$

$$= 106 \text{ N-mm}.$$

$$q = \frac{Gd}{8C^3 n}$$

$$106 = \frac{0.84 \times 10^5 \times 13.4}{8 \times 6^3 \times n}.$$

$$n = 6 \text{ turns}$$

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Square and Ground end

$n' = n+2$
$= 6+2$
$= 8$ turns.

$l_s = d(n+2)$
$= 14(8)$
$= 112$ mm.

$l_f = l_s + \delta_{max} + (n'-1)$ gap between the coils
$= 112 + 40 + 7\times1$
$= 159$ mm

$l_f = pn + 2d$

pitch $= \frac{\text{Free length}}{(N_t - 1)}$
$= \frac{159}{7}$

$159 = p\times6 + 2\times14$
$= 6p + 28$
$p = 22$ mm

1. A helical compression spring is to be designed for the operating load of range of 90 N to 135 N and deflection for variable load is 7.5 mm. Permissible shear stress for spring materials is 480 N/mm². The modulus of rigidity is 0.8×10^5 N/mm². Spring index c=10. Design the spring.

$P_{max} = 135$ N
$P_{min} = 90$ N
$\delta = 7.5$ mm
$\tau = 480$ N/mm²
$G = 0.8 \times 10^5$ N/mm²
$c = 10$

Solution :-

Coil diameter

$$\tau = K_s \frac{8 P_{max} C}{\pi d^2}$$

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

$$= \frac{39}{36} + \frac{0.615}{10}$$

$$K_s = 1.144$$

$$480 = (1.144) \cdot \frac{8 \times 135 \times 10}{\pi d^2}$$

$$d = 2.86 \text{ mm.}$$

Active coil

$$q = \frac{Gd}{8C^3 n}$$

$$q = \frac{P_{max} - P_{min}}{\delta}$$

$$q = \frac{135 - 90}{7.5}$$

$$= 6$$

$$q = \frac{P_{max}}{\delta_{max}}$$

$$6 = 135 / \delta_{max}$$

$$\delta_{max} = 22.5$$

$$6 = \frac{1.8 \times 10^5 (2.86)}{8 (10)^3 n}$$

$n = 4.76$

$n = 5$ coils.

End Condition.

Squared and Ground.

Total coils $n' = n + 2$

$= 7$

Solid length

Leaf Spring:

Laminated Spring, Locomotive Spring.
Truck Spring.

Master leaf length $= 2L + \pi (d+t)^2$.

$$n = n_f + n_g$$

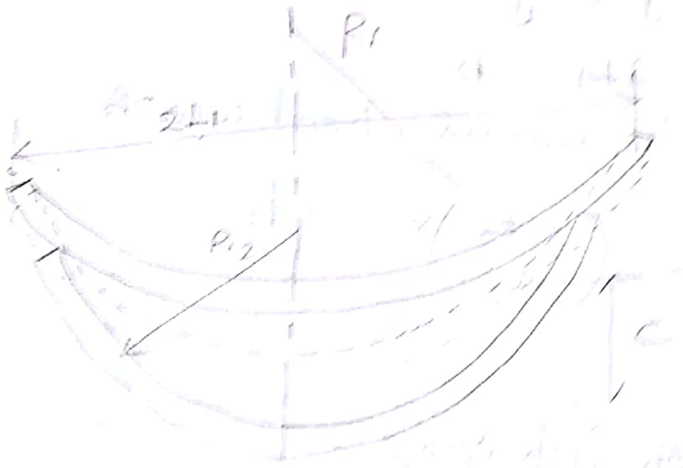
$$2L = 2L_1 - b$$

b- Central band width

$$l_1 = \left(\frac{2L}{n-1}\right) \times 1 + b.$$

Nipping of Leaf Spring

The stress in the full length leaves of 50%. greater than graduated ~~than grad~~ leaves in order to utilize the material is a best advantage all leaves are in equally stressed. This may be achieved by pre-stressing in the leaves. The pre-stressing of the spring can be done by giving greater radius of curvature to the full length leaves than the graduated leaves before assembly. Initial gap (C) b/w full length leaves and graduated leaves before assembly is called nib. When the central bolt holding leaves together is tightened the extra full length leaves will ... shown by dotted lines and having an initial stress in the direction opposition that of normal load. Graduated leaf will have an initial stress in the same direction as that of normal load.



1. A truck spring has 12 number of leaves. Two of which are full length leaves. The spring supports 1.05 m apart. Central band is 85 mm wide. Ratio of total depth to the width of the spring is 3. The central load is given as 5.4 kN. The permissible stress is 280 Mpascal. Determine i) Thickness and width of the steel spring leaves and ii) Deflection of the spring iii) Length of each leaves.

Given :-

$2P = 5.4\,kN$

$2L_1 = 1050\,mm$

$B = 85\,mm$.

$\frac{n_t}{b} = 3$

$\sigma_b = 280\,MPa$.

