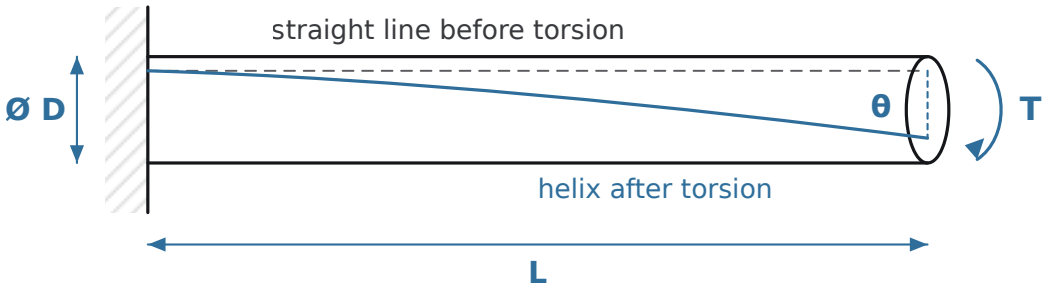
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Shaft torsion: shear stress, angle of twist and minimum diameter

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1. Torsion formulas



Quantity	Solid shaft (Ø D)	Hollow shaft (Ø D, bore d)
Polar moment of inertia J	π·D⁴ / 32	π·(D⁴ − d⁴) / 32
Maximum shear stress τmax	16·T / (π·D³)	16·T·D / (π·(D⁴ − d⁴))
Angle of twist θ (rad)	T·L / (G·J)	T·L / (G·J)
Minimum diameter for τallow	(16·T / (π·τadm))^(1/3)	solve for a chosen d/D ratio
Torque from power	T (N·m) = 9,549 × P (kW) / n (rpm); T (lbf·in) = 63,025 × P (hp) / n	

Units must be consistent: T in N·mm, D and L in mm, G in MPa give τ in MPa and θ in radians (× 180/π for degrees). The shear modulus of steel is G = E / (2·(1 + ν)) ≈ 81,000 MPa (Eurocode 3 value); AISC uses 11,200 ksi, i.e. 11,200,000 psi. The polar moment of inertia J is also explained in the moment of inertia memo.

2. Metric and inch examples

7.5 kW motor at 1,450 rpm, Ø 25 shaft (metric units)

Quantity	Calculation	Result
Torque T	9,549 × 7.5 / 1,450	**49.4 N·m**
Stress τmax	16 × 49,393 / (π × 25³)	**16.1 MPa**
Polar moment J	π × 25⁴ / 32	**38,350 mm⁴**
Angle over 500 mm (G = 81,000 MPa)	49,393 × 500 / (81,000 × 38,350)	**0.0080 rad = 0.46°**
Minimum diameter for τallow = 40 MPa	(16 × 49,393 / (π × 40))^(1/3)	**18.5 mm**

The 40 MPa allowable stress is an example, not a value to copy: it depends on the material, the safety factor, shocks and stress concentrations (grooves, shoulders, keyway). Here the Ø 25 leaves margin in pure torsion; bending, stiffness or the bearing often sets the diameter.

Reference values taken from the article https://www.baouch.fr/en/blog/arbre-torsion-calcul-diametre/, which explains the assumptions, formulas and edge cases. For critical use, check the current standard or the manufacturer's documentation. Free to print and share with credit to the source.