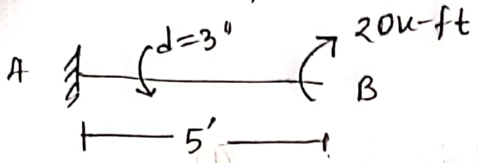
Q1.| Calculate maximum torsional stress and angle of twist, $E = 12\times10^6$ psi



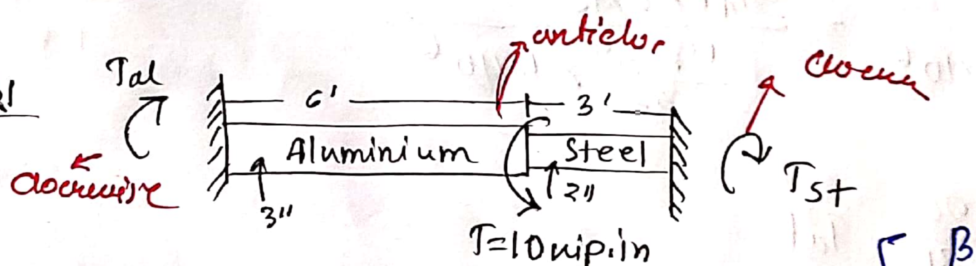
Ans:

$$S_s = \frac{TC}{J} = \frac{20000\times12\times1.5}{\frac{\pi\times3^4}{32}} = 45270 \text{ psi}$$

$$= 45.27 \text{ ksi}$$

$$\theta = \frac{TL}{JE} = \frac{20000\times12\times5\times12}{\frac{\pi\times3^4}{32}\times12\times10^6} = 0.151 \text{ rad}$$

Singer-3 Q1



$G_{al} = 4\times10^6$ psi

$G_{st} = 12\times10^6$ psi

[Both ends fixed হলে দুই পাশে θ same তবে opposite হবে]

The torque T=10kip in, is applied at the junction of two segments. Compute the maximum shearing stress developed in the assembly.

Solution: This problem is statically indeterminate. Thus, for, statically indeterminate axially loaded members we ~~m~~ need to apply the conditions of static equilibrium and geomentry.

For static equilibrium,

$\Sigma M = 0$,

$$T_{al} + T_{st} - T = 0$$

$$\Rightarrow T_{al} + T_{st} = 10\times10^3 \text{ lb.in} \quad \text{--- (1)}$$

From the geometrical relation, as the shaft is rigidly fastened in both ends thus,

$$\theta_{st} - \theta_{al} = 0$$

$$\Rightarrow \theta_{st} = \theta_{al}$$

$$\Rightarrow \left(\frac{TL}{JG}\right)_{st} = \left(\frac{TL}{JG}\right)_{al}$$

$$\Rightarrow \frac{T_s \times \cancel{3\times12}}{\frac{\pi\times3^4}{32}\times \cancel{12\times10^6}} = \frac{T_{Al}\times \cancel{6\times12}}{\frac{\pi\times3^4}{32}\times \cancel{4\times10^6}}$$

$$\therefore T_s = \frac{96}{81} T_{al}$$

pulling this on (1)

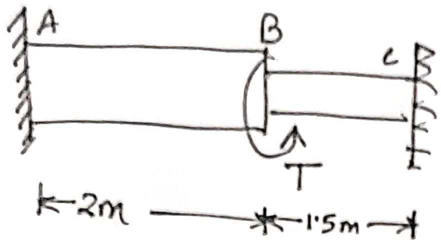
$T_s = 5420$ lb in

$T_{al} = 4580$ lb in

$$\therefore \tau_{st} = \frac{16T_s}{\pi\times2^3} = \frac{16\times5420}{\pi\times2^3} = 3450 \text{ psi} \quad \text{Ans.}$$

$$\tau_{al} = \frac{16T_s}{\pi\times3^3} = \frac{16\times4580}{\pi\times3^3} = 864 \text{ psi} \quad \text{Ans.}$$

3191



AB,

$D = 75\,mm$

$\tau \le 60\,MPa$

$G = 35\,GPa$

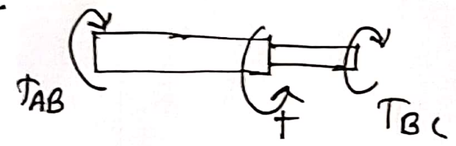
BC,

$D = 50\,mm$

$\tau \le 80\,MPa$

$G = 83\,GPa$

Solution:



$\Sigma M = 0$

$\Rightarrow T_{AB} + T_{BC} = T$

$\therefore \tau_{AB} = \left(\frac{Tc}{J}\right)_{AB} = \frac{T \times (75 \times 0.5)}{\frac{\pi 75^4}{32}}$

$\therefore T_{AB} = 4970097.753$ N.mm

$\tau_{BC} = \left(\frac{Tc}{J}\right)_{BC} = \frac{T_{BC} \times 25}{\frac{\pi \times 50^4}{32}}$

$\therefore$ ~~$T_{BC} = 2037126.486$ N.mm~~

$\therefore T_{BC} = \cancel{0.6246}\ 3.104$ kN m

For $\tau_{Br} \le 60\,MPa$

$\therefore$ Max torque for Bronze $T_{AB} = 4970$ kN.m

For, $\tau_{st} \leq 80$ MPa

$$\therefore \tau_{st} = \frac{T \times 25}{\frac{\pi \times 50^4}{32}}$$

$\therefore T_{st} = 1.963$ kN.m

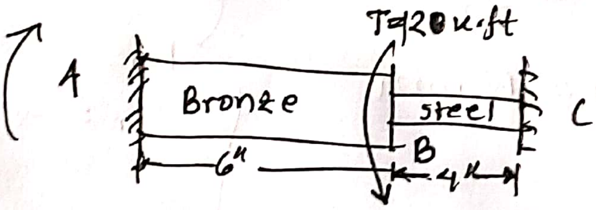
$\therefore T = T_{st} + T_{Br}$

$= 1.963 + 4.770$

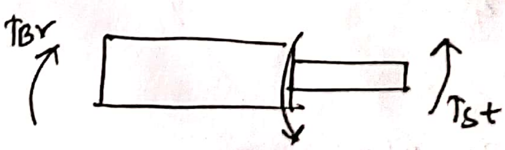
$= 6.733$ kN.m Ans.

PYQ [2019] [2017] [2016, 2015] [2013]

324/ For bronze segment the max shearing stress is limited to 8000psi and for steel segment it's 12ksi. Determine Diameters of each material will be simultaneously stressed to its permissible limit when a torque $T = 120$ k-ft is applied. $G_{Br} = 6 \times 10^6$ psi and $G_s = 12 \times 10^6$



Solution:



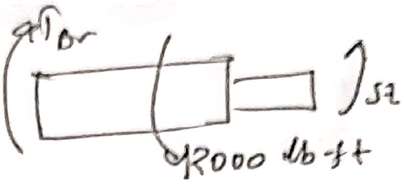
$\therefore T_{Br} + T_{st} = 1200 \times 12 = 144000$

Again,

$$\delta_{Br} = \delta_{st}$$

$$\Rightarrow \left(\frac{TL}{JG}\right)_{Br} = \left(\frac{TL}{JG}\right)_{st}$$

Solution:



$\therefore T_{Br} + T_{st} = 12000 \times 12 = 144000$ $\qquad \tau = \frac{16T}{\pi d^3}$

$\Rightarrow \frac{8000 \times \pi \times d_{br}^3}{16} + \frac{12000 \times \pi}{16} d_{st}^3 = 144000$

$\Rightarrow 1570.79\, d_{br}^3 + 2356.19\, d_{st}^3 = 144000$ —— (i)

Again, $\theta_{Br} = \theta_{st}$

$\left(\frac{TL}{JG}\right)_{br} = \left(\frac{TL}{JG}\right)_{st}$

$\Rightarrow \frac{T_{Br} \times \cancel{6}\, 3}{\frac{\pi D_{Br}^4}{32} \times \cancel{6 \times 10^6}} = \frac{T_{st} \times \cancel{4 \times 2}}{\frac{\pi D_{st}^4}{32} \times \cancel{12 \times 10^6}\, 2}$

$\Rightarrow \frac{3 T_{Br}}{D_{Br}^4} = \frac{T_{st}}{D_{st}^4}$

$\Rightarrow \frac{8000\pi \times D_{Br}^3 \times 3}{16 \times D_{Br}^4} = \frac{\cancel{T_{st}}\, 12000 \times D_{st}^3}{16 \times D_{st}^4}$

$\Rightarrow \frac{1500\pi}{D_{Br}} = \frac{750\pi}{D_{st}}$

$\Rightarrow D_{st} = 0.5\, D_{Br}$ —— (ii)

