General information

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Thermal stresses: example
Components are designed to account for thermal expansions

Expansion joints
Thermal stresses: example
In electronic components
Thermal stresses: example
In electronic components: J-lead attachment
Thermal stresses: example
In electronic components: J-lead attachment
Thermal stresses: example
In electronic components: J-lead attachment
Thermal stresses: uniaxial effects

\[ \varepsilon_T = \alpha \Delta T \]
(Thermal strains)

\[ \delta_T = \varepsilon_T \cdot L = \alpha \Delta T \cdot L \]
(Thermal deformations)

\( \alpha \) = linear coefficient of thermal expansion, \( 1/\text{oC}, 1/\text{oF} \)

\( \Delta T \) = temperature differential

\( L \) = original length of component
Principle of superposition

Applied when a component is subjected to complicated loading conditions → break a complex problem into series of simple problems

\[ P = P_1 + P_2 \]

Can only be applied for:

(a) small deformations;
(b) deformations in the elastic (linear) range of the \( \sigma - \varepsilon \) diagram
Axial load: example A

Three bars each made of different materials are connected together and placed between two walls when the temperature is $T_1 = 12 \, ^\circ\text{C}$. Determine the force exerted on the (rigid) supports when the temperature becomes $T_2 = 18 \, ^\circ\text{C}$. The material properties and cross-sectional area of each bar are given in the figure.

<table>
<thead>
<tr>
<th>Material</th>
<th>Modulus of Elasticity ($E$) (GPa)</th>
<th>Coefficient of Thermal Expansion ($\alpha$) (10^{-6}/^\circ\text{C})</th>
<th>Cross-Sectional Area ($A$) (mm$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel</td>
<td>$E_{\text{st}} = 200$</td>
<td>$\alpha_{\text{st}} = 12$</td>
<td>$A_{\text{st}} = 200$</td>
</tr>
<tr>
<td>Brass</td>
<td>$E_{\text{br}} = 100$</td>
<td>$\alpha_{\text{br}} = 21$</td>
<td>$A_{\text{br}} = 450$</td>
</tr>
<tr>
<td>Copper</td>
<td>$E_{\text{cu}} = 120$</td>
<td>$\alpha_{\text{cu}} = 17$</td>
<td>$A_{\text{cu}} = 515$</td>
</tr>
</tbody>
</table>
Axial load: example B

A 6 ft long steam pipe is made of A-36 steel with $\sigma_Y = 40$ ksi. It is connected directly to two turbines $A$ and $B$ as shown. The pipe has an outer diameter of 4 in and a wall thickness of 0.25 in. The connection was made at $T_1 = 70$ °F. If the turbines’ points of attachment are assumed rigid, determine the force the pipe exerts on the turbines when the steam and thus the pipe reach a temperature of $T_2 = 275$ °F.

**Approach:**

1) Compute thermal deformations

2) Apply compatibility equations & superposition

3) Compute force
Axial load: example C

The bronze C86100 pipe has an inner radius of 0.5 in. and a wall thickness of 0.2 in. If the gas flowing through it changes the temperature of the pipe uniformly from $T_A = 200 \, ^{\circ}\text{F}$ at $A$ to $T_B = 60 \, ^{\circ}\text{F}$ at $B$, determine the axial force it exerts on the walls. The pipe was fitted between the walls when $T = 60 \, ^{\circ}\text{F}$.
Axial load: example D

The A-36 steel rod has a diameter of 50 mm and is lightly attached to the rigid supports at $A$ and $B$ when $T_1 = 50 \, ^\circ C$. Determine the force $P$ that must be applied to the collar at its midpoint so that, when $T_2 = 30 \, ^\circ C$, the reaction at $B$ is zero.

Approach:

1) Compute thermal deformations

2) Apply compatibility equations & superposition

3) Compute force
Reading assignment

• Chapters 3 and 4 of textbook
• Review notes and text: ES2001, ES2501
Homework assignment

• As indicated on webpage of our course