Torsion Test: Shear Stress–Strain by Nadai's Method

Surface shear strain and true surface shear stress from a torque–twist curve of a solid bar by Nadai's method, compared with the elastic and fully plastic formulas.

Method: Nadai's analysis of the torsion test

Input parameters

Unit system: SI

Parameter	Value	Unit
Torque	420.00	N·m
Slope of torque against twist per length	3.2000	
Twist per unit length (rad/m)	12.000	
Bar radius	10.000	mm

Calculated results

Parameter	Value	Unit
Surface shear strain	0.12000	
Surface shear stress (Nadai)	206.65	MPa
Elastic formula $2T/\pi a^3$	267.38	MPa
Fully plastic formula $3T/2\pi a^3$	200.54	MPa
Equivalent tensile stress $\sqrt{3}\tau$ (von Mises)	357.92	MPa

Notes for this case

• Beyond yield the stress across a twisted bar is not linear, so the elastic formula misleads. Nadai: $\tau_a = (\theta' \cdot dT/d\theta' + 3T)/(2\pi a^3)$, using the local slope of the torque–twist curve; surface strain $\gamma_a = a\theta'$. With no hardening (slope zero) it reduces to the fully plastic $3T/2\pi a^3$; in the elastic range $dT/d\theta' = T/\theta'$ and it gives $2T/\pi a^3$. Torsion reaches large strains without necking, useful for hot-working flow curves.

Formula and method

The formula is shown on the calculator page: https://calc.firecad.com/materials/properties/torsion-test-shear-stress

Variables

T	Torque	N·m
dT/d\theta'	Slope of torque against twist per length	-
\theta'	Twist per unit length (rad/m)	-
a	Bar radius	m
γ_a	Surface shear strain	-
τ_a	Surface shear stress (Nadai)	Pa
τ_{el}	Elastic formula $2T/\pi a^3$	Pa
τ_{pl}	Fully plastic formula $3T/2\pi a^3$	Pa
σ_{eq}	Equivalent tensile stress $\sqrt{3}\tau$ (von Mises)	Pa

Method and standards

Torsion test.

Assumptions and limits

- Solid round bar; small change of length; isotropic material.

References

Nadai's analysis of the torsion test

Report details

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Release checks	3 reference cases of this calculator, computed independently, are checked on every release

Results are for engineering estimation. Verify critical designs against the referenced standards and your own data.

This calculator online

https://calc.firecad.com/materials/properties/torsion-test-shear-stress

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.