$\Rightarrow \left(\frac{TL}{JG}\right)_{br} = \left(\frac{TL}{JG}\right)_{st}$

$\Rightarrow \left(\frac{\tau_{br} \times J \times L}{J \times c \times G}\right)_{br} = \left(\frac{\tau_{st} \times J \times L}{J \times c \times G}\right)_{st}$

$\Rightarrow \frac{8000 \times 6 \times 12}{d_{br} \times 6 \times 10^6} = \frac{12000 \times 4 \times 12}{d_{st} \times 12 \times 10^6}$

$d_{br} = 2\, d_{st}$

from (i) & (ii)

$1570.79\, d_{Br}^3 + 2356.19 \times 0.5^3\, D_{Br}^3 = 144000$

$\therefore D_{Br} = 4.257$ mm, $D_{st} = 2.128$ mm Ans.

$$\Rightarrow \frac{T_{Br} \times \cancel{6}\,3}{\frac{\pi D_{Br}^4}{32} \times \cancel{6 \times 10^6}} = \frac{T_{St} \times \cancel{4}\,\cancel{2}}{\frac{\pi D_{St}^4}{32} \times \cancel{12 \times 10^6}\,2}$$

$$\Rightarrow \frac{3 T_{Br}}{D_{Br}^4} = \frac{T_{St}}{D_{St}^4} \Rightarrow \quad T_{Br}$$

Again,

$$\tau_{Br} = \frac{T_{Br} \times D_{Br}/2}{\frac{\pi D^4}{32}}$$

$$\Rightarrow 8000 = \frac{16\, T_{Br}}{\pi D_{Br}^3}$$

$$\therefore T_{Br} = 1570.79\, D_{Br}^3$$

$$\tau_{St} = \frac{16\, T_{St}}{\pi D_{St}^3}$$

$$\Rightarrow 12000 = \frac{16 \times T_{St}}{\pi \times D_{St}^3}$$

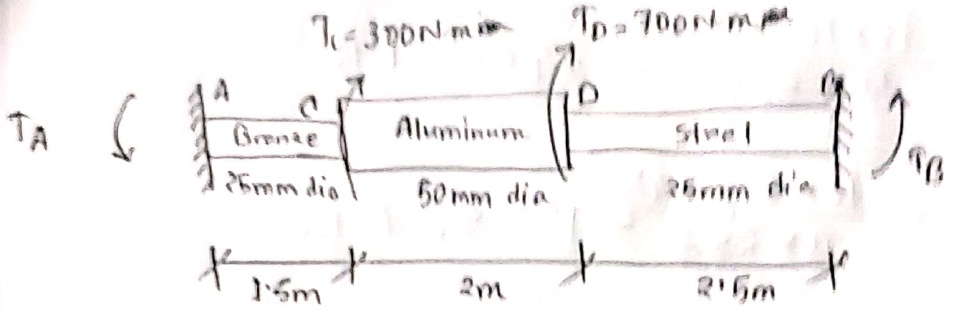
$$\therefore T_{St} = 2356.19\, D_{St}^3$$

$\therefore$ from (1)

$$1570.79\, D_{Br}^3 + 2356.19\, D_{St}^3 = \cancel{120}\ 144000$$

$$\Rightarrow 1570.79\, D_{Br}^3 + 2356.19$$

323| For $G_{br} = 35$ GPa, $G_{al} = 28$ GPa, $G_s = 83$ GPa. Determine the max shearing stress developed in each segment. [2011, 2014] [2012] [illegible]



Solution:

$T_A + T_B = 1000$ ~~Nm~~ $\times 10^3$ N.mm

$$\Sigma\left(\frac{TL}{JG}\right)_{AB} = 0$$

$$\Rightarrow \frac{T_A \times 1.5 \times 10^3}{\frac{\pi \times 25^4}{32} \times 35 \times 10^3} + \frac{(T_A - 300)^{\times 10^3} \times 2 \times 10^3}{\frac{\pi \times 50^4}{32} \times 28 \times 10^3} + \frac{(T_A - 1000)^{\times 10^3} \times 2.5 \times 10^3}{\frac{\pi \times 25^4}{32} \times 83 \times 10^3} = 0$$

$$\Rightarrow \frac{T_A \times 1.5}{25^4 \times 35} + \frac{(T_A - 300)^{\times 10^3} \times 2}{50^4 \times 28} + \frac{(T_A - 1000)^{10^3} \times 2.5}{25^4 \times 83} = 0$$

$$\Rightarrow \frac{16 \times 1.5 \times T_A}{35} + \frac{(T_A - 300)^{\times 10^3}}{14} + \frac{40(T_A - 1000)^{\times 10^3}}{83} = 0$$

$$\Rightarrow \frac{24 T_A}{35} + \frac{(T_A - 300)^{\times 10^3}}{14} + \frac{40(T_A - 1000)^{\times 10^3}}{83} = 0$$

$$\Rightarrow \frac{24 T_A}{35} + \frac{T_A}{14} - \frac{300^{\times 10^3}}{14} + \frac{40 T_A}{83} - \frac{40 \times 1000^{\times 10^3}}{83} = 0$$

$\Rightarrow$ ~~$1.23907\, T_A = 503.356$~~

$\therefore T_A = 406.26^{\times 10^3}$ N.mm $= T_{Br}$

$\therefore T_{Al} = 406.26 - 300 = 106.2371$ N.mm

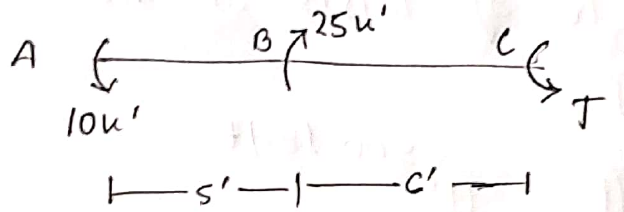
$T_{St} = 406.26 - 1000$
$= -593.74$ N.mm

$$\tau_{Br} = \frac{16 T_{Br}}{\pi D^3} = \frac{16 \times 406.26 \times 10^3}{\pi \times 25^3} = 132.42 \text{ MPa}$$

$$\tau_{Al} = \frac{16 T_{Al}}{\pi D^3} = \frac{16 \times 1062.371 \times 10^3}{\pi \times 50^3} = 34.627 \text{ MPa}$$

$$\tau_{st} = \frac{16 T_{st}}{\pi D^3} = \frac{16 \times 523.74 \times 10^3}{\pi \times 25^3} = 173.52 \text{ MPa}$$

03| Calculate maximum torsional stress and angle of twist between A & C. $G = 12 \times 10^6$ psi and $d = 4''$



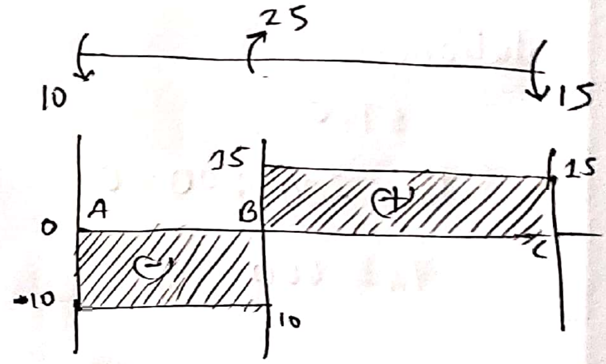
Solution:

For static equilibrium,

$\Sigma T = 0$

$\Rightarrow -10 + 25 - T = 0$

$\therefore T = 15k'$



Maximum stress occurs on BC, because 15k' is the max torque and the diamenters of bot AB & BC is same

$$\therefore S_s = \frac{Tc}{J} = \frac{15 \times 12 \times 4}{\frac{\pi\, 4^3}{32}} = 14.32 \text{ ksi}$$

Angle of twist between A & C,

$\theta_{AC} = \theta_{BC} - \theta_{AB}$ [because, BC has (+) or clockwise torque thus clockwise twist]

$$= \left(\frac{TL}{JG}\right)_{BC} - \left(\frac{TL}{JG}\right)_{AB}$$

$$= \frac{15 \times 12 \times 5 \times 12}{\frac{\pi \times 4^3}{32} \times 12 \times 10^3} - \frac{10 \times 12 \times 6 \times 12}{\frac{\pi \times 4^3}{32} \times 12 \times 10^3}$$

