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## Mechanical Engineering - Strength of Materials

### Torsion in Circular Shafts

#### Given Data and Introduction

- The radius of the solid shaft (r) = 20 mm = 0.02 m
- Power transmitted by the shaft (P) = 2.5 kW = 2500 W
- Frequency (f) = 50 Hz

The objective is to determine the maximum shear stress (\(\tau_{max}\)) in the shaft.

#### Step 1: Calculating the Torque

The relationship between power (P), torque (T), and angular velocity (\(\omega\)) is given by:

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P = T \cdot \omega
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First, calculate the angular velocity (\(\omega\)) using the frequency (f):

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\(\omega = 2 \pi f\)
Substitute \( f = 50 \, \text{Hz} \):
\(\omega = 2 \pi \times 50\)
\(\omega = 100 \pi \, \text{rad/s}\)
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Explanation: The angular velocity is calculated from the rotational frequency using the relation \(\omega = 2 \pi f\).

Supporting Statement: Calculating \(\omega\) is essential because it is directly used in the power-torque relationship.

Step 2: Solving for Torque (T)

Using the power-torque relationship:

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P = T \cdot \omega
Rearrange to solve for T:
T = \frac{P}{\omega}
Substitute \( P = 2500 \, \text{W} \) and \( \omega = 100 \pi \, \text{rad/s}
\):
T = \frac{2500}{100 \pi}
T = \frac{2500}{314.16}
T \approx 7.96 \, \text{N}\cdot\text{m}
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Explanation: The torque is obtained by dividing the power by the angular velocity, reflecting the load on the shaft due to angular motion.

Supporting Statement: Torque calculation is critical as it directly relates to the shear stress in the shaft material.

Step 3: Calculating Maximum Shear Stress

The maximum shear stress (\(\tau_{max}\)) in a solid shaft is given by:

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\(\tau_{max} = \frac{T \cdot r}{J} \)
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Where:
- \(J \) is the polar moment of inertia for a solid circular shaft
- \(J = \frac{\pi}{2} r^4 \)

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Substitute \( r = 0.02 \, \text{m} \):
J = \frac{\pi}{2} (0.02)^4
J = \frac{\pi}{2} \times 1.6 \times 10^{-7}
J = 8 \times 10^{-8} \pi
J \approx 2.513 \times 10^{-7} \, \text{m}^4
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Now, substitute \( T = 7.96 \, \text{N} \cdot \text{m} \), \( r = 0.02 \,
\text{m} \), and J = 2.513 \times 10^{-7} \, \text{m}^4:
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\(\tau_{max} = \frac{7.96 \times 0.02}{2.513 \times 10^{-7}}\)
\(\tau_{max} = \frac{0.1592}{2.513 \times 10^{-7}}\)
\(\tau_{max} \approx 633,200 \, \text{Pa}\)
\(\tau_{max} \approx 633.2 \, \text{kPa}\)
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Explanation: Shear stress is derived from the torque and physical dimensions of the shaft using its polar moment of inertia, capturing the resistance of the shaft to torsional stress.

Supporting Statement: The shear stress calculation provides the measure of internal forces acting in a tangential direction, critical for material strength assessments.

Final Solution

The maximum shear stress in the solid shaft is approximately $633.2 \, \text{kPa}$