Solution :-

$2L = 2L_1 - \frac{B}{85}$

$= 1050 - 85$

$= 965\,mm$

$L = 482.5\,mm$

$2P = 5.4\,kN$

$P = 2.7\,kN$

$n_g = 10$

$n_f = 2$

$n = 12$

Psg Databook 7.104

$\sigma_b = \frac{6PL}{W\,t^2}$

$\sigma_b = \frac{6PL}{n \times \frac{nt}{3} \times t^2}$

$= \frac{18PL}{n^2 t^3}$

$$280 = \frac{18 \times 2.7 \times 10^3 \times 482.5}{(12)^2 \cdot t^3}$$

$$t^3 = 581.5$$

$$t = 8.34\ mm$$

$$b = \frac{n \times t}{3}$$

$$= \frac{12 \times 8.34}{3}$$

$$b = 33.3\ mm$$

Deflection

$$Y = \frac{12PL^3}{bt^3E(3n_e + 2n_g)}$$

$$= \frac{12 \times 2.7 \times 10^3 \times (482.5)^3}{210 \times 10^9 \times 33.3 \times 581.5\ (3 \times 2 + 2 \times 10)}$$

$$= \frac{\cancel{15633000}}{\cancel{5034627.7}} = \frac{3.63 \times 10^{12}}{1.057 \times 10^{11}}$$

$$Y = 34\ mm$$

$$l_1 = \left(\frac{2L}{n-1}\right) \times 1 + b_{and}$$

$$= \frac{965}{11} + 85$$

$$= 172.72\ mm$$

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$$l_2 = \frac{965}{12-1} \times 2 + 85$$

$$= 260.4 \text{ mm}$$

$$l_3 = \frac{965}{12-1} \times 3 + 85$$

$$= 348.18 \text{ mm}$$

$l_4 = 435.88$

$l_5 = 523.6$

$l_6 = 611.32$

$l_7 = 699.04$

$l_8 = 786.76$

$l_9 = 874.48$

$l_{10} = 962.2$

$l_{11} = 1049.92$

$$l_n = 2L_1 + \pi(d+t)^*$$

$$= 2 \times 525 + 2\pi(17 + 8.34)^*$$

$$= 1229.6 \text{ mm}$$

1. In Locomotive spring has a ~~load on~~ overall length of 1.1 m and sustain a load of 75 kN at the centre. The spring has extra 3 full length leaves and 15 graduated leaves with central band 100 mm wide. All leaves are equally stressed to 420 N/mm² when fully loaded. Ratio of total spring depth to width ratio is approximately is 2

Modulus of rigidity = 2.1×10^5 N/mm^2. Determine i) Width and thickness of leaves ii) Length of each leaves iii) Initial space that should be provide btwn full length & graduated leaves before band load is applied iv) The load exerted on spring is assembled.

Given :-

$E = 2.1 \times 10^5$ N/mm^2 $\quad$ $2P = 75$ kN

$= 37.5$ kN

$2L_1 = 1100$ mm

$n_f = 3$, $n_g = 15$

$n = 18$

$w = 100$ mm.

$\sigma = 420$ N/mm^2

$\frac{nt}{b} = 2$.

Solution :-

$$C = \frac{2PL^3}{Enbt^3}$$

Pre load $P_i = \frac{P n_g n_f}{n(1.5 n_f + n_g)}$

$2L = 2L_1 - 100$

$= 1000$ mm

$$\sigma_b = \frac{12PL}{n^2 t^3}$$

$$420 = \frac{12 \times 37.5 \times 500 \times 10^3}{18^2 \times t^3}$$

$t^3 = 1653$.

$t = 11.82$ mm

$b = \frac{n \times t}{2}$

$= \frac{18 \times 11.82}{2}$

$b = 106.42$ mm.

$l_1 = \frac{2L}{(n-1)} \times 1 + W$

$= \frac{1000}{17} \times 1 + 100$.

$= 158.82$ mm

$l_2 = 217.64$ mm

$l_3 = 276.46$ mm

$l_4 = 335.28$ mm

$l_5 =$

$l_6 =$

$l_7 =$

$l_8 =$

$l_9 =$

$l_{10} =$

$l_{11} =$

$l_{12} =$

$l_{13} =$

$l_{14} =$

$l_{15} =$

$l_{16} =$

$l_{17} =$

PROBLEMS ON TORSIONAL SPRINGS.

Helical Torsional Springs — Construction

Similar to Helical Tension Spring

Difference is Helical Torsion spring the ends are given in a shape, so that torque can be applied

Transmitting small torques as door hinges, rolling shutters

Helical Torsional Springs not applicable for high torque

Automobile starter, brush holder in electrical rotor.

1. Helical Torsional spring mean dia of 50 mm is made of round wire 5 mm dia. The torque of 4 N.m is applied on spring. Find the bending stress and angular deflection of the spring. Modulus of elasticity of spring is 2×10^5 N/mm². Assume no. of effective turn is 6?