$= 0.019$ rad

$\therefore$ It will twist clockwise 0.019 rad

From the moment Diagram we get,

$T_{AB} = 10k'$

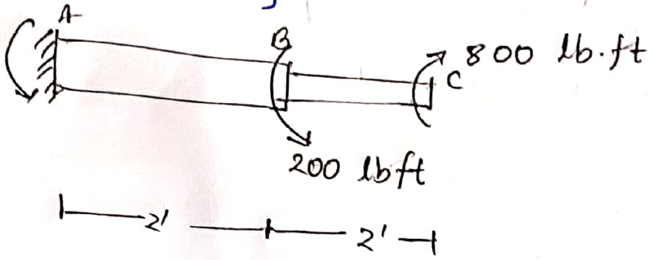
$T_{BC} = 15k'$

750N.m 1200N.m

using G=83 GPa, determine the required diameter of the shearing shaft if the ... to 60MPa

318

041 A solid Aluminium shaft is subjected to two torques as shown. Determine the maximum shearing stress and the angle of twists at the face-end. $G = 4\times10^6$ psi [2008]

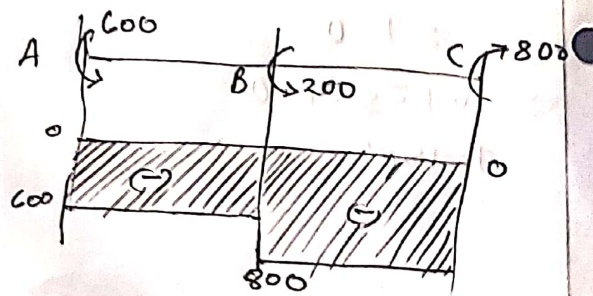


Solution:

$\Sigma T = 0,$

$-T_A - 200 + 800 = 0$

$\therefore T_A = 600$



Shearing stress at AB,

$S_s = \dfrac{Tc}{J} = \dfrac{(600\times12)\times1.5}{\frac{\pi\times3^4}{32}}$

$= 1358.12$ psi

From moment diagram,

Torque at AB = 600

" " BC = 800

At BC,

$S_s = \dfrac{(800\times12)\times1}{\frac{\pi\times2^4}{32}} = 6111.55$ psi

$\therefore$ Max $S_s = 6111.55$ psi

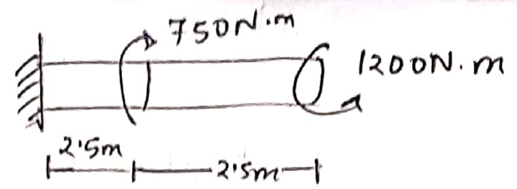
moment diagram same হলে angle add হবে

As both at AB & BC, Torques are anti clockwise thus they both twist at the same direction.

$\theta = \theta_{AB} + \theta_{BC} = \left(\dfrac{TL}{JG}\right)_{AB} + \left(\dfrac{TL}{JG}\right)_{BC} = \ldots$

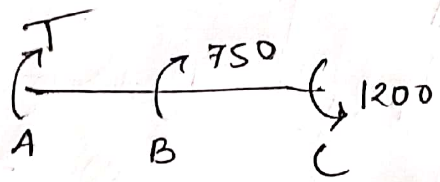
$= 0.042$ rad.

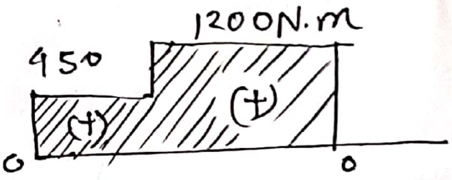
32D1



using $G = 83$ GPa, determine the required diameter of the shaft if the shearing stress is limited to 60MPa and the angle of deflectio at free end is not to exceed 4°.

solution:





$\Sigma T = 0$,

$T + 750 - 1200 = 0$

$\Rightarrow T = 450$ N.m

For part AB,

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

$\Rightarrow d_1 = \sqrt[3]{\frac{16 \times 450 \times 10^3}{\pi \times 60}} = 33.67$

For BC,

$\tau_{ABC} = \frac{16 T_{BC}}{\pi d^3}$

$\Rightarrow d_2 = \sqrt[3]{\frac{16 \times 1200 \times 10^3}{\pi \times 60}} = 46.7017$ mm

Fromg deflection,

$4^\circ \times \frac{\pi}{180} = \theta_{AB} + \theta_{BC}$

$\Rightarrow \frac{4\pi}{180} = \left(\frac{TL}{JG}\right)_{AB} + \left(\frac{TL}{JG}\right)_{BC} = \frac{450 \times 10^3 \times 2.5 \times 10^3}{\frac{\pi d^4}{32} \times 83 \times 10^3} + \frac{1200 \times 10^3 \times 2.5 \times 10^3}{\frac{\pi d^4}{32} \times 83 \times 10^3}$

$= \left(\frac{\tau L}{cG}\right) + \left(\frac{\tau L}{cG}\right)$

$= \frac{2\tau L}{cG} = \frac{2 \times 60 \times 2.5 \times 10^3}{c \times 83 \times 10^3}$

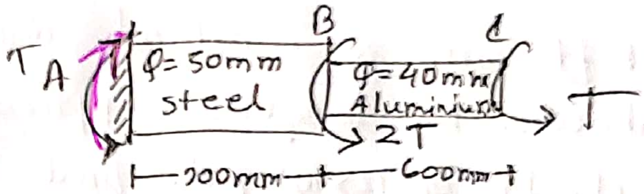
$\therefore c =$

$\therefore d_3 = 51.822$ mm

$\therefore$ Ans, $d_3 = 51.822$ mm

3/6/ ~~2/6/~~

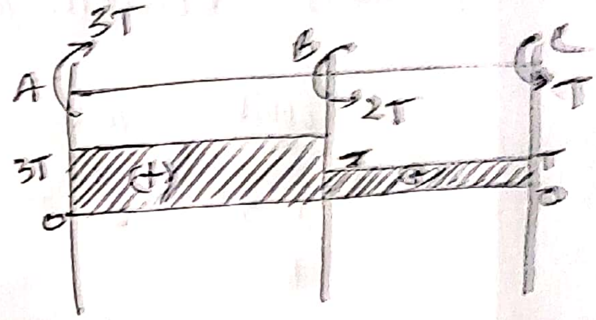
051 Determine the maximum safe value of T to the following conditions $\tau_{st} \le 83$ MPa, $\tau_{al} \le 55$ MPa and the angle of twist at the free-end is limited to 6°. $G_{st} = 83$ GPa, $G_{al} = 28$ GPa



Solution: $\Sigma T = 0$,

$+T_A - 2T - T = 0$

$\therefore T_A = 3T$



From moment diagram, $T_{AB} = 3T$

$T_{BC} = T$

$\therefore$ For steel,

$83 = \dfrac{16 \times 3T}{\pi \times (50)^3} = 679042.26$ Nmm $= 679.042$ Nm

For Aluminium,

$55 = \dfrac{16 \times T}{\pi \times 40^3} \Rightarrow T = 691.15$ Nm

~~Thus the safe value of Torque is 679 Nm~~

Angle of twist,

As both are clockwise,

$\theta_{AC} = \theta_{AB} + \theta_{AC}$

convert to radian

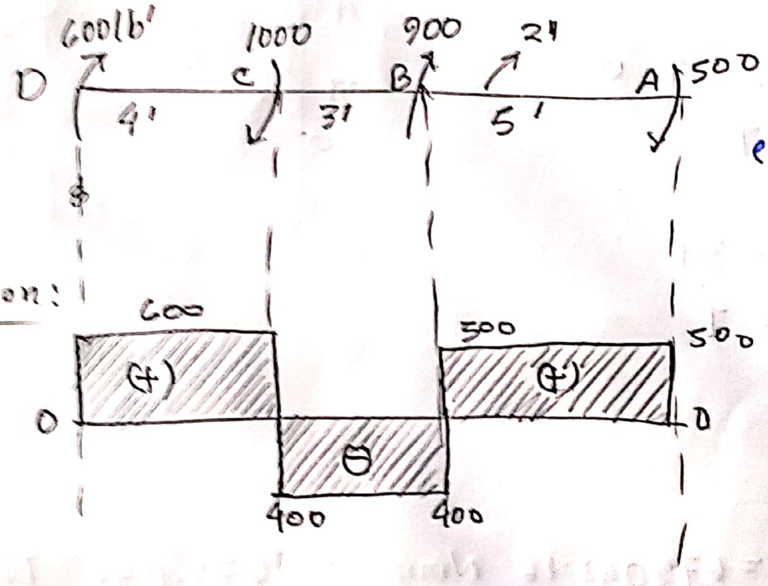
$\Rightarrow \dfrac{6°}{57.3} = \dfrac{3T \times 200}{\pi \times (50)^4 \times 83 \times 10^3} + \dfrac{T \times 600}{\pi \times (40)^4 \times 28 \times 10^3} \Rightarrow T = 757.26$ Nm

Thus the safe value of torque is 679 Nm

Ans.

