6.2 Torsion

Name: _____ Class: _____ Date: _____ **Total: 14 marks**

KEY WORDS torsion • angle of twist

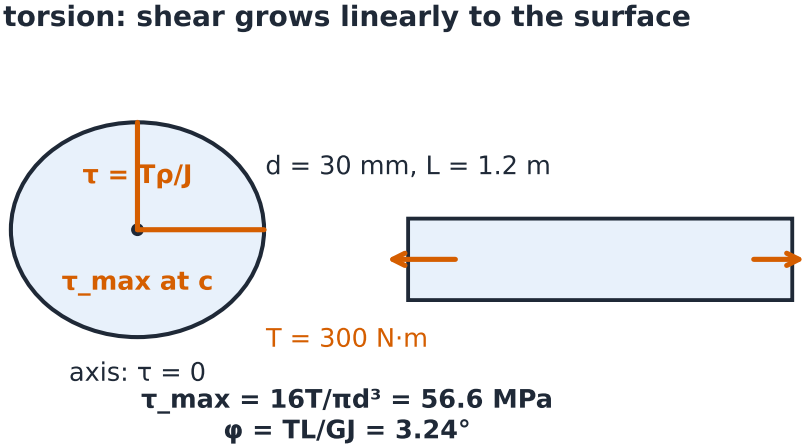
Objective

Price a shaft in torsion: surface shear, angle of twist, transmitted power and the diameter a stress limit demands.

1 Key knowledge and worked examples

■ **Circular-shaft torsion**

$\tau_{max} = 16T/\pi d^3$, $\phi = TL/GJ$, $J = \pi d^4/32$, $P = T\omega$; steel $G = 80$ GPa.



*Shear grows linearly from the axis

■ **Worked example. The 30 mm drive shaft**

$T = 300$ N · m: $\tau = 56.6$ MPa, $\phi = 3.24°$ over 1.2 m ✓; at 180 rpm it transmits 5.65 kW.

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2 Practice

Solid steel shafts, $G = 80$ GPa.

2.1 A shaft of $d = 40$ mm, $L = 2.0$ m carries $T = 600$ N m (steel, $G = 80$ GPa): the maximum shear stress (one decimal, MPa) and the angle of twist (two decimals, degrees). [5]

2.2 The same torque at 240 rpm: the transmitted power (one decimal, kW). [3]

2.3 A shaft for $T = 800$ N m at $\tau_{allow} = 75$ MPa: the required diameter (one decimal, mm). [3]

2.4 One sentence each: where is torsional shear zero and where is it worst, and why does a longer shaft twist more? [3]

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Solutions

2.1

- $\tau_{max} = 16T/\pi d^3 = 9600/(0.2011 \times 10^{-3}) = \mathbf{47.7}$ MPa.
- $J = \pi(0.04)^4/32 = 2.513 \times 10^{-7}$ m^4; $\phi = 1200/(2.011 \times 10^4) = \mathbf{0.0597}$ rad.
- $\phi = 0.0597 \times 180/\pi = \mathbf{3.42}^\circ$.

2.2

- $\omega = 2\pi(240)/60 = 25.13$ rad/s.
- $P = T\omega = 600 \times 25.13 = \mathbf{15.1}$ kW.

2.3

- $d^3 = 16 \times 800 \times 10^3/(\pi \times 75) = \mathbf{54{,}330}$ mm^3, so $d = \mathbf{37.9}$ mm.

2.4

- Zero on the axis, worst at the surface: $\tau = T\rho/J$ is linear in radius.
- $\phi = TL/GJ$ is linear in L - twist accumulates along the shaft.

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