3.2. (a) Determine the T which causes \( \tau_{\text{max}} = 45 \text{ MPa} \) in a hollow shaft.
(b) Determine \( \tau_{\text{max}} \) caused by \( T \) in a solid shaft of the same cross area.

Solution:
(a) From the eqn:
\[
\tau_{\text{max}} = \frac{TC}{J} \Rightarrow T = \frac{\tau_{\text{max}} C}{J}
\]
\[
J = \frac{2}{3} \pi \left( (45 \text{ mm})^4 - (30 \text{ mm})^4 \right) = 5.17 \times 10^6 \text{ m}^4
\]
\[
T = \frac{45 \times 10^6 \text{ Pa} \times 5.17 \times 10^{-2} \text{ m}^4}{45 \times 10^{-3} \text{ m}} = 5.17 \text{ KN-m}
\]

(b) \( \tau_{\text{max}} = \frac{TC}{J} \)

\[
\tau_{\text{max}} = \frac{3 \text{ kip-in}}{J}
\]
\[
J = \frac{3}{2} \pi \left( 33.5 \text{ mm} \right)^4
\]
\[
\tau_{\text{max}} = \frac{3 \times 1920 \text{ ksi}}{5.8 \pi (33.5 \text{ mm})^3} = 4.46 \text{ ksi}
\]

3.24. (a) Determine \( \phi \) caused by \( T = 40 \text{ kip-in} \) in a solid shaft with \( G = 3.7 \times 10^6 \text{ psi} \).

(b) Solve part (a) for a hollow shaft with \( d_{\text{in}} = 3'' \), \( d_{\text{out}} = 1'' \).

Solution:
Rotation of end A:
\[
\phi_A = \phi_{\text{AE}} + \phi_B \tag{1}
\]
\( \phi_B \) is the twist angle at B = rotation of gear B.
Need \( \phi_B \), can be found from gear system:

\[ \Rightarrow \phi_B = \frac{25}{4} \frac{Ta}{JG} \]

\[ \phi_A/B = \frac{Ta/AB}{JG} = \frac{Ta(24 \text{ in})}{JG} \]

\[ \Rightarrow \phi_A = \frac{1}{J} [ \frac{Ta(24 \text{ in}) (25/4 + 1)}{JG} ] \]

\[ J = (174 \text{ in}) \frac{Ta}{\phi_A/G} \]

\[ \phi_A = 7.5^\circ \]

\[ J = 0.237 \text{ in}^4 \]

\[ \Rightarrow d = 1.24 \text{ in.} \]

So, to have \( \phi_A = 7.5^\circ \), \( d \geq 1.24 \text{ in.} \)

But we also have \( \tau_{11} = 12 \text{ ksi} \), need to check it out:

- \( \tau_{AB} = \frac{TaC}{J} = \frac{(2 \text{ kip} \cdot \text{in})(0.62 \text{ in})}{\frac{1}{12} \pi (0.62 \text{ in})^4} = 5.34 \text{ ksi} < 12 \text{ ksi} \)

So \( d = 1.24 \text{ in.} \) is fine for \( AB \)

- \( \tau_{CD} = \frac{TaC}{J} = \frac{(TaC)(C/2)}{J} = \frac{(2 \text{ kip} \cdot \text{in})(2)}{J} = 13.134 \text{ ksi} > \tau_{11} \)
Cont. 3.38.

\[ d = 1.24 \text{ in} \text{ doesn't satisfy } T_{CD} < T_{all} \]

For \[ T_{CD} = \left( \frac{5}{2} \right) \left( 2 \text{ kip in} \right) \left( \frac{1}{2} \pi \right) C^3 \]

\[ C \geq 0.6425 \text{ in} \]
\[ d \geq 1.285 \text{ in} \]

We need to take the larger one to make \[ C \leq T_{all} \]
\[ \phi_A \leq 7.5^\circ \]

\[ d = 1.285 \text{ in} \]

3.50. b.
Given: \[ T = 20 \text{ kip in} \]
Find: (b) \( T_{CD} \) in sleeve CD

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\[ T = T_{AB} + T_{CD} \] (1)

(1) From the geometry condition:
\[ \phi_E = \phi_{AB} = \phi_{CD} \] (they're all fixed to each other)

\[ T_{AB} = \frac{T_{CD}}{J_{AB} G_{AB}} \]
\[ T_{AB} = \frac{T_{CD}}{J_{AB} G_{AB}} \]

\[ T_{CD} = \frac{T_{CD}}{J_{AB} G_{AB}} \frac{J_{CD}}{J_{AB}} \]

\[ \frac{T_{CD}}{J_{AB} G_{AB}} \frac{J_{CD}}{J_{AB}} \]

\[ = \frac{(0.75 \text{ in})^4}{(1.2 \times 10^6 \text{ psi}) \cdot 1.25 \text{ in}} \]

\[ = 0.16 \]

\[ T_{CD} = 0.161 T_{CD} \] (2)

Put (2) \( \Rightarrow \)

\[ T = 1.161 T_{CD} = 20 \text{ kip in} \]

\[ T_{CD} = 17.2 \text{ kip in} \]

\[ T_{CD} = \frac{0.364 \text{ in}^3}{T_{CD}} \]

\[ \frac{T_{CD}}{T_{CD}} = 0.364 \times 17.2 \text{ kip in}^2 \]

\[ = 6.26 \text{ ksi} \]

\[ T_{max} (\text{CD}) = 6.26 \text{ ksi} \]