More than 2 gears:

*Singer-303 — A shaft with a constant diameter of 2" is loaded (as shown) by torques applied to gears fastened to it. If $G = 12\times10^6$ psi, find the angle of twist between A and D.



Solution:

$\therefore T_{AB} = 500,\ T_{BC} = 400,\ T_{CD} = 600$

moment diagram

opposite হলে angle ও opposite

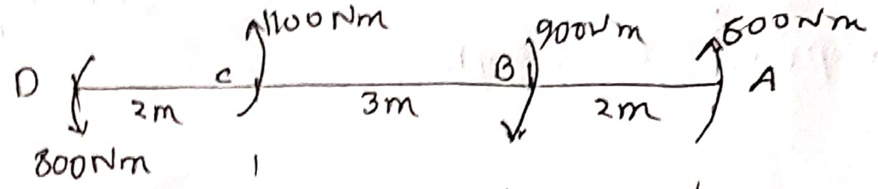
$\therefore \theta_{DC} = \theta_{CD} - \theta_{BC} + \theta_{AB}$

$$= \frac{(500\times12)\times(5\times12)}{\frac{\pi 2^4}{32}\times12\times10^6} - \frac{(400\times12)\times(3\times12)}{\frac{\pi 2^4}{32}(12\times10^6)} + \frac{(600\times12)\times(4\times12)}{\frac{\pi\times2^4}{32}\times12\times10^6}$$

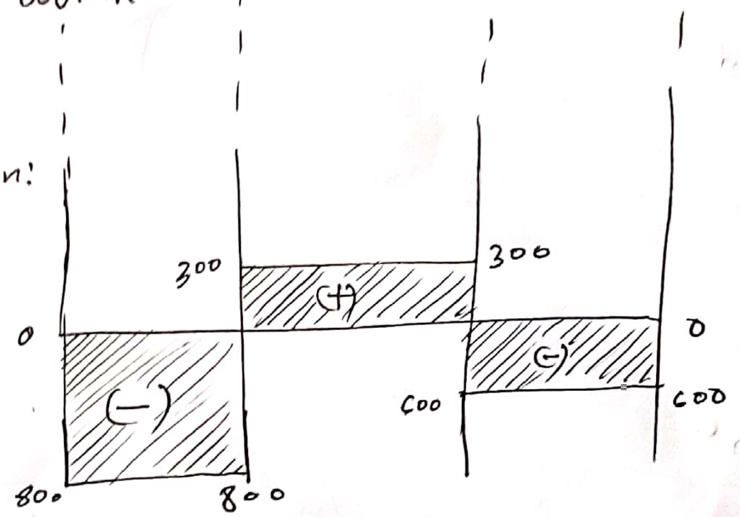
$=$

Ans:

Singer-311 — Determine the angle of twist of gear D relative to A. G = 28 GPa and ϕ = 50mm



Solution:



∴ Angle of twist,

$$\theta_{D/A} = -\theta_{DC} + \theta_{BC} - \theta_{AB}$$

$$= \frac{1}{\frac{\pi \times 0.04^4}{32} \times 28 \times 10^6} \left[(600 \times 12) - (300 \times 3) + (800 \times 2) \right]$$

$$= -0.1106 \text{ rad}$$

(−) sign indicates counterclockwise twist.

Ans:

* What is the max. dia of a solid 6m steel shaft that will not twist not more than 3° when subjected to a torque of 12 kN.m ? what maximum shearing stress is developed? $G = 83 GPa$

Solve:

$$\theta = \frac{3}{57.3} \text{ rad}$$

$$L = 6m$$

$$\therefore \theta = \frac{TL}{JG}$$

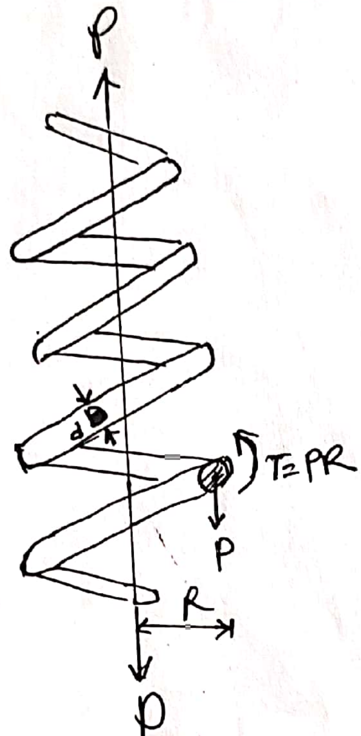
$$\frac{3}{57.3} = \frac{12 \times 10^3 \times 6}{\frac{\pi d^4}{32} \times 83 \times 10^6}$$

$$\therefore d = 0.114 m$$

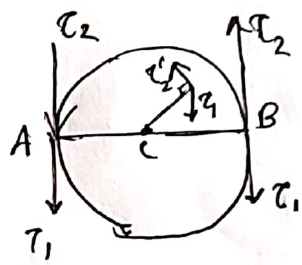
$$\therefore S_s = \frac{16T}{\pi d^3} = 41.25 \text{ MPa}$$

Ans

Hellical Springs



d= diameter of the spring wire
R= Radius of the spring
D= dia " "



Max shearing stress of a hellical spring:

τ_1= Uniformly distributed normal shearing stress

τ_2= torsional shearing stress

torsion, T=PR

$$\therefore \tau_1 = \frac{P}{A} = \frac{P}{\frac{\pi d^2}{4}} = \frac{4P}{\pi d^2}$$

$$\tau_2 = \frac{Tr}{J} = \frac{PR \times d/2}{\frac{\pi d^4}{32}} = \frac{16PR}{\pi d^3}$$

$$\therefore \tau = \tau_1 + \tau_2 = \frac{4P}{\pi d^2} + \frac{16PR}{\pi d^3}$$

$$\boxed{\therefore \tau_{max} = \frac{16PR}{\pi d^3}\left(1 + \frac{d}{4R}\right)} \rightarrow \text{Use this normally}$$

$$\left\{ \begin{array}{ll} \tau_{max} = \frac{16PR}{\pi d^3}\left(\frac{4m-1}{4m-4} + \frac{0.615}{m}\right) & \text{; for heavy springs} \\ \tau_{max} = \frac{16PR}{\pi d^3}\left(1 + \frac{0.5}{m}\right) & \text{; for light spring} \end{array} \right\} \quad m = \frac{D}{d}$$

(d) **Spring Deflection:**

$$\delta = \frac{64PR^3n}{Gd^4}$$

S931 Determine the max shearing stress and elongation in a helical steel spring composed of 20 turns of 20mm dia wire on a mean radius of 90mm when the spring is supporting load of 1.5kN. G = 83 GPa [use normal formulae]

Soln:

$n = 20$

$d = 20mm$

$R = 90mm$

$P = 1500N$

$G = 83 \times 10^3$ MPa

$\therefore$ Max. $\tau = \frac{16PR}{\pi d^3}\left(1 + \frac{d}{4R}\right)$

$= \frac{16 \times 1500 \times 90}{\pi \times 20^3}\left(1 + \frac{20}{4 \times 90}\right)$

$= 90.718$ MPa

$\therefore$ Deflection, $\delta = \frac{64PR^3}{Gd^4} n$

$= \frac{64 \times 1500 \times 90^3}{83 \times 10^3 \times 20^4} \times 20$

$= 105.397$ mm

As:

347) Two steel spring arranged in series. The upper spring has 12 turns of 25 mm diameter wire on a mean radius of 100 mm. The lower spring consists of Jo turns of 20mm dia. wire on a mean radius of 75mm. If the max shearing stress in either spring must not exceed 200MPa, compute the max value of P and the total elongation of the assembly. $G = 83\,GPa$

[use normal eqn]

Soln: For upper spring,

$n = 20$ $\quad R = 100\,mm$

$d = 25\,mm$

$\therefore \tau_{max} = \frac{16PR}{\pi d^3}\left(1+\frac{d}{4R}\right) = \frac{16 \times P \times 100}{\pi \times 25^3}\left(1+\frac{25}{4\times 100}\right)$

$\Rightarrow 200 = P \times 0.03463$

$\therefore P = 5774.98\,N$

For lower spring,

$200 = \frac{16 \times P \times \cancel{100}\,75}{\pi \times 20}\left(1+\frac{20}{4\times 75}\right)$

$\therefore P = 3926.99\,N$

$\therefore$ Max. value $= 5774.98\,N$

Safe value $= 3926.99\,N$

Safe value দিয়ে কাজ করতে হবে

$\therefore$ Total elongation, $\delta = \delta_1 + \delta_2$

$$= \frac{64PR_1^3 n_1}{Gd_1^4} + \frac{64PR_2^3 n_2}{Gd_2^4}$$

$$= \frac{64P}{G}\left(\frac{100^3 \times 20}{25^4} + \frac{75^3 \times 10}{20^4}\right)$$

$$= \frac{64 \times 3926.99}{83 \times 10^3}\left(\frac{100^3 \times 20}{25^4} + \frac{75^3 \times 10}{20^4}\right)$$

$$= 234.87 \text{ mm}$$

Ans.