Soln :-

$T = M = 4000$ N.mm

$n = 6$.

$d = 5$ mm

$D = 50$ mm.

$E = 2 \times 10^5$ N/mm².

$C = D/d = 10$.

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

$$= \frac{39}{36} + \frac{0.615}{10} = 1.144$$

$$\sigma = \frac{32 \times K_b M}{\pi d^3}$$

$$= \frac{32 \times 1.14 \times 4000}{\pi \times 5^3}$$

$$= 373.15 \ N/mm$$

$$\theta = \frac{\pi M D n c}{E I}$$

$$= \frac{\pi \times 4000 \times 50 \times 6 \times 64}{2 \times 10^5 \times \pi \times 5^4}$$

$$= 35.2^\circ$$

A helical torsional spring deflect through 90° subject to a torque of 4 N-m Spring index is 6. Determine coil dia, Wire dia, No. of turns with the following data.

Rigidity = 80 GPas Elasticity = 200 GPas

Allowable stress = 500 N/mm^2.

$\sigma = 500 \ N/mm^2$

$c = 6$.

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

$M = 4000 \ N.mm$

$$K_b = \frac{23}{20} + \frac{0.615}{6}$$

$= 1.25 25$.

$$\sigma = \frac{32 K_b M}{\pi d^3}$$

$$500 = \frac{32 \times 1.25 \times 4000}{\pi \times d^3}$$

$$d^3 = \frac{32 \times 1.25 \times 4000}{\pi \times 500}$$

$$d = 5 \text{ mm}$$

$$D = d \cdot C$$

$$= 5 \times 6$$

$$D = 30 \text{ mm}$$

$$\theta = \frac{\pi M D n_c}{EI}$$

$$1.570 = \frac{\pi \times 4000 \times 30 \times n_c \times 64}{2 \times 10^5 \times \pi \times 5^4}$$

$$n_c = \frac{1.570 \times 2 \times 10^5 \times 5^4}{4000 \times 30 \times 64}$$

$$\boxed{n_c = 21 \text{ turns}}$$

Disc Spring

Bellevile spring (or) Disc spring are used where high spring stiffness is required. are made up of number of conical springs are held together

1. The bellevel spring is made of 3mm steel metal sheet with outside diameter of 125 mm and diameter ratio as 2·5. The spring is dished by 4·5 mm. The maximum stress produced at the inner edge is 560 N/mm². Determine i) Deflection 2) Load that may safely carry 3) Check the stress at the outside fibre.

Solution:

$\sigma_i = 560\ N/mm^2$

$y = ?$

$P = ?$

$d_o = 125\ mm$

$d_i = ?\ 50\ mm$

$d_o/d_i = 2.5$

$h = 4.5\ mm$

$t = 3\ mm$

$$M = \frac{6}{\pi \log_e (d_o/d_i)} \left[\frac{(d_o/d_i - 1)}{d_o/d_i} \right]^2$$

$$= \frac{6}{\pi \log_e (2.5)} \left[\frac{1.5}{2.5} \right]^2$$

$$= \frac{2.16}{2.87} = 0.75$$

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$$C_1 = \frac{6}{\log_e\left(\frac{d_o}{d_i}\right)}\left[\frac{d_o/d_i - 1}{\log_e(d_o/d_i)} - 1\right]$$

$$= \frac{6}{\pi \ln(2.5)}\left[\frac{1.5}{0.916} - 1\right]$$

$$= \frac{3.822}{0.916}$$

$$C_1 = 1.32$$

$$C_2 = \frac{6}{\pi \log_e(d_o/d_i)}$$

$$= \frac{6}{\pi \times 0.916}$$

$$= 2.08$$

$$\gamma = 0.3$$

$$\sigma_i = \frac{EY}{(1-\gamma^2)\, M\left(\frac{d_i}{2}\right)^2}\left[C_1\left(h - Y/2\right) + C_2 t\right]$$

$$560 = \frac{2\times10^5\, Y}{(1 - 0.09)\, 0.75 \times 625}\left(1.32\left(4.5 - Y/2\right) + 2.08\times3\right)$$

$$= \frac{2\times10^5}{426.56}\left[\left(5.94 - \frac{1.32Y}{2}\right) + 6.24\right]$$

$$560 = \frac{2\times10^5 Y\left[12.18 - 0.66Y\right]}{426.56}$$

$$560 \times 426.56 = 2436000\,Y - 132000\,Y^2$$

$$238313.6 = 2436000\,Y - 132000\,Y^2$$

$$132000\,Y^2 - 2436000\,Y + 238313.6 = 0$$

$$y = 0.098$$

$$\sigma_i = \frac{EY}{(1-\gamma^2)M\left(\frac{d_o}{2}\right)^2}\left[C_1\left(h - Y/2\right) + C_2 t\right]$$

