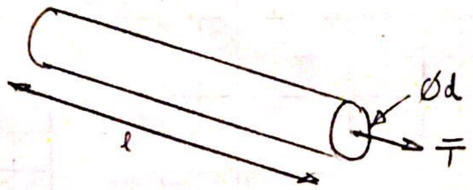
CH3 #'s : 4, 11, 20, 40, 42, 45, 71, 76, 77, 87, 89

3.4

Given:



$d = 3\,in$
$l = 4\,ft$
$T = 40\ kip\cdot in$

Find: a) Find maximum shearing stress τ for solid shaft
b) " " " " " " hollow shaft with 1in ID.

Solution:

$$T = \frac{J\tau}{\rho} \quad \text{or} \quad \tau = \frac{T\rho}{J}$$

a) $\rho = \frac{d}{2}$, $J = \frac{\pi}{2}\left(\frac{d}{2}\right)^4$

$$\rightarrow \tau = \frac{40\,kip\cdot in \cdot 1.5\,in}{\frac{\pi}{2}(1.5\,in)^4}$$

$$\boxed{\tau = 7.55\ kip/in^2 \text{ or } ksi}$$

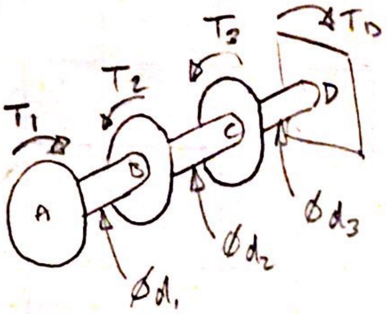
b) $\tau = \frac{T\rho}{J}$, $J = \frac{\pi}{2}(\rho_0^4 - \rho_1^4)$

$$\rightarrow \tau = \frac{T\rho_0 \cdot 2}{\pi(\rho_0^4 - \rho_1^4)}$$

$$\boxed{\tau = 7.64\ ksi}$$

3.11 :

Given:



$T_1 = 48$ Nm $d_1 = 15$ mm
$T_2 = 144$ Nm $d_2 = 18$ mm
$T_3 = 60$ Nm $d_3 = 21$ mm

Find : a) shaft w/ highest stress
b) magnitude of that stress

Solution :

$\Sigma M = 0 \rightarrow T_1 + T_2 + T_3 - T_D = 0$
$T_D = -156$ Nm

AB:

$\tau_{AB} = \frac{T_1 c}{J}$, $J = \frac{\pi}{2} c^4$, $c = \frac{d_1}{2}$

$\tau_{AB} = \frac{T_1 \cdot 16}{\pi d_1^3}$

$\tau_{AB} = 72.4$ MPa

BC: opposing torques, can't be lowest stress

CD:

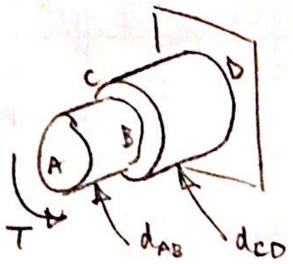
$\tau_{CD} = \frac{T_D \cdot c}{J}$, $J = \frac{\pi}{2} c^4$, $c = \frac{d_3}{2}$

$\tau_{CD} = \frac{T_D \cdot 16}{\pi d_3}$

$\boxed{\tau_{CD} = 85.8 \text{ MPa}}$ ← highest stress a), b)

3.20:

Given:



$d_{AB} = 60\,mm$
$d_{CD} = 90\,mm$, $t = 6\,mm$
$\tau_{max} = 75\,MPa$

Find: Largest T that can be applied

Solution:

AB: $\tau_{AB} = \frac{Tc}{J}$ $J = \frac{\pi}{2}c^4$, $c = \frac{d_{AB}}{2}$

$\rightarrow T = \tau_{AB} \frac{\pi}{2} c^3$
$T = 3.18\ kN\,m$

CD: $T = \tau_{AB} \frac{J}{c}$, $J = \frac{\pi}{2}(c_2^4 - c_1^4)$ $c_2 = \frac{d_{CD}}{2}$, $c_1 = \frac{d_{CD} - 2t}{2}$