যেখানে Hinge থাকবে এই ~~...~~ Process use করা যাবে

For ~~348~~, 350 & for 3 variables

* Get 3 equations from:

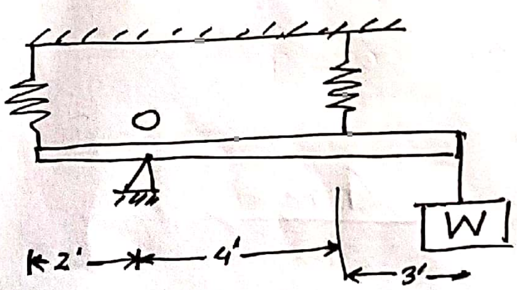
(i) $F_y = 0$

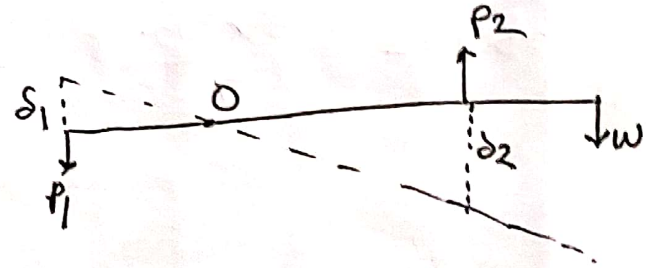
(ii) $M = 0$

(iii) Geometrical deformation

[2013, 2017]

348| A rigid bar, pinned at O, is supported by two identical springs as shown in fig. Each spring consists of 20 turns of $\frac{3}{4}$" dia wire having a mean dia of 6". Determine the max load (W) that may be supported if the shearing stress is limited to 20 ksi. [2013, 2017]





Solution:

$\sum M_O = 0$

$\Rightarrow P_1 \times 2 + P_2 \times 4 - 7W = 0$

$\therefore 2P_1 + 4P_2 = 7W$ ——— (i)

From the geometrical deformation

$$\frac{\delta_1}{2} = \frac{\delta_2}{4}$$

$$\Rightarrow 2\left(\frac{64PR^3 n}{Gd^4}\right)_1 = \left(\frac{64PR^3 n}{Gd^4}\right)_2$$

(ii)

From the geometry, max stress will occur in spring 2.

$\therefore \tau_{max} = \frac{16 P_2 R}{\pi d^3}\left(1 + \frac{d}{4R}\right)$

$\Rightarrow 20 \times 10^3 = \frac{16 \times P_2 \times \cancel{6}\,3}{\pi \times (3/4)^3}\left(1 + \frac{3/4}{4 \times \cancel{6}\,3}\right)$

$\Rightarrow 20 \times 10^3 = 73.4644\, P_2$

$\therefore P_2 = \cancel{272.24\ lb}\ 517.75\ lb$

$\therefore \cancel{P_2 = P_1/2 = 136.120\ lb}$

From eqn (i),

$2P_1 + 4P_2 = 7W$

$\Rightarrow \cancel{W = \frac{2P_1 + 4P_2}{7} = \frac{2 \times 272.24 + 4 \times 136.120}{7}}$

$\cancel{\Rightarrow 2P_1 + 8P_1 = 7W}$

$\cancel{\Rightarrow W = \frac{10P_1}{7}}$

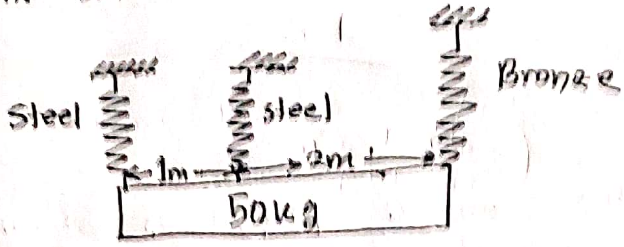
$\Rightarrow 5P_2 = 7W$

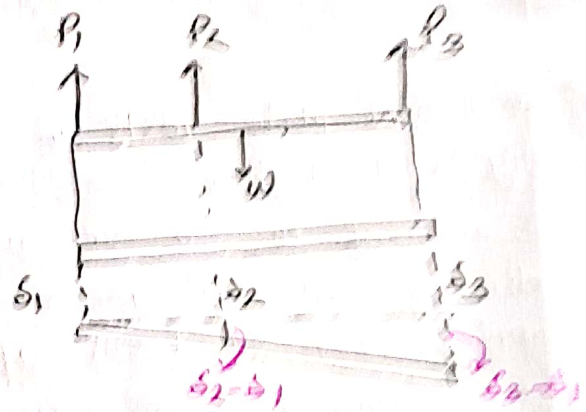
$\Rightarrow W = \frac{5 \times 517.75}{7} = 371\ lb$

Ans.

[2008, 2016, 2018, 2019]

35Q Each steel spring has 24 turns of 10mm dia wire on a mean dia of 100mm, and G = 83 GPa. The bronze spring has 48 turns of 20mm dia wire on a mean dia of 150mm and G = 42 GPa. Compute τ_{max} of each spring.





Soln:

$P_1 + P_2 + P_3 = W = 50 \times 9.8$

$\therefore P_1 + P_2 + P_3 = 490.5$ ——— ①

Now,

$$\frac{\delta_2 - \delta_1}{1} = \frac{\delta_3 - \delta_1}{3}$$

$\Rightarrow 3(\delta_2 - \delta_1) = \delta_3 - \delta_1$

$$\Rightarrow \frac{3P_2\, 50^3 \times 24}{83 \times 10^3 \times 10^4} - \frac{3P_1 \times 50^3 \times 24}{83 \times 10^3 \times 10^4} = \frac{P_3 \times 75^3 \times 48}{42 \times 10^3 \times 20^4} - \frac{P_1 \times 50^3 \times 24}{83 \times 10^3 \times 10^4}$$

$$\Rightarrow \frac{2P_1 \times 50^3 \times 24}{83 \times 10^3 \times 10^4} - \frac{3P_2 \times 50^3 \times 24}{83 \times 10^3 \times 10^4} + \frac{P_3 \times 75^3 \times 48}{42 \times 10^3 \times 20^4} = 0$$

$$\Rightarrow \frac{2P_1 \times 50^3}{83 \times 10^4} - \frac{3P_2 \times 50^3}{83 \times 10^4} + \frac{P_3 \times 75^3 \times 2}{42 \times 20^4} = 0$$

——— ⑪

$\Rightarrow \sum M_1 = 0,$

$W \times 1.5 - P_2 \times 1 - P_3 \times 3 = 0$

$\therefore P_2 + 3P_3 = 735.75$ ——— ⑪

Now solve ① & ⑪

....

Now solve these 3 equations.

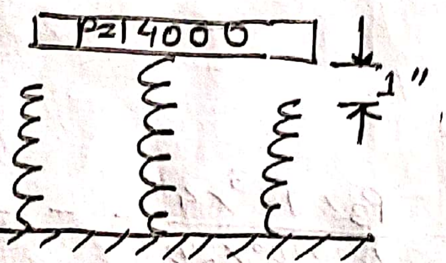
~~Find the safe load.~~

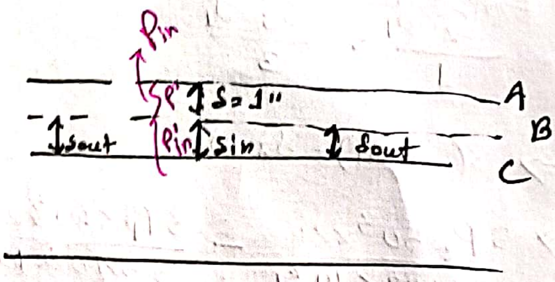
Then find stress in 3 springs.

Ans:

\# A rigid plate rests on the central spring as shown in the fig is 1" higher than the symmetrically loaded outer springs. Each of the outer springs consists of 18 turns of 0.5" dia of wire of mean dia of 4" each. The central spring has 24 turns of 0.75" dia wire of mean dia 6". Determine maximum shearing stresses using R.A.M Wahl formulae in each spring for P=14000 lb.

