PROBLEM NO. 6-139	MECHANICAL ENGINEERING DEPARTMENT	NAME KOUL
DATE		SECTION

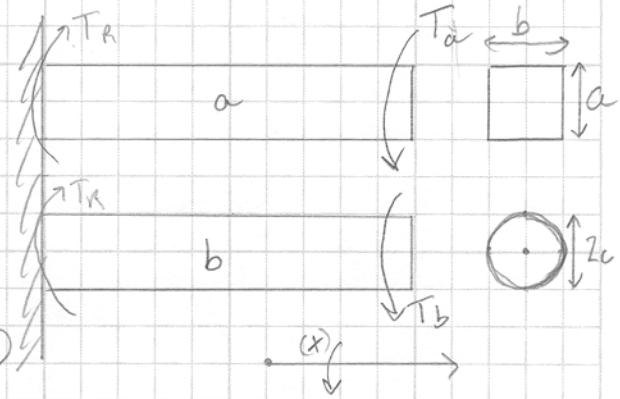
Given: $G = 4000\ ksi$, $L_A = L_B = 3\ ft$
$\tau_{max} \le 12\ ksi$ $\quad d = 2c = a = b = 1.5\ in$

Find: (a) T_{allow} for (a) + (b).
(b) θ_a, θ_b at $T = T_{allow}$

Relationships:

$J_b = \frac{\pi}{2}(0.75)^4 \qquad T_b = \frac{\tau J}{c} \qquad \theta_b = \frac{LT}{JG}$

$T_{rect\ bar\ (a)} = \tau_{max}\alpha a^2 b \qquad \theta_a = \frac{TL}{\beta a^3 b G}$ (Fig 6-28)



System Sketch or FBD

Solution:

Bar b:

$T_{allow} = \frac{\tau_{max} J}{c} = \frac{(12)(\pi(0.75)^3)10^3}{2}$

$\boxed{T_{allow_{(b)}} = 7952\ in\cdot lbs.}$

$\theta_b = \frac{L_b T_{allowb}}{J_b G} = \frac{(3\cdot 12)(7952)}{\frac{\pi}{2}(0.75^4)4{,}000\times 10^3}$

$\boxed{\theta_b = 0.144\ rad}$

Bar a:

$a = b = 1.5\ in$, From Fig 6-28,
$\alpha = 0.21 \quad \beta = 0.145$ for $b/a = 1$

$T_{allow} = \tau_{max}\alpha a^2 b = (12{,}000)(0.21)(1.5)^3$

$\boxed{T_{allow_{(a)}} = 8505\ in\cdot lbs.}$

$\theta_a = \frac{T_{allow} L}{\beta a^3 b G} = \frac{(8505)(3)(12)}{(0.145)(1.5^4)(4000\times 10^3)}$

$\boxed{\theta_a = 0.104\ rad.}$

Conclusion → Square bar can handle more Torque and is stiffer than the circular section, resulting in a smaller deformation.

PROBLEM NO. 6-144 | MECHANICAL ENGINEERING DEPARTMENT | NAME KOUL

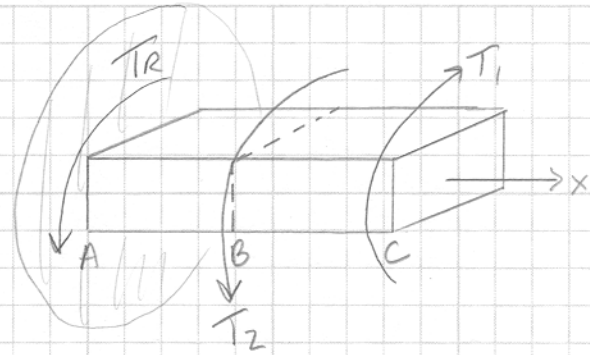
DATE | SECTION

Given: P6-144 $T_1 = T_2 = 2T$

$a = 0.075\,m$ $L_1 = L_2 = 0.8\,m$

$b = 0.100\,m$ $\tau_{max} \le 80\,MPa$

Find: T



Relationships:

$T_r = q2A = \tau 2At$

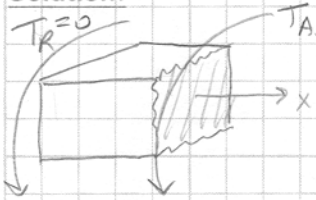
$\Sigma M_x = T_R + T_2 - T_1 = 0$

$T_R + 2T - 2T = 0$

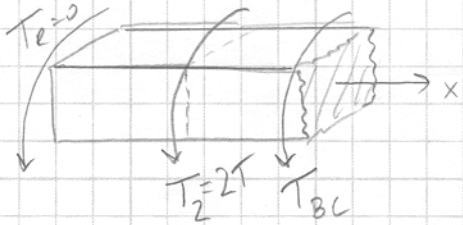
$T_R = 0$

System Sketch or FBD

Solution:



T_{AB}. $T_{AB} = -T_R = 0$

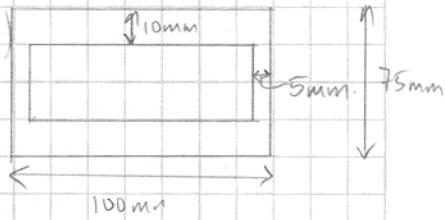


$\Sigma M_x =$

$2T + T_{BC} = 0$

$T_{BC} = -2T$

Given:



