Torsion in Shafts. Question 5-41 Solution

Tuesday, 11 March, 2025 08:07 AM

•5-41. The A-36 steel tubular shaft is 2 m long and has an outer diameter of 50 mm. When it is rotating at 40 rad/s, it transmits 25 kW of power from the motor M to the pump P. Determine the smallest thickness of the tube if the allowable shear stress is T_{allow} 80 MPa.

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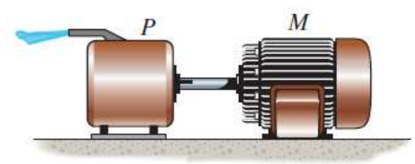
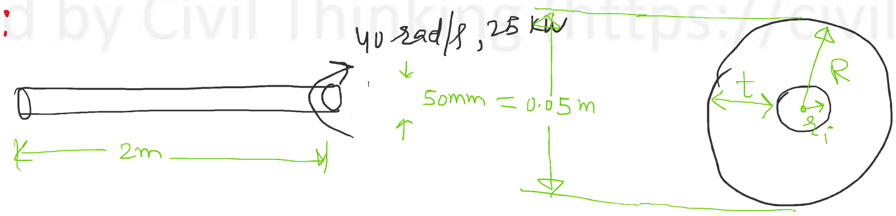


Given Data:



$R = r_i + t$

$\frac{d_o}{2} = r_i + t$

$\frac{0.05}{2} = r_i + t$

$0.025\,m = r_i + t$

$\Rightarrow t = 0.025 - r_i$

$\tau_{allow} = 80\,MPa = 80\times10^6\,N/m^2$

To find: thickness, t

Since $t = 0.025 - r_i$ it means once we get the internal radius, r_i of the shaft, we can find thickness, t from it.

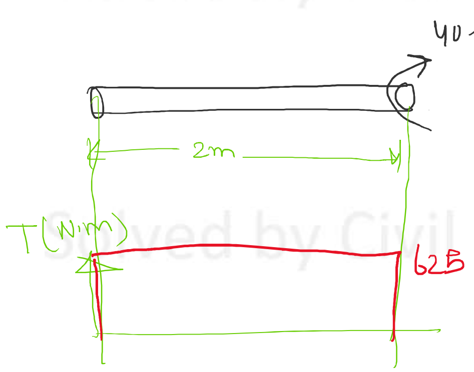
We know:

$$\frac{\tau}{R} = \frac{T_{max}}{J} \Rightarrow \frac{80\times10^6\,N/m^2}{\frac{d_o}{2}} = \frac{T_{max}}{\frac{\pi}{2}\left[\left(\frac{d_o}{2}\right)^4 - \left(\frac{d_i}{2}\right)^4\right]} \quad (1)$$

$$\frac{d_o}{2} = \frac{50mm}{2} = 0.025m \; ; \; \frac{d_i}{2} = r_i$$

T_{max} will be absolute max. internal torque, since we are designing (finding dimension) the given shaft.

40 rad/s, 25 kW



$$T = \frac{P}{\omega} = \frac{25\times10^3 \text{ watt}}{40 \text{ rad/s}} = 625 \text{ N.m}$$

⇓

$T_{max,abs.} = 625$ N.m

Substituting it in equation ①:

$$\frac{80\times10^6 \text{ N/m}^2}{\frac{d_o}{2}} = \frac{625 \text{ N.m}}{\frac{\pi}{2}\left[\left(\frac{d_o}{2}\right)^4 - \left(\frac{d_i}{2}\right)^4\right]}$$

$\frac{d_o}{2}$ = 0.025m ; $\frac{d_i}{2}$ → r_i

Solving the equation, yields $r_i \simeq 0.022716$ m

We found earlier, $t = R - r_i = 0.025\text{m} - 0.022716\text{ m} = 0.002284\text{m}$

⇒ thickness of the shaft $\geq$ 2.28 mm ≃ 2.5 mm

ANS.

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