$G = 30\times10^6$ psi





Solution:

$$\delta = \frac{64PR^3 n}{Gd^4} = \frac{64\times P\times3^3\times24}{30\times10^6\times0.75^4}$$

$\Rightarrow P' = 228.88$ lb

At level B-C,

$P'_{in} + 2P_{out} = 14000 - 228.88$

$$\boxed{\therefore P'_{in} + 2P_{out} = 13771.12 \quad \text{——— (1)}}$$

Outer springs,

$n = 18$

$d = 0.5$

$R = 2$

Central springs,

$n = 24$

$d = 0.75$

$R = 3"$

From geometric Deformation,

$$\delta_{in} = \delta_{out}$$

$$\Rightarrow \left(\frac{64 P'_{in} R_{in}^3 n}{G d^4}\right)_{in} = \left(\frac{64 P R^3 n}{G d^4}\right)_{out}$$

$$\Rightarrow \frac{P'_{in} \times 3^3 \times \cancel{24}}{\cancel{30 \times 10^6} \times 0.75^4} = \frac{P_{out} \times \cancel{2^3} \times 18}{\cancel{30 \times 10^6} \times 0.5^4}$$

$$\Rightarrow \boxed{P'_{in} - 1.125 P_{out} = 0} \text{ ——— (ii)}$$

solving (i) & (ii),

$$P'_{in} = 4957.6 \text{ lb}$$

$$P_{out} = 4406.76 \text{ lb}$$

$$\therefore P_{in} = P'_{in} + P' = 4957.6 + 228.88$$

$$= 5186.48 \text{ lb}$$

$$\tau_{max\,inner} = \frac{16PR}{\pi d^3}\left(1 + \frac{0.5}{m}\right); \quad m = \frac{6}{0.75} = 8$$

$$= \frac{16 \times 5186.48 \times 3}{\pi \times 0.75^3}\left(1 + \frac{0.5}{8}\right)$$

$$= 199576.6476 \text{ psi}$$

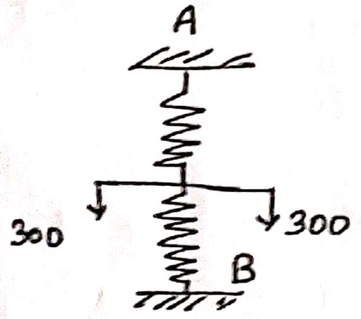
$$\tau_{max\text{-}outer} = \frac{16PR}{\pi d^3}\left(1 + \frac{0.5}{m}\right); \quad m = \frac{4}{0.5} = 8$$

$$= \frac{16 \times 4406.76 \times 2}{\pi \times 0.5^3}\left(1 + \frac{0.5}{8}\right)$$

$$= 381538.5545 \text{ psi}$$

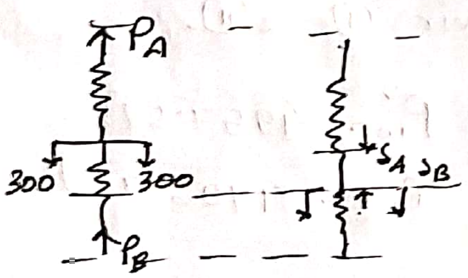
Argue

* Two springs are shown in the following figure, are joined at C. Then placed unstressed between the supports A & B. Find the reactions at the supports if a force of 600lb acts as shown. $G = 12\times10^6$ psi [2013,



Spring-1	Spring-2
$n=20$	$n=10$
$d=1/4''$	$d=1/2''$
$D=5''$	$D=6''$

Solution: $\Sigma F_y = 0$



$P_A + P_B = 600$ ——— (i)

from geometric deformation,

$\delta_A = \delta_B$

$$\Rightarrow \frac{64 \times P_A \times 2.5^3 \times 20}{12\times10^6 \times (1/4)^4} = \frac{64 P_B \times 3^3 \times 10}{(1/2)^4}$$

$\Rightarrow P_A - 1.054 P_B = 0$ ——— (ii)

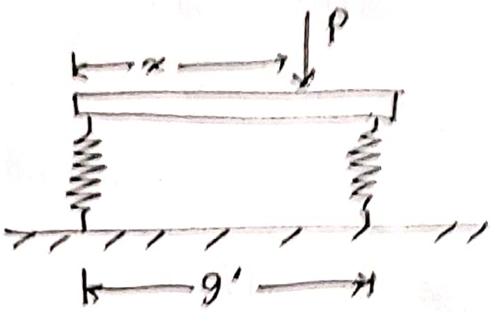
Solving (i) & (ii)

$P_B = 569.25$ lb

$P_A = 30.74$

Ans:

A rigid horizontal bar of negligible weight is supported by two springs as shown in the following figure. Determine the distance x for which the bar remains horizontal when a load P is applied. [2015

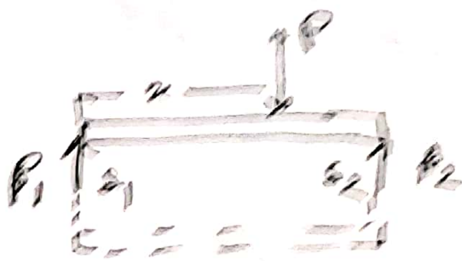


Spring-1	Spring-2
$d = 0.25''$	$d = 0.40''$
$R = 1''$	$R = 2''$
$n = 25$	$n = 10$

$G = 12\times10^6$ psi

3 variables thus 3 eqns
(i) $F_y = 0$
(ii) Geometrical defor
(iii) $\Sigma M = 0$

Solution:



$\Sigma F_y = 0$

$P_1 + P_2 = P$ → 3 variats

And,

$\delta_1 = \delta_2$

$\Rightarrow \dfrac{P_1 \times 1 \times 25}{(0.25)^4} = \dfrac{P_2 \times 2^3 \times 10}{(0.4)^4}$

$\therefore 2.048\, P_1 = P_2$ —— (ii)

$\therefore$ solving (i) & (ii)

$P_1 = \dfrac{P}{3.048}$

$\Sigma M_2 = 0,$

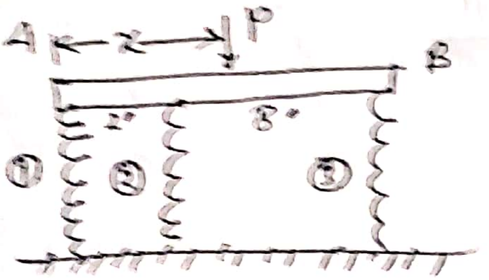
$P_1 \times 9 - P(9 - x) = 0$

$\Rightarrow \dfrac{P}{3.048} \times 9 - P(9 - x) = 0$

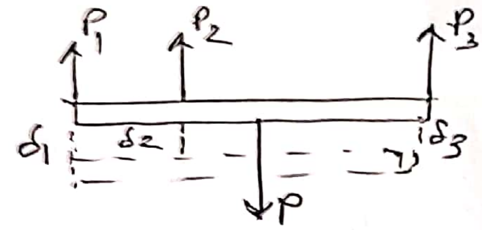
$\Rightarrow x = 6.05'$

Ans.

* The rigid bar AB weighs 100 lb and supports a load P=1000 lb. If these free lengths of the springs are equal prior to loading, where should be the load 'P' placed if the bar is to remain horizontal? $G=12\times10^6$ psi



S-1	S-2	S-3
$n=28$	$n=24$	$n=20$
$d=1/2''$	$d=3/4''$	$d=1''$
$D=4''$	$D=6''$	$D=8''$



Solution: $\Sigma F_y=0$,

$P_1+P_2+P_3=1000$ ——— (i)

$\delta_1=\delta_2$

$\Rightarrow \cancel{\dfrac{64\times P_1\times 2^3\times 28}{G\times(1/2)^4}} = \cancel{\dfrac{64\times P_2\times(3/4)\times 24}{G\times(3/4)^4}}$

$\Rightarrow \dfrac{7P_1}{(1/2)^4} = \cancel{\dfrac{P_2 3}{(3/4)^4}}$

$\Rightarrow \cancel{112 P_1 = 16 P_2}$

$\therefore \cancel{P_1 = \frac{16}{112} P_2}$

$\Rightarrow \dfrac{64\times P_1\times 2^3\times 28}{G\times(1/2)^4} = \dfrac{64\times P_2\times 3^3\times 24}{G\times(3/4)^4}$

$\Rightarrow 448 P_1 = 256 P_2$

$\therefore P_1 = \frac{4}{7} P_2$

$\Rightarrow P_1 - \frac{4}{7}P_2 = 0$ ——— (ii)

Again,

$\delta_2=\delta_3$

$\dfrac{64\times P_2\times 3^3\times 24}{G\times(3/4)^4} = \dfrac{64\times P_3\times 4^3\times 20}{G\times 1^4}$

$\Rightarrow P_2 = \frac{5}{8}P_3$

$P_2 - \frac{5}{8}P_3 = 0$ ——— (iii)

Solving (i), (ii), (iii)

$P_1 = 180.18$
$P_2 = 315.31$
$P_3 = 504.5$

$\Sigma M_A = 0$

$-R_2 \times 2 + P x - P_3 \times 10 = 0$

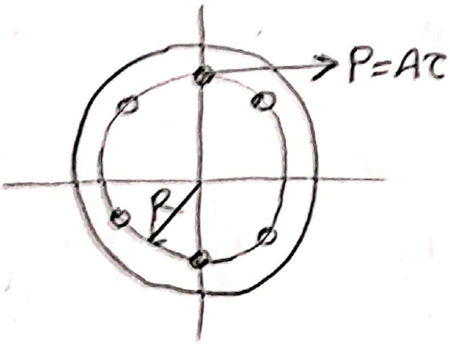
$\Rightarrow x = \dfrac{315.31 \times 2 + 604.5 \times 10}{1000}$

$\therefore x = 6.67502$ ft.