$T_{BC} = \tau_{max} 2At$ ← t for thinnest section

$T_{BC} = (80 \times 10^6)(2)(0.075 - 0.01)(0.1 - 0.005)(0.005)$

$T_{BC} = 4940\,N \cdot m$

$T = -\frac{T_{BC}}{2} = -\frac{4940}{2} = -2470\,N \cdot m$

$\boxed{T = -2470\,N \cdot m}$

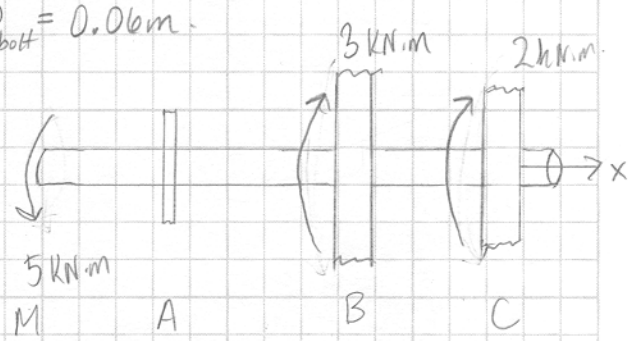
PROBLEM NO. 6-160 | MECHANICAL ENGINEERING DEPARTMENT | NAME KOUL

DATE | SECTION

Given: $T_m = 5\,kN\cdot m$, $T_B = 3\,kN\cdot m$, $T_C = 2\,kN\cdot m$.
$\tau_{allow} \le 80\,MPa$, $\theta_{C/A} \le 2° = 0.03491\,rad$
$L_{AB} = 1\,m$, $L_{BC} = 1.5\,m$, $\tau_{bolt} \le 42\,MPa$, $P_{bolt} = 0.06\,m$.
$G = 76\,GPa$

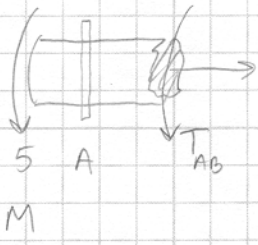
Find: (a) d_s to the nearest 5 mm.
(b) d_{bolt} to the nearest 5 mm

Relationships:



System Sketch or FBD

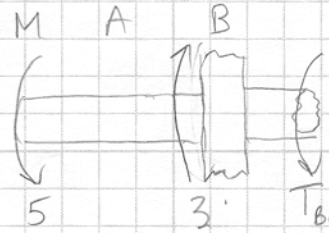
Solution:



$T_{AB} + 5 = 0$

$T_{AB} = T_A = -5\,kN\cdot m$

$T_A = 5\,kN\cdot m$ ↑



$T_{BC} - 3 + 5 = 0$

$T_{BC} = -2\,kN\cdot m$

$T_{BC} = 2\,kN\cdot m$ ↑

(a) $T = \frac{\tau J}{c} = \tau \frac{\pi c^3}{2} \Rightarrow 2c = 2\sqrt[1/3]{\frac{2T}{\tau\pi}} = d_{min}$

$$d_{min\,(shaft)} = 2\sqrt[1/3]{\frac{2T_A}{\tau_{allow}\pi}} = 2\sqrt[1/3]{\frac{(5000)(2)}{80(10^6)(\pi)}} = 0.0683\,m$$

$d_{min\,(shaft)} = 70\,mm$

$$\theta_{C/A} = \theta_{B/A} + \theta_{C/B} = \frac{L_{AB}T_{AB}}{JG} + \frac{L_{BC}T_{BC}}{JG} \Rightarrow J = \frac{1}{\theta G}\left[L_{AB}T_{AB} + L_{BC}T_{BC}\right]$$

$\pi/2\, c^4$

$$d_{min} = 2c = 2\left(\frac{2}{\pi\theta G}\left[L_{AB}T_{AB} + L_{BC}T_{BC}\right]\right)^{1/4} = 2\left[2.3995\times10^{-10}\left[5000 + 3000\right]\right]^{1/4}$$

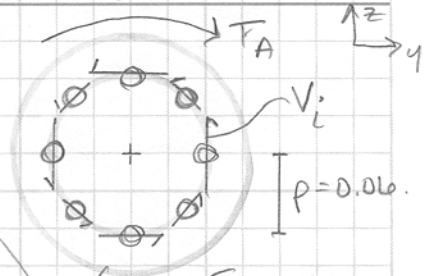
$d_{min\,(shaft)} = 0.074\,m$

$\boxed{d_{min} = 75\,mm}$

6-60 cont'd

System Sketch or FBD

Solution:



(b) Bolt ring must resist T_A

① $T_A = V\rho = 8V_i\rho$ where V_i is the shear load that each bolt carries and ρ is the radius of the bolt ring

From FBD:

$$\left(\Sigma M_x = 8V_i\rho - T_A = 0\right)$$

$$V_i = \frac{T_A}{8\rho}$$

$$V_i = \frac{T_A}{8\rho} = \frac{5000\ \text{N}\cdot\text{m}}{8\,(0.06\ \text{m})} = 10416.7\ \text{N}$$

$$\tau_{bolt} = \frac{V_i}{\frac{\pi}{4} d_{bolt}^2} = 42\ \text{MPa}$$

$$d_{bolt} = \sqrt{\frac{4V_i}{\pi \tau_{bolt}}} = \sqrt{\frac{4(10416.7)}{\pi(42\times10^6)}} = 0.0178\ \text{m}$$

$$\boxed{d_{bolt} = 20\ \text{mm}}$$