

Thermal Stress

Mechanical Engineering

Why restraint, not temperature alone, is what creates thermal stress.

A part free to expand carries strain but no stress. A fully restrained one carries E times α times the change.

free: $\delta = \alpha L \Delta T$ · restrained: $\sigma = E \alpha \Delta T$

Steel bar, $\Delta T = 50$ K

If fully restrained.

$\sigma \approx 120$ MPa

Same bar, free to move

Strain, but no stress.

Zero stress

1 m bar, $\Delta T = 50$ K

$\alpha = 12 \mu\text{m/m per K}$.

$\delta = 0.6$ mm

THE COMMON MISTAKE

✗ **Multiplying total thermal strain by E**

✓ **Only the prevented part causes stress**

Free thermal expansion produces strain with no stress at all. Stress appears only in the fraction of the expansion the supports refuse to allow.

Assumes uniform temperature and constant expansion coefficient.
Gradients and bimetal effects also bend the part.