Ans:

Flanged Bolt Couplings

[1] Relationship of stresses in two or more concentric circles in a flanged and bolted coupling.



If the stress is uniformly distributed, the load in any bolt is given by, $\tau = \frac{P}{A}$ & $\tau = \frac{T\rho}{J}$

$P = A\tau = \frac{\pi d^2}{4}\tau$

∴ The resistance torque,

$$T = PRn$$

$$= \frac{\pi d^2}{4}\tau Rn$$

| R = Radius of the bolt circle.

If there are two circles then,

Total torsion ∴ $T = P_1R_1n_1 + P_2R_2n_2$

| n_1, n_2 nom of rivets per circle

If the shear deformation of the bolts are proportional to the radius of the circle,

$$\frac{\gamma_1}{R_1} = \frac{\gamma_2}{R_2}$$

$$\Rightarrow \frac{\tau_1}{G_1R_1} = \frac{\tau_2}{G_2R_2}$$

$$\Rightarrow \frac{P_1}{G_1R_1A_1} = \frac{P_2}{G_2R_2A_2} \quad ; \quad G_1 = G_2,\ A_1 = A_2$$

$$\therefore \frac{P_1}{R_1} = \frac{P_2}{R_2}$$

326)

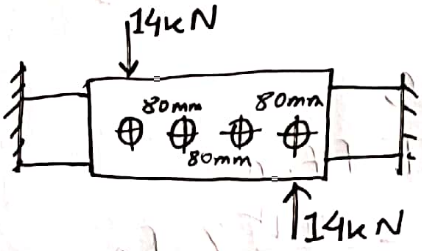
$T = PRn$

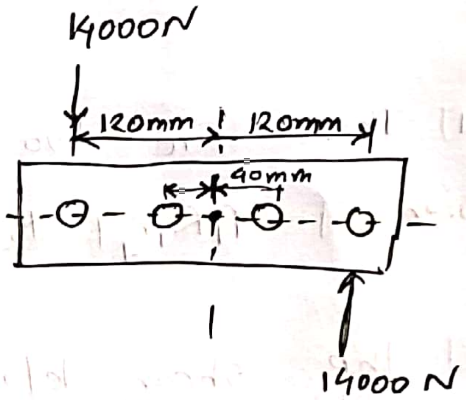
$= \frac{\pi 20^2}{4} \times 40 \times 200 \times 10$

$= 25132.74$ kN.mm

$= 25.13$ kN.m   Ans.

333) A plate is fastened to a fixed member by four 20 mm dia rivets. Compute the max and minimum shearing stress.





Soulion:

Here the torsional Shearing stress of the ~~member~~, bolts,

$\tau = \frac{T\rho}{J}$

$T = 14000 \times 240 = 3360000$ N.mm

$J = \sum A\rho^2 = \frac{\pi 20^2}{4}\left[2 \times 40^2 + 2 \times 120^2\right]$

$= 3200000\pi$ mm^4

∴ Max shearing stress ($\rho = 120$)

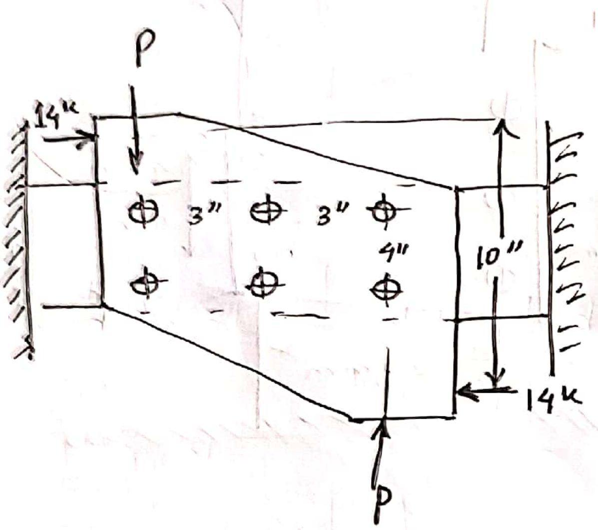
$\tau = \frac{3360000 \times 120}{3200000\pi} = 40.11$ MPa

min s_s ($\rho = 40$):

$\tau = \frac{3360000 \times 40}{3200000\pi} = 13.37$ MPa

2017

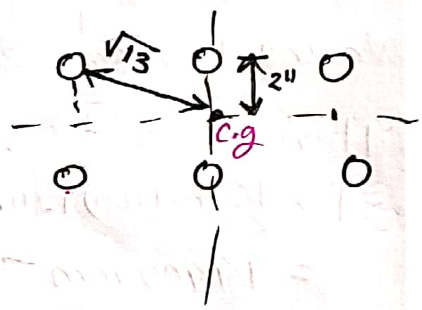
3341. Six $\frac{7}{8}$" dia rivets are fasten the plate to a fixed member. Using Determine the average shearing stress caused in each rivets by 14kips. What additional loads P can be applied before the average shearing stress in any rivet exceeds 8000 psi?



Solution:

$T = 14000 \times 10 = 140 \text{ kip.in}$

$J = \Sigma A\rho^2 = \frac{\pi (7/8)^2}{4} \left[2\times2^2 + 4\times(\sqrt{13})^2\right] = 36.08$



$\therefore \tau_{max} = \frac{140\times\sqrt{13}}{36.08} = 14.0 \text{ ksi}$ Ans

$\tau_{min} = \frac{140\times2}{36.08} = 7.76$ ksi Ans

Determination of p:

(i) P<14 kips:

Allowable $\tau = 8000$

$T = 14\times10 - 6P = 140 - 6P$

$\therefore 8000 = \frac{(140-6P)(\sqrt{13})}{36.08}$ → because outer bolt has the most stress

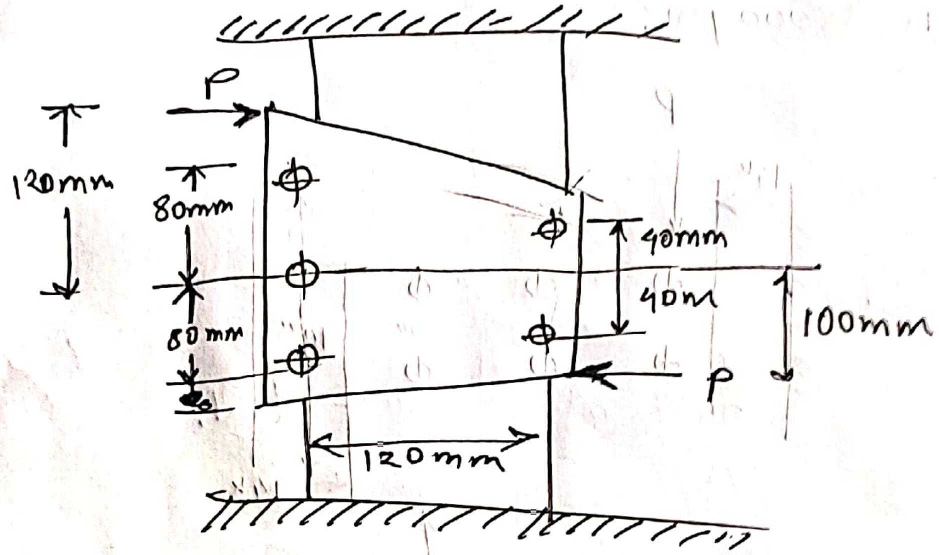
$\Rightarrow P = 10$ kips

(ii) P> 14 kips:

$T = 6P - 14\times10 = 6P - 140$; $8000 = \frac{(6P-140)\sqrt{13}}{36.08}$ $\therefore$ $P = 36.68$ kips

Ans

3351 The plate is fastened to the fixed member by 10mm diameter rivets. Compute the value of the P so that the average S_s in any rivets does not exceed 70 MPa.