$T = \tau_{AB} \cdot \frac{\pi}{2c_2}(c_2^4 - c_1^4)$ $c_2 = 45mm$, $c_1 = 39mm$

$T = 4.68\ kN\,m$

$\rightarrow$ largest allowable $\boxed{T = 3.18\ kN\,m}$

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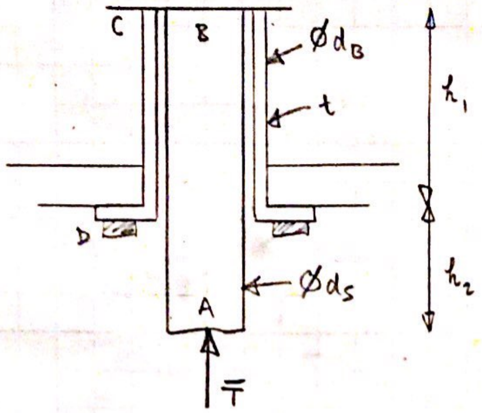
3.40 :

Given :



$h_1 = 8\,in$, $h_2 = 4\,in$

$d_s = 1.5\,in$, $d_B = 3\,in$, $t = 0.25''$

$G_S = 11.2 \cdot 10^6\,psi$ $\quad G_B = 5.6 \cdot 10^6\,psi$

$\tau_{as} = 12\,ksi$ $\quad \tau_{aB} = 7\,ksi$

Find : largest angle through which A can be rotatied

Solutron :

recall : $\phi = \frac{TL}{JG}$

steel rod : $\phi_s = \frac{T \cdot (h_1 + h_2)}{J \cdot G}$, $J = \frac{\pi}{2} \cdot \left(\frac{d_s}{2}\right)^4$

$\phi_s = \frac{32\,T\,(h_1 + h_2)}{\pi\, d_s^4 \cdot G}$

$\tau_s = \frac{Tc}{J} \rightarrow T = \frac{J\tau_s}{c}$

$T = \frac{\pi}{2} c^3 \tau_s$

$T_s = \frac{\pi}{16} d_s^3 \tau_s = 7.95\,kip\,in$

for brass, $T_b = \frac{J\tau_B}{c}$, $J = \frac{\pi}{2}(c_o^4 - c_I^4)$

$T_b = \frac{\frac{\pi}{2}(c_o^4 - c_I^4)\tau_B}{c_o}$ $\quad c_o = \frac{d_B}{2}$, $c_I = \frac{d_B}{2} - t$

$T_b = 19.2\,kip\,in$

$\rightarrow T_s = 7.95\,kip$ highest allowable Torque

$\phi_s = \frac{32 T_s (h_1 + h_2)}{\pi\, d_s^4 \cdot G_s} = 0.0171\,rad = 0.982^\circ$

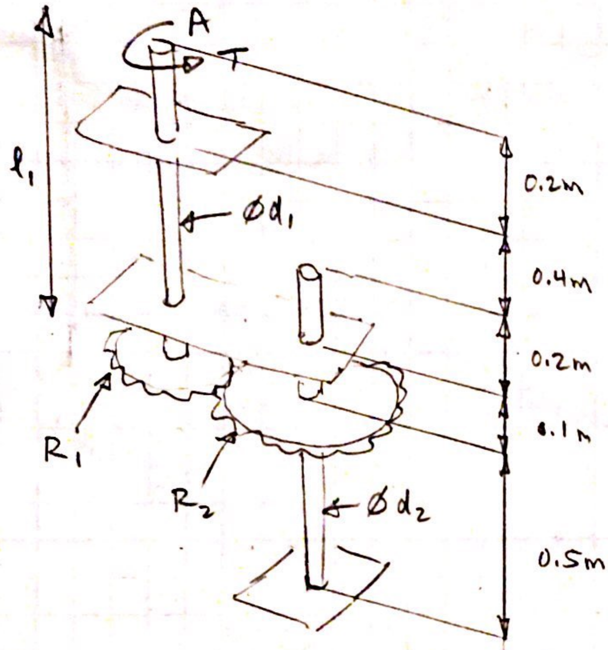
$\phi_B = \frac{T_s h_1}{J_B\, G_B}$, $J_B = \frac{\pi}{2}(c_o^4 - c_I^4)$