$$560 = \frac{2\times10^5\,y}{0.91\times0.75\times3906.25}\left[12.18 - 0.66Y\right]$$

$$1492968.75 = 2436000\,Y - 132000\,Y^2$$

$$y = 0.63$$

$$P = \frac{EY}{(1-\gamma^2)M\left(\frac{d_o}{2}\right)^2}\left[\left(h - y/2\right)(h-y)t + t^3\right]$$

$$P = \frac{2\times10^5\times0.63}{0.91\times0.75\times3906.25}\left[(4.5 - 0.315)(11.61) + 27\right]$$

$$= 3.57\,kN$$

1. Belleval spring made of silicon steel compress completely flat when subjected to the axial force of 4500 N corresponding maximum stress is 1375×10^6 N/m^2. $D_o/D_i = 1.75$. $H/t = 1.5$, Calculate thickness of washer Free height of washer – thickness. Outside dia and Inside dia of washer.

Solution

$P = 4500 N$

$\sigma = 1375 \times 10^{+6} \ N/m^2.$

$= \frac{1375 \times 10^6}{10^6}$

$\sigma = 1375 \ N/mm^2$

$\frac{d_o}{d_i} = 1.75$

$h/t = 1.5$

$$M = \frac{6}{\pi \log_e\left(\frac{d_o}{d_i}\right)} \left[\frac{\left(d_o/d_i - 1\right)}{d_o/d_i}\right]^2$$

$$= \frac{6}{\pi (0.559)} \times 0.183$$

$$= 0.627.$$

$$C_1 = \frac{6}{\pi \log_e (d_o/d_i)} \left[\frac{\frac{d_o}{d_i} - 1}{\log_e\left(\frac{d_o}{d_i}\right)} - 1\right]$$

$$= \frac{6}{\pi \times 0.559} \left[\frac{0.75}{0.559} - 1\right]$$

$$C_1 = 1.162$$

$$C_2 = \frac{6}{\pi \log_e\left(\frac{d_o}{d_i}\right)}$$

$$= \frac{6}{\pi \log_e(1.75)}$$

$$C_2 = 3.4$$

$$\sigma_i = \frac{F\left(C_1 \frac{h}{2} + C_2 t\right)}{t^3}$$

$$1375 = \frac{4500\left(1.162 \times \frac{1.5t}{2} + 3.4t\right)}{t^3}$$

$$t^3 = \frac{4500}{1375}(0.8715t + 3.4t)$$

$$t^2 = 13.97$$

$$t = 3.7 \text{ mm}$$

$$h = 5.6 \text{ mm}$$

$$P = \frac{Ey}{(1-\nu^2) M \left(\frac{d_o}{2}\right)^2}\left[t^3\right]$$

$$4500 = \frac{2\times10^5 \times 5.6}{(1-(0.3)^2)\, 0.627 \frac{d_o^2}{4}} (3.7)^3$$

$$d_o^2 = \frac{226925440}{0.57057 \times 4500}$$

$$d_o = 297$$

$$d_i = 163$$

Nested Spring (or) Concentric Spring.

The springs are used to obtain greater spring force in a given space and ensure the operation of mechanism in the extent that one spring will break in order to obtain the above condition, two or more springs are used are called nested spring.

$$\tau_1 = K_s \frac{8 P_1 D_1}{\pi d_1^3} \qquad \tau_2 = K_{s2} \frac{8 P_2 D_2}{\pi d_2^3}$$

$$\tau_1 = \tau_2$$

$$\cancel{K_s} \frac{\cancel{8} P_1 D_1}{\cancel{\pi} d_1^3} = \cancel{K_{s2}} \frac{\cancel{8} P_2 D_2}{\cancel{\pi} d_2^3}$$

$$\frac{P_1 D_1}{d_1^3} = \frac{P_2 D_2}{d_2^3}$$

$$Y_1 = \frac{8 P_1 D_1^3 n_1}{G d_1^4} \qquad Y_2 = \frac{8 P_2 D_2^3 n_2}{G d_2^4}$$

$$\frac{8 P_1 D_1^3 n_1}{G d_1^4} = \frac{8 P_2 D_2^3 n_2}{G d_2^4}$$

$$n_1 d_1 = n_2 d_2$$

$$\frac{\cancel{8} P_1 D_1^3 \cancel{n_2} d_2}{\cancel{G} d_1^5} = \frac{\cancel{8} P_2 D_2^3 \cancel{n_2}}{\cancel{G} d_2^4}$$

$$\frac{P_1 D_1^3 d_2}{d_1^5} = \frac{P_2 D_2^3}{d_2^4}$$

$$\frac{P_1 D_1^3}{d_1^5} = \frac{P_2 D_2^3}{d_2^5}$$

$$\frac{D_1^2}{d_1^2} = \frac{D_2^2}{d_2^2}$$

taking square root on both sides

$$\frac{D_1}{d_1} = \frac{D_2}{d_2} = C$$

$$\frac{P_1 C}{d_1^2} = \frac{P_2 C}{d_2^2}$$

$$\frac{P_1}{P_2} = \frac{d_1^2}{d_2^2}$$

$$e = \left(\frac{D_1}{2} - \frac{D_2}{2}\right) - \left(\frac{d_1}{2} + \frac{d_2}{2}\right) \quad -(i)$$