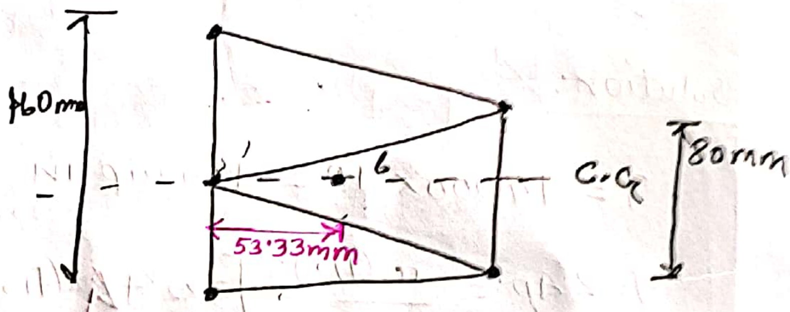
Solve: finding the C.G:

We know, $A\bar{x}_G = \Sigma ax$

∴ Here,

$A = \frac{1}{2}(80+160)\,120$

$= 14400\ mm^2$



$a_1 = a_2 = a_3 = \frac{1}{2} \times 80 \times 120 = 4800 mm^2$

$\bar{x}_3 = \bar{x}_1 = 120 \times \frac{1}{3} = 40mm$

$\bar{x}_2 = 120 \times \frac{2}{3} = 80\ mm$

$\therefore A\bar{x}_G = \Sigma a\bar{x}$

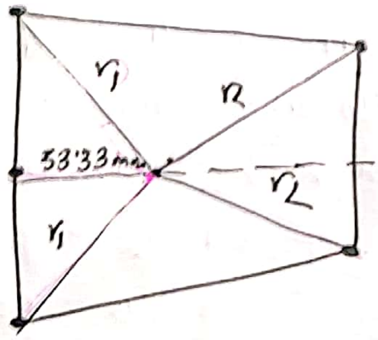
$\Rightarrow 14400 \times \bar{x}_G = 2 \times 4800 \times 40 + 80 \times 4800$

$\therefore \bar{x}_G = 53.33\ mm$

Here,

$r_1 = \sqrt{53.33^2 + 80^2} = 96.146$ mm

$r_2 = \sqrt{40^2 + (120-53.33)^2} = 77.746$mm



$\therefore T = 220P$

$J = \Sigma a\rho^2 = \frac{\pi \times 10^2}{4}\left[2 \times 96.146^2 + 2 \times 77.746^2 + 53.33^2\right]$

$= 2624885.215$ mm^4

For the outermost rivet,

$\tau = \frac{T\rho}{J}$

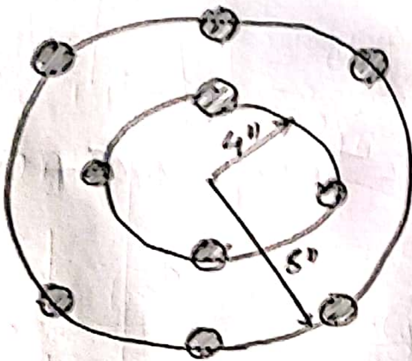
$\Rightarrow 70 = \frac{220P \times 96.146}{2624885.215}$

$\therefore P = 8686.8N$

Ans:

2017

* Ten 1/2" diameter bolts are arranged in two concentric circles in a flanged coupling similar to that shown in the following figure. Find the maximum horse power that can be transmitted by the coupling if the shaft speed is 315 rpm and the max permissible shearing stress is 5000psi.



Solution

$R_1 = 4"$

$R_2 = 8"$

$d = 1/2"$

$\tau = 5000psi$

$N = 315$

We know max τ occurs at outer rivets.

$\therefore \tau_2 = 5000psi$

We know,

$$\tau_2 = \frac{P_2}{A_2} = \frac{P_2}{\frac{\pi \times (1/2)^2}{4}}$$

$$\Rightarrow P_2 = \frac{\pi \times 0.5^2}{4} \times 5000 = 981.7477 \ lb$$

$\therefore$ We know,

$$\frac{P_1}{R_1} = \frac{P_2}{R_2}$$

$$\Rightarrow P_1 = \frac{981.7477}{8} \times 4 = 490.87 \ lb$$

$\therefore$ Total Torsion, $T = P_1 R_1 n_1 + P_2 R_2 n_2$

$= 490.87 \times 4 \times 4 + 981.747 \times 8 \times 6$

$= 54977.76 \ lb\text{-}in$

We know,

Power, $P = \frac{T\theta}{t}$

$= T\omega$

$= \frac{54977.76 \times 2\pi \times 315}{60 \times 12}$

$= 151128.011\ (lb\text{-}ft)/s$

$= \frac{151128.011}{550}\ hp$

$= 274.89$

$1Hp = 550(lb\text{-}ft)/s$

$\omega = \frac{2\pi N}{60} = \frac{2\pi \times 315}{60}$

For circular Flangel couplings

Shearing stress means,

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

3261 A flanged bolt coupling consists of ten steel 20mm diameter bolts spaced evenly around a bolt circle 400mm In diameter. Determine the torque capacity of the coupling if the allowable shearing stress in the bolts is 40 MPa.

ans:

$d = 20mm$

$n = 10$

$R = 200mm$

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

$\Rightarrow 40 = \frac{P}{\frac{\pi \times 20^2}{4}}$

$\therefore P = 4000\pi$

$\therefore T = PRn$

$= 4000\pi \times 200 \times 10$

$= 25.1 kN.m$ Ans:

3281

$d_1 = 10mm$ $d_2 = 10mm$

$R_1 = 200mm$ $R_2 = 150mm$

$n_1 = 8$ $n_2 = 6$

$\tau = \frac{P_1}{A_1}$

$\Rightarrow 60 = \frac{P_1}{\frac{\pi \times 10^2}{4}}$

$\therefore P_1 = 1500\pi$

$\tau = \frac{P_2}{A_2}$

$\Rightarrow 60 = \frac{P_2}{\frac{\pi \times 10^2}{4}}$

$P_2 = 1500\pi$

$T = P_1R_1n_1 + P_2R_2n_2$

$= 1500\pi(200 \times 8 + 150 \times 6)$

$= 11.78 kN.m$

Ans

For the outermost circle, shearing stress will be highest

$\tau = \frac{P_1}{A_1}$

$\Rightarrow 60 = \frac{P_1}{\frac{\pi \times 10^2}{4}}$

$\therefore P_1 = 1500\pi$

We know,

$\frac{P_1}{R_1} = \frac{P_2}{R_2}$

$\Rightarrow P_2 = \frac{1500\pi}{200} \times 150$

$\therefore P_2 = 1125\pi$

$\therefore$

$T = P_1 R_1 n_1 + P_2 R_2 n_2$

$= 1500\pi \times 200 \times 8 + 1125\pi \times 150 \times 6$

$= 10.7$ k.N.m

Ans:

→ Total torque is given

3291. A torque 7000 lb.ft is to be carried by a flanged bolt coupling that consists of eight 1/2" dia steel bolts on a circle of dia 12" and six 1/2" dia steel bolts on a circle of dia 9". Determine the shearing stress in the bolts.

Ans: $R_2 = 6"$ $\quad R_1 = 4.5"$

$d_2 = 0.5"$ $\quad d_1 = 0.5"$

$n_2 = 8$ $\quad n_1 = 6$

$T = P_1 R_1 n_1 + P_2 R_2 n_2$

$\Rightarrow 7000 \times 12 = 4.5 \times 6 \times P_1 + 6 \times 8 \times P_2$

$= 27 P_1 + 48 P_2$

Now,

$\frac{P_1}{R_1} = \frac{P_2}{R_2}$

$\Rightarrow P_1 = P_2 \times \frac{R_1}{R_2}$

$\therefore P_1 = P_2 \times \frac{4.5}{6}$

$\therefore 7000 \times 12 = 27 \times \frac{4.5}{6} \times P_2 + 48 P_2$

$\therefore P_2 = 1230.769$ lb

$P_1 = 923.07$ lb

$\therefore \tau_1 = \frac{P_1}{A_1} = \frac{1230.769}{\frac{\pi \times 0.5^2}{4}} = 6.26$ ksi

$\tau_2 = \frac{P_2}{A_2} = 4.70$ ksi

Ans: