Thermal Stress in a Composite Bar (Two Materials)

Stresses in two bars of different materials joined to share the same length (bar in a tube, bolt in a sleeve) when heated, from expansion coefficients and areas.

Method: Textbook mechanics (compatibility and equilibrium of a compound bar, Timoshenko, Strength of Materials)

Input parameters

Unit system: SI

Parameter	Value	Unit
Temperature rise	80.000	K
Expansion coefficient of material 1	17.000	µm/(m·K)
Modulus of material 1	110.00	GPa
Area of material 1	600.00	mm²
Expansion coefficient of material 2	12.000	µm/(m·K)
Modulus of material 2	200.00	GPa
Area of material 2	400.00	mm²

Calculated results

Parameter	Value	Unit
Stress in material 1 (negative = compression)	-24.110	MPa
Stress in material 2	36.164	MPa
Force carried (equal and opposite)	14.466	kN
Common strain	0.001141	

Formula and method

$$\sigma_1 = \frac{(\alpha_2 - \alpha_1)\Delta T}{\frac{1}{E_1} + \frac{A_1}{A_2 E_2}}, \quad \sigma_2 = -\sigma_1 \frac{A_1}{A_2}$$

Variables

ΔT	Temperature rise	K
α_1	Expansion coefficient of material 1	1/K
E_1	Modulus of material 1	Pa
A_1	Area of material 1	m²
α_2	Expansion coefficient of material 2	1/K
E_2	Modulus of material 2	Pa
A_2	Area of material 2	m²
σ_1	Stress in material 1 (negative = compression)	Pa
σ_2	Stress in material 2	Pa
F	Force carried (equal and opposite)	N
ε	Common strain	-

Method and standards

Equal strains and equal and opposite forces.

Assumptions and limits

- Elastic, joined at the ends.

References

- Textbook mechanics (compatibility and equilibrium of a compound bar, Timoshenko, Strength of Materials)

Report details

Report reference	FCC-9T39-KF32 (the same inputs always give the same reference)
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Results are for engineering estimation. Verify critical designs against the referenced standards and your own data.

This calculator online

https://calc.firecad.com/mechanical/strength-of-materials/composite-bar-thermal-stress

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Reopens the calculator with the inputs of this report.