$$e = \frac{d_1 - d_2}{2}$$

$$\frac{D_1}{2} - \frac{D_2}{2} - \left(\frac{d_1}{2} + \frac{d_2}{2}\right) = \frac{d_1 - d_2}{2}$$

$$\frac{D_1 - D_2}{2} = \frac{d_1}{2} - \cancel{\frac{d_2}{2}} + \frac{d_1}{2} + \cancel{\frac{d_2}{2}}$$

$$D_1 - D_2 = 2d_1$$

$$cd_1 - cd_2 = 2d_1$$

$$cd_1 - 2d_1 = cd_2$$

$$d_1(c-2) = cd_2$$

$$\frac{d_1}{d_2} = \frac{c}{c-2}$$

1. Design a composite helical spring with operating load range of 135 N. Maximum deflection of spring is 10mm. Permissible shear stress is 450 N/mm². The modulus of rigidity is 0.8×10^5 N/mm². The spring index is 10. Design the composite spring. Find the dimension and sketches.

Given:

$\tau_1 = \tau_2 = 450 \, N/mm^2$

$G = 0.8 \times 10^5 \, N/mm^2$

$C = 10$

$P = 135 \, N$

$Y = 10 \, mm.$

$P = P_1 + P_2$

$$\frac{P_1}{P_2} = \frac{d_1^2}{d_2^2}$$

$$\left(\frac{d_1}{d_2}\right)^2 = \left(\frac{C}{C-2}\right)^2$$

$$\frac{P_1}{P_2} = \left(\frac{C}{C-2}\right)^2$$

$$= \left(\frac{10}{10-2}\right)^2$$

$$\frac{P_1}{P_2} = 1.56$$

$P_1 = 1.56 P_2$

$P_2 + 1.56 P_2 = 135$

$P_2 = 52.68 N.$

$P_1 = 82.3 N.$

Case (i)

$P_1 = 82.3\ N$

$y = 10\ mm$

$\tau = 450\ N/mm^2$

$G = 0.8 \times 10^5\ N/mm^2$

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

$$= \frac{39}{36} + \frac{0.615}{10}$$

$$= 1.144$$

$$\tau_1 = K_s \frac{8PC}{\pi d^2}$$

$$450 = \frac{1.14 \times 8 \times 82.3 \times 10}{\pi d^2}$$

$$d^2 = \frac{1.14 \times 8 \times 82.3 \times 10}{\pi \times 450}$$

$d = \cancel{48.8mm}\ 2.3\ mm$

$$C = \frac{D_1}{d_1}$$

$D_1 = 10 \times 2.3$

$= 23\ mm$

$$q = \frac{Gd}{8C^3 n}$$

~~q = P/y~~

$$y = \frac{8PC^3 n}{Gd}$$

$$10 = \frac{8 \times 82.3 \times 10^3 \times n}{0.8 \times 10^5 \times 2.3}$$

$$n = \frac{10 \times 0.8 \times 10^5 \times 2.3}{8 \times 82.3 \times 10^3}$$

$n = 3$

Solid height.

