Torsion in Shafts. Question 5-63 Solution

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5-63. The device serves as a compact torsional spring. It is made of A-36 steel and consists of a solid inner shaft CB which is surrounded by and attached to a tube AB using a rigid ring at B. The ring at A can also be assumed rigid and is fixed from rotating. If a torque of T 2 kip • in. is applied to the shaft, determine the angle of twist at the end C and the maximum shear stress in the tube and shaft.

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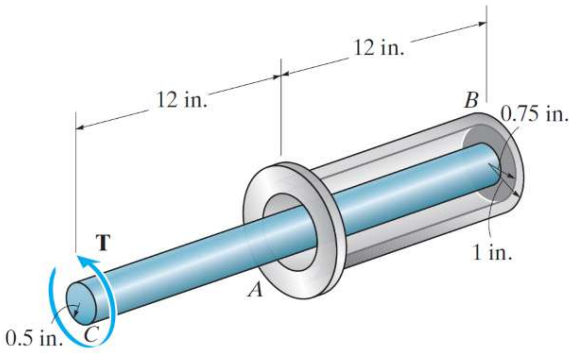


Given data:

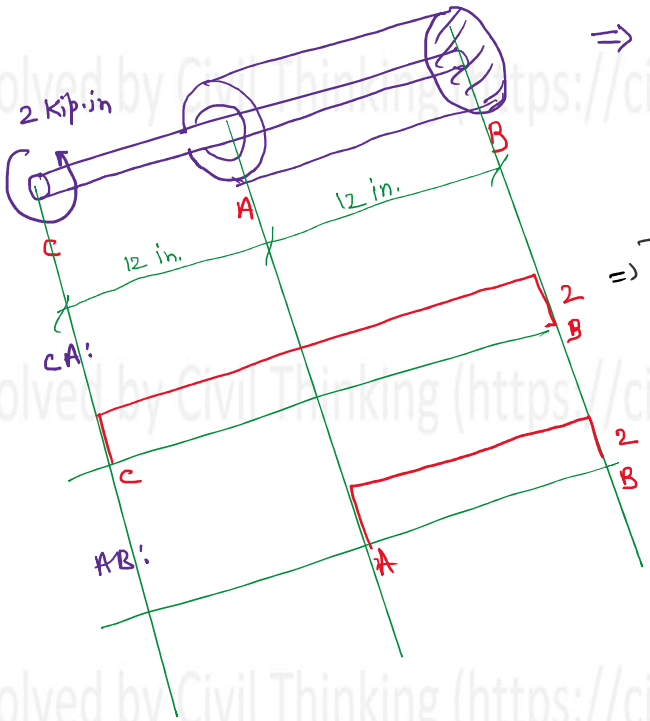
A-36 steel $\Rightarrow G = 11\times10^3$ kips

Shaft: $r = 0.5$ in., $T = 2$ kip·in

Tube: $R = 1$ in., $r = 0.75$ in.

To find:

$\phi_{C/B}$, $\tau_{max-tube}$, $\tau_{max-shaft}$



$\Rightarrow \phi_C = \phi_{CB} + \phi_{BA}$

$\Rightarrow T_{max,BC} = 2$ kip.in

$\Rightarrow T_{max,AB} = 2$ kip.in

$$\frac{\tau_{max,AB}}{R_{AB}} = \frac{T_{AB}}{J_{AB}} \quad [\text{Torsion Equation}]$$

$$\Rightarrow \frac{\tau_{max,AB}}{1\ inch} = \frac{2\ kips.in}{\frac{\pi}{2}\left[(1)^4 - (0.75)^4\right]} = 1.8623\ ksi \quad \text{ANS.}$$

$$\frac{\tau_{max,BC}}{R_{BC}} = \frac{T_{BC}}{J_{BC}}$$

$$\Rightarrow \frac{\tau_{max,BC}}{0.5} = \frac{2\ kips.in}{\frac{\pi}{2} \times 0.5^4} = 10.186\ ksi \quad \text{ANS.}$$

$$\phi_c = \phi_{CB} + \phi_{BA} = \left(\frac{TL}{GJ}\right)_{CB} + \left(\frac{TL}{GJ}\right)_{BA} = \frac{2 \times 24}{11 \times 10^3 \times \frac{\pi}{2} \times 0.5^4} + \frac{2 \times 12}{11 \times 10^3 \times \frac{\pi}{2}\left(1^4 - 0.75^4\right)}$$

$$\Rightarrow \phi_c = 0.04648\ \text{Radians} \times \underbrace{\frac{180}{\pi}}_{\text{converts Radian to degree}} \simeq 2.66^\circ \quad \text{ANS.}$$

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