$\phi_B = \frac{7.95\,kip \cdot in \cdot 8\,in}{\frac{\pi}{2}(1.5\,in^4 - 1.25\,in^4) \cdot 5.6 \cdot 10^6\,psi} = 0.00276\,rad = 0.158^\circ$

$$\boxed{\phi_{tot} = \phi_s + \phi_B = 1.14^\circ}$$

3.42

Given:



$T = 200$ N·m
$G = 77.2$ GPa

$d_1 = 30$ mm $\rightarrow r_1 = 15$ mm
$R_1 = 60$ mm
$l_1 = 0.9$ m

$d_2 = 30$ mm $\rightarrow r_2 = 15$ mm
$R_2 = 90$ mm
$l_2 = 0.5$ m

Find: angle through which A rotates

Solution: $\underbrace{T_1 = F_g R_1 \quad ; \quad T_2 = F_g R_2}$

$$\frac{T_1}{R_1} = \frac{T_2}{R_2} \longrightarrow T_2 = T_1 \cdot \frac{R_2}{R_1}$$

$$\phi_1 = \frac{T_1 l_1}{J_1 G} \quad , \quad J = \frac{\pi}{2} r_1^4$$

$$\phi_1 = \frac{T_1 l_1 \cdot 2}{\pi r_1^4 \cdot G}$$

$$\phi_1 = 0.0293 \text{ rad} = 1.68^\circ$$

$$\phi_2 = \frac{T_2 l_2 \cdot 2}{\pi r_2^4 \cdot G}$$

$$\phi_2 = 0.0244 \text{ rad} = 1.40^\circ$$

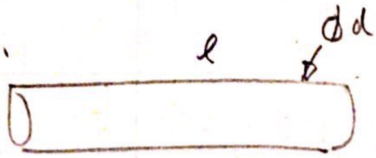
$$\phi_{2/1} = \phi_2 \cdot \frac{R_2}{R_1} = 2.1^\circ$$

$$\boxed{\rightarrow \phi_{tot} = \phi_1 + \phi_{2/1} = 3.78^\circ}$$

3.45:

Given:

$l = 1.2\,m$
$\phi_{all} = 4^{\circ}$
$T = 750\,N\cdot m$
$\tau = 90\,MPa$
$G = 77.2\,GPa$



Find: required diameter d

Solution:

$$\phi = \frac{TL}{JG} \quad , \quad J = \frac{\pi}{2} r^4$$

$$\phi = \frac{TL \cdot 2}{\pi r^4 G}$$

$$\rightarrow r = \left(\frac{2TL}{\pi \phi G}\right)^{\frac{1}{4}} \quad , \ \phi \text{ in rad} \rightarrow \phi_{rad} = 0.0698$$

$$r = 0.01805\,m$$

$$\rightarrow d = 2r = 36.1\,mm \quad \text{by } G$$

$$\tau = \frac{Tc}{J}$$

$$\tau = \frac{Tc}{\frac{\pi}{2} c^4}$$

$$\rightarrow c^3 = \frac{2T}{\pi \tau}$$

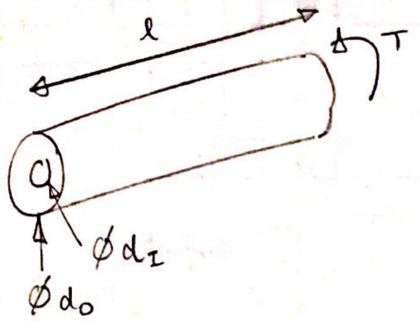
$$c = \left(\frac{2T}{\pi \tau}\right)^{1/3} = 0.0174\,m$$

$$\rightarrow d = 2c = 34.9\,mm \quad \text{by } \tau$$

by G larger $\rightarrow$ $\boxed{d = 36.1\,mm}$

3.71:

Given:



$\tau_a = 50\text{ MPa}$
$G = 77.2\text{ GPa}$

$\omega = 240\text{ rpm} = 8\pi\text{ rad/s}$
$d_o = 60\text{ mm}$
$d_I = 25\text{ mm}$
$\ell = 5\text{ m}$