$l_s = dn + d$

$= (2.3 \times 3) + 2.3$

$= 9.2\,mm$

$l_f = l_s + \delta_{max} + (n' - 1)$ gap between the coils

$= pn + d$

$= 9.2 + 10 + 2 \times 1$

$= 21.2\,mm.$

$pn + d = 21.2$

$3p + 2.3 = 21.2.$

$p = 6.3\,mm.$

Case 2:-

$P_2 = 52.68\,N.$

$$450 = \frac{1.14 \times 8 \times 52.68 \times 10}{\pi \times d^2}$$

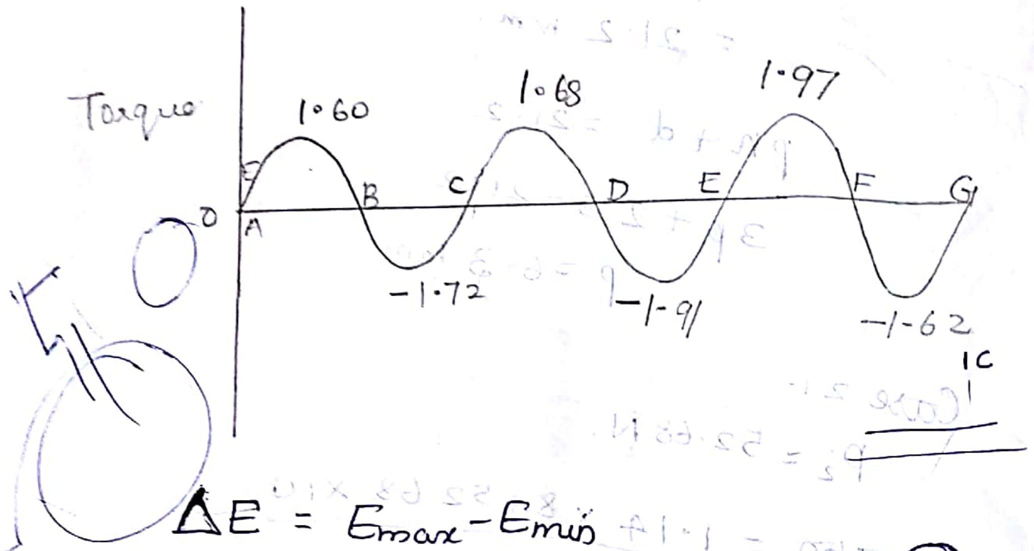
$$d^2 = \frac{1.14 \times 8 \times 52.68 \times 10}{\pi \times 450}.$$

$d = 1.84\,mm.$

$D_1 = 18.4\,mm.$

FLYWHEEL

1. A multi cylinder engine is to have constant load and run at 500 rpm on the crank effort drawing of scale 1 cm = 2500 N-m. & 1 cm = 60°. The area above and below the mean torques are measured in order +1·60, −1·72, +1·68, −1·91, +1·97, −1·62. Coefficient of fluctuation is 0·02. Assume density of flywheel is 7200 kg/m³. Allowable tensile stress is 6 MPascal.



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

Energy at $A = E$

$B = E + 1.60$

$C = E + 1.60 - 1.72$

$= E - 0.12$

$D = E - 0.12 + 1.68$

$= E + 1.56$

$E = E + 1.56 - 1.91$

$= E - 0.35$

$F = E - 0.35 + 1.97$

$= E + 1.62$

E at $C = E$.

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

$$= (E + 1.62) - (E - 0.35)$$

$$= 1.97 \times 2617.99$$

$$= 5157.4 \ Nm$$

$1 cm^2 = 60 \times \pi/180 \ ^{\times 2500}$

$= 2617.99$.

$$\Delta E = E \times 2C_s$$

$$5157.4 = E \times 2(0.02)$$

$$E = 128935 \ N\text{-}m$$

$b/h = 2$.

$$m = A \times \pi \times D \times \rho$$

$$= b \times h \times \pi \times D \times \rho$$

$$\sigma_t = \rho V^2$$

$$6 \times 10^6 = 7200 \times V^2$$

$E = \frac{1}{2} m V^2$

$$V = 28.87.$$

$$E = \frac{1}{2} m v^2$$

$\sigma_t = \rho V^2$

$$128935 = \frac{1}{2} m v^2$$

$V = m/.$

$V = \frac{\pi D N}{60}$

$\Delta E = E \times 2C_s$

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

$$\frac{128935 \times 2}{833.33} = m.$$

$$m = 310 \ kg.$$

$m = A \times \pi \times D \times \rho$

$E = \frac{1}{2} m v^2$

$V = \frac{\pi D N}{60}$

$$V = \frac{\pi D N}{60}$$

$$28.87 = \frac{\pi \times 500 \times D}{60.}$$

$$D = 1.1 \ m$$

Scanned by CamScanner

$$310 = 2h \times h \times \pi \times 1.1 \times 7200$$

$$h^2 = \frac{310}{2 \times \pi \times 1.1 \times 7200}$$

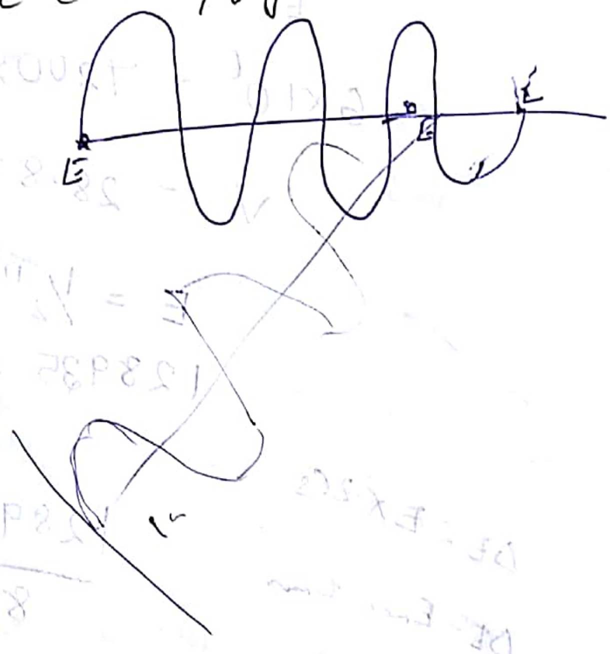
$h = 0.0789\ m$

$h = 78mm$

$b = 2h$

$= 156\ mm$

1 A single cylinder double acting steam engine delivers 185 kW at 100 rpm. The maximum fluctuation energy per revolution is 15% of energy developed per revolution. Speed variation is limited to 1% neither from mean. Mean dia of rim is 2.4 m Design a cast iron flywheel for the engine.



$P = 185\ kW$

$N = 100\ rpm$

$C_s = \pm 1\ \%$

$= 2\%$

$= 0.02$

$D = 2.4m$

$\Delta E = 0.15 \times E$

$\Delta E = E \times 2C_s$

$= mv^2 C_s$

$= m \times (12.56)^2 \times 0.02$

Design of Rim :-

$$V = \frac{\pi D N}{60}$$

$$= \frac{\pi \times 2.4 \times 100}{60}$$

$$= 12.56 \text{ m/s}$$

$$E = \frac{60 \times P}{N}$$

$$= \frac{60 \times 185 \times 10^3}{100}$$

$$= 111000 \text{ N·m}.$$

$$0.15 \times 111000 = m(12.56)^2 \times 0.02.$$

$$m = 5277.2 \text{ kg}$$

$$5277.2 = 2h \times h \times 7200 \times \pi \times 2.4 \quad \frac{\text{N·m}}{\text{sec}}$$

$$h = 220.46 \text{ mm}$$

$$b = 440.9 \text{ mm}.$$

Shaft Design

$$T_{mean} = \frac{60 P}{2\pi N}$$

$$T_{mean} = \frac{60 \times 185 \times 10^3}{2\pi \times 100}$$

$$T_{mean} = 17666.19 \text{ N·m}.$$

$$= 17666.19 \times 10^3 \text{ N·mm}.$$

d_1 – dia of shaft.

$$\tau = \frac{16 T_{max}}{\pi d_1^3}.$$

Mild steel Allowable shear stress = 40 M Pa
shaft → Mild steel.

$$40 = \frac{16 \times 35332.4 \times 10^3}{\pi d^3}$$

$d_1 = 165$ mm.

Outer dia of hub = 2 × shaft dia
= 330 mm.

1. Design rim type cast iron flywheel for an I.C engine to store 10,000 N.m energy. Speed of engine is to be 500 rpm. Coefficient of fluctuation is 0.02. Assume the suitable stresses if necessary.

Density of grey cast iron = 7200 kg/m³.

Tensile stress of grey cast iron = 6 MPa

$E = 10,000$ N.m

$C_s = 0.02$

$N = 500$ rpm

Considering 2-stroke engine

$$\Delta E = E \times K_E \qquad K_E = 0.5 - 1.5$$

Consider $K_E = 1$

$\Delta E = E$

$\Delta E = 10,000$

Tensile stress

$$\sigma_t = \rho V^2$$

$$6 \times 10^6 = 7200 \times V^2$$

$V = 28.86 \text{ m/s}$

$= 28.86 \times 10^3 \text{ mm/s}$

$$28.8 = \frac{\pi \times D \times 500}{60}$$

$D = 1.1 \text{ m}$

$\Delta E = mv^2 C_s$

$\Delta E = m \times (28.86)^2 \times 0.02$

$10{,}000 = m \times (28.86)^2 \times 0.02$

$m = 600 \text{ kg}$

$m = A \times \pi \times D \times \rho$

$m = b \times h \times \pi \times D \times \rho$

$600 = 2h^2 \times \pi \times 1.1 \times 7200$

$h = 0.109 \text{ m}$

$b = 0.219 \text{ m}$

$$E = \frac{60 \times P}{N}$$

$$10{,}000 = \frac{60 \times P}{500}$$

$P = 84 \text{ kW}$

$$T_{mean} = \frac{60 \times P}{2\pi N}$$

$$= \frac{60 \times 84 \times 10^3}{2\pi \times 500}$$

$= 1604.2 \text{ N.m}$

$$T_{max} = 1.15 \times T_{mean}$$

$$= 1844.8 \text{ N-m}.$$

$$\tau = \frac{16\, T_{max}}{\pi d^3}.$$

$$10^6 \times 50 = \frac{16 \times 1844.6}{\pi d^3}$$

$$d = 0.0572 \text{ m}$$

diameter of hub $= 2 \times 0.0572$

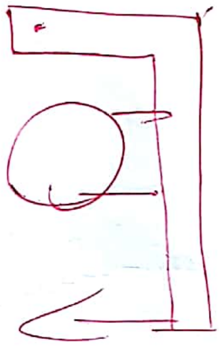
$$D = 0.1145 \text{ m}.$$

$$\simeq 114 \text{ mm}.$$

Elliptical Cross Section (Design of arms)