Find:

a) maximum power that can be transmitted
b) corresponding ϕ

Solution:

a) $\tau = \dfrac{Tc}{J} \rightarrow T = \dfrac{\tau J}{c}$, $J = \dfrac{\pi}{2}(c_o^4 - c_I^4)$, $c_o = \dfrac{d_o}{2}$, $c_I = \dfrac{d_I}{2}$

$$T = \frac{\tau_a \cdot \pi (c_o^4 - c_I^4)}{2 \cdot c_o}$$

$$T = 2057\text{ N}\cdot\text{m}$$

$$P = T\omega$$
$$P = 2057\text{ N}\cdot\text{m} \cdot 8\pi\text{ rad/s}$$
$$\boxed{P = 51.7\text{ kW}}$$

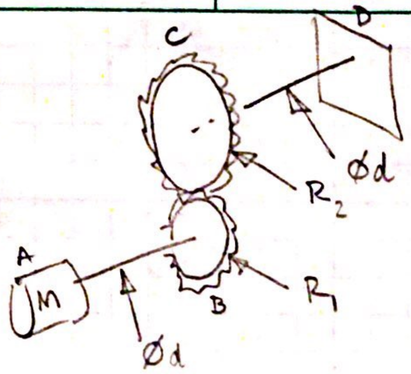
b) $\phi = \dfrac{TL}{JG}$, $J = \dfrac{\pi}{2}(c_o^4 - c_I^4)$

$$\phi = \frac{2TL}{\pi(c_o^4 - c_I^4)\,G}$$

$$\boxed{\phi = 0.108\text{ rad} = 6.19^\circ}$$

3.76:

Given:



$P = 16$ hp
$\omega = 1260$ rpm $= 42\pi$ rad/s
$d = 1$ in
$R_1 = 3$ in , $R_2 = 5$ in

Find: a) τ_{max} in AB
b) τ_{max} in CD

Solution:

note: 1 hp = 550 lb ft/s = 6600 lb in/s

$$P = T\omega \longrightarrow T = \frac{P}{\omega}$$

$$T = \frac{16 \text{ hp} \cdot 6600 \text{ lb in/s/hp}}{42\pi \text{ rad/s}}$$

$$T_m = 800 \text{ lb in}$$ torque from motor

a) $$\tau_{AB} = \frac{T_m c}{J}$$

$$= \frac{2T_m}{\pi c^3}, \quad c = \frac{d}{2}$$

$$\boxed{\tau_{AB} = 4.08 \text{ ksi}}$$

b) $$\frac{T_m}{R_1} = \frac{T_{CD}}{R_2} \longrightarrow T_{CD} = \frac{R_2}{R_1} T_m$$

$$\tau_{CD} = \frac{2T_{CD}}{\pi c^3}$$

$$= \frac{2R_2 T_m}{\pi R_1 c^3} = \frac{R_2}{R_1}\tau_{AB}$$

$$\boxed{\rightarrow \tau_{CD} = 6.8 \text{ ksi}}$$

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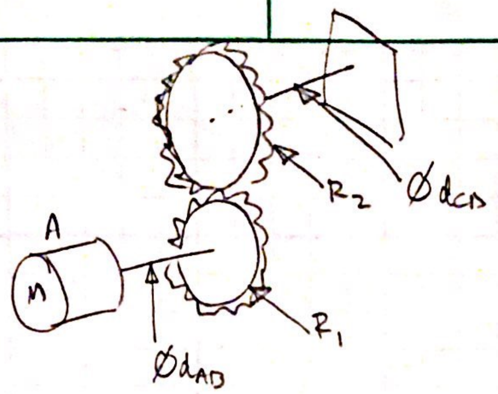
3.77:

Given:



$P = 16$ hp
$\omega = 1260$ rpm
$\tau_a = 8$ ksi
$R_1 = 3$ in $\quad R_2 = 5$ in

Find: a) d_{AB}
b) d_{CD}

Solution: $1\text{ hp} = 6600\text{ lb in/s}$

a) $P_A = \dfrac{T_{AB}}{\omega}$, $\omega = 1260\text{ rpm} = 42\pi\text{ rad/s}$

$$T_{AB} = \frac{16\text{ hp} \cdot 6600\text{ lb in/s/hp}}{42\pi\text{ rad/s}}$$

$$T_{AB} = 800\text{ lb in}$$

$$\tau = \frac{Tc}{J} \quad , \quad J = \frac{\pi}{2}c^4$$

$$\rightarrow \tau_{AB} = \frac{T_{AB} \cdot 2}{\pi c^3}$$

$$c^3 = \frac{2T_{AB}}{\pi \tau_{AB}} \longrightarrow c = \left[\frac{2T_{AB}}{\pi \tau_{AB}}\right]^{1/3}$$

$$c_{AB} = 0.40\text{ in}$$

$$\rightarrow \boxed{d_{AB} = 0.80\text{ in}}$$

b) $$\frac{T_{CD}}{R_2} = \frac{T_{AB}}{R_1}$$

$$T_{CD} = \frac{R_2}{R_1} T_{AB}$$

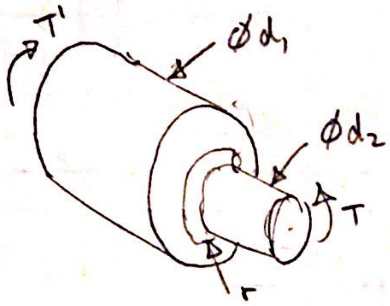
$$\rightarrow c_{CD} = \left[\frac{R_2}{R_1} \cdot \frac{2T_{AB}}{\pi \tau_{AB}}\right]^{1/3}$$

$$c_{CD} = 0.473\text{ in}$$

$$\rightarrow \boxed{d_{CD} = 0.947\text{ in}}$$

3.87:

Given:



$\omega = 50\ hz$

$r = 8\ mm$

$d_1 = 60\ mm \quad d_2 = 30\ mm$

$\tau = 45\ MPa$

Find: P_{max}

Solution:

from p. 188, K for $r/d = 0.267$, $\frac{D}{d} = 2 \rightarrow K \sim 1.17$

$$\tau_{max} = K\frac{Tc}{J}, \quad J = \frac{\pi}{2}c^4, \quad c = \frac{d_2}{2}$$

$$\tau_{max} = K\frac{2T}{\pi c^3}$$

$$\rightarrow T = \frac{\tau_{max}}{K} \cdot \frac{\pi c^3}{2}$$

$$T = 204\ N\cdot m$$

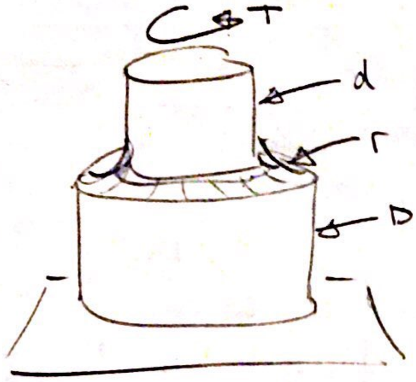
$$P = T\omega, \quad \omega = 50\,hz = 100\pi\ rad/s$$

$$P = 20.4\pi\ kW$$

$$\boxed{P = 64.1\ kW}$$

3.89:

Given:



$D = 1 \text{ in}$

$r = \frac{1}{2}(D-d)$

$T = 200 \text{ lb in}$

Find: a) τ_{max} for $d = 0.8$ in

b) τ_{max} for $d = 0.9$ in

Solution:

a) $\tau_{max} = K\frac{Tc}{J}$

K for $D=1$, $d=0.8$, $r=0.1 \rightarrow K \sim 1.31$

$\rightarrow \tau_{max} = K\frac{T \cdot 2}{\pi c^3}$, $c = d/2$

$\boxed{\tau_{max} \approx 2606 \text{ psi for } d = 0.8 \text{ in}}$

b) K for $D=1$, $d=0.9$, $r=0.05 \rightarrow K \sim 1.42$

$\tau_{max} = K\frac{2T}{\pi c^3}$, $c = d/2 = 0.45$

$\boxed{\tau_{max} \approx 1984 \text{ psi for } d = 0.9 \text{ in}}$

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