$$\frac{c}{a} = 0.5 \qquad a - \text{major axis}, \quad c - \text{minor}$$

$$\cancel{Z = \frac{\pi}{32} a^2 c}$$

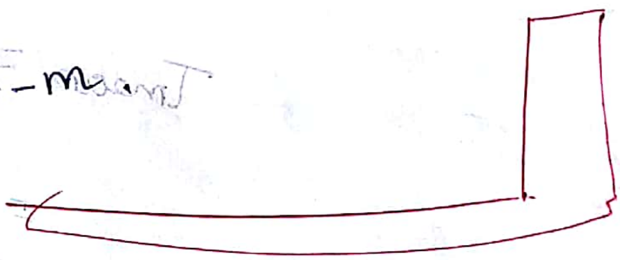


$$\sigma_b = \frac{M_b}{Z}$$

$$M_b = \frac{T_{mean}}{D \times n}\left[D - d\right]$$

$$= \frac{1604.2}{1.1 \times 4}\left[1.1 - 0.114\right]$$

$$= 359.48 \text{ N-m}$$



$$Z = \frac{\pi}{32} a^2 c$$

$$Z = \frac{\pi}{32}(2c)^2(c^{\not{2}})$$

$$\sigma_b = \frac{359 \cdot 4}{\frac{\pi}{32}(4c^3)}$$

Assume $\sigma_b = 14 \ N/mm^2$

$$14 \times 10^6 = \frac{359 \cdot 4 \times 32}{\pi \times 4 \times c^3}$$

$$c = 0 \cdot 0402$$

$$c = 40 \ mm$$

$$\frac{c}{a} = 0 \cdot 5$$

$$a = 80 \ mm$$

Previous Problem.

$$\frac{c}{a} = 0 \cdot 5$$

$$\sigma_b = \frac{M_b}{Z}$$

$$M_b = \frac{T_{mean}}{D \times n}[D - d]$$

$$M_b = \frac{17666 \cdot 19 \times 10^3}{2 \cdot 4 \times 10^3 \times 4}[2 \cdot 4 \times 10^3 - 330]$$

$$= 380 \times 10^4 \ N \cdot mm.$$

$$\sigma_b = \frac{380 \times 10^4}{\frac{\pi}{32}(4c^3)}$$

$$14 \times 10^6 = \frac{380 \times 10^4 \times 32}{\pi \times 4 \times c^3}$$

Design a flywheel for a punching maching to punch 30 holes of 20 mm dia per minute in a steel plate of 18 mm thickness. The ultimate shear strength for plate material is 300 MPas. The actual punching operation is to be $1/5^{th}$ angular rotation of crank shaft. Crank shaft is powered by flywheel having a ratio of 1:10. The flywheel is made of cast iron (Density = 7250 kg/m³) and having a working stress of 6 MPascal. Hub and spokes provide 5 percentage of rotational moment of inertia of the wheel. The diameter of flywheel is not to exceed by 1 m. Estimate the power required for driving the motors. Assume the mechanical efficiency is 70%.

Given:-

$d = 20\ mm$

No. of holes = 30/min

$t = 18\ mm$

$\tau = 300\ MPa$

$\rho = 7250\ Kg/m^3$.

$\eta = 0.70$

$= 70\%$.

$i = 10$

$D = 1.0\ m$

$$F_s = \tau \times A$$
$$= \tau \times \pi \times d \times t$$
$$= 300 \times \pi \times 20 \times 18$$
$$= 340 \text{ KN}.$$

$$E_1 = \frac{1}{2} F_s \times t$$
$$= \frac{1}{2} \times 340 \times 10^3 \times 18$$
$$= 3.05 \times 10^6 \text{ N-mm}.$$

$$E = 30 \times 3.05 \times 10^6$$
$$= 91.8 \times 10^6 \text{ N-mm}$$

$F_s = \tau \times A$

$$P = \frac{E}{\eta_{max} \times 60}$$

$$= \frac{91.8 \times 10^6}{0.70 \times 60}$$

$$= 2.2 \text{ kW}.$$

Punching machine takes 1/5 revolution of crank. Then 4/5 revolution of crank shaft energy stored in flywheel is.

$N = 30$ rpm (Assume)

$$\Delta E = 4/5 \times E_1$$
$$= 2.4 \times 10^6 \text{ N·mm}$$

$$\Delta E_{(rim)} = 0.95 \times \Delta E$$
$$= 2.3 \times 10^6 \text{ N·mm}$$

Crank speed = 30 rpm

$N = 30 \times 10$
$= 300$ rpm.

$\omega = \frac{2\pi N}{60}$

$= \frac{2 \times \pi \times 300}{60}$

$= 31.41$ rad/s.

$C_s = 0.02$

$\Delta E = mR^2 \times \omega^2 C_s$

$2.3 \times 10^6 = m \times (500)^2 \times (31.42)^2 \times 0.02$

$2300 = m \times (0.5)^2 \times (31.42)^2 \times 0.02$

$m = 465$ kg

$m = \pi D \times \rho \times A$ $\qquad$ $b/h = 2$

$465 = \pi \times 1 \times 7250 \times 2h^2$

$h = 101$ mm.

$b = 202$ mm