

MODELOWANIE I SYMULACJA ZAGADNIENÍ BIOMEDYCZNYCH

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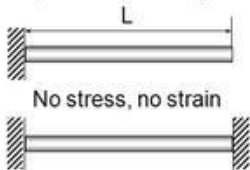
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THERMAL STRESS

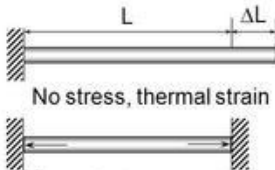
THERMAL STRESSES

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- Temperature change causes thermal strain



(a) at $T = T_{ref}$



(b) at $T = T_{ref} + \Delta T$

- Constraints cause thermal stresses
- Thermo-elastic stress-strain relationship

$$\sigma = E(\varepsilon - \alpha\Delta T)$$

Thermal expansion coefficient

$$\varepsilon = \frac{\sigma}{E} + \alpha\Delta T$$



EQUATIONS

The screenshot displays the COMSOL Multiphysics 5.3.0.260 software interface. The top menu bar includes File, Home, Definitions, Geometry, Materials, Physics, Mesh, Study, Results, and Developer. The ribbon below the menu bar contains various tool icons for building models, adding materials, and performing calculations.

The **Model Builder** window on the left shows a tree view of the model structure:

- TS01.mph (root)
 - Global Definitions
 - Materials
 - Component 1 (comp.1)
 - Definitions
 - Geometry 1
 - Cylinder 1 (cy.1)
 - Cylinder 2 (cy.2)
 - Form Union (fin)
 - Materials
 - Solid Mechanics (solid)
 - Linear Elastic Material 1
 - Free 1
 - Initial Values 1
 - Heat Transfer in Solids (ht)
 - Solid 1
 - Initial Values 1
 - Thermal Insulation 1
 - Multiphysics
 - Thermal Expansion 1 (te.1)
 - Temperature Coupling 1 (tc.1)
 - Mesh 1
 - Study 1
 - Step 1: Time Dependent
 - Results

The **Settings** window in the middle shows the configuration for **Cylinder 2**:

- Object Type: Solid
- Size and Shape: Radius: 0.05 m, Height: 0.5 m
- Position: x: 0.5 m, y: 0 m, z: 0 m
- Axis: Axis type: x-axis
- Rotation Angle: Rotation: 0 deg

The **Graphics** window on the right shows a 3D visualization of the cylinder. The cylinder is centered at (0.5, 0, 0) with a radius of 0.05 m and a height of 0.5 m. The coordinate system (x, y, z) is shown, with x pointing right, y pointing up, and z pointing out of the page. The cylinder's length along the x-axis is 0.5 m, and its radius is 0.05 m. The z-axis ranges from -0.1 to 0.1 m.

The **Messages** window at the bottom shows the text: COMSOL Multiphysics 5.3.0.260

▼ Equation

Show equation assuming:

Study 1, Time Dependent ▼

$$0 = \nabla \cdot \mathbf{S} + \mathbf{F}_v$$

$$\mathbf{S} = \mathbf{S}_{ad} + \mathbf{C} : \boldsymbol{\epsilon}_{el}, \quad \boldsymbol{\epsilon}_{el} = \boldsymbol{\epsilon} - \boldsymbol{\epsilon}_{inel}$$

$$\mathbf{S}_{ad} = \mathbf{S}_0 + \mathbf{S}_{ext} + \mathbf{S}_q$$

$$\boldsymbol{\epsilon}_{inel} = \boldsymbol{\epsilon}_0 + \boldsymbol{\epsilon}_{ext} + \boldsymbol{\epsilon}_{th} + \boldsymbol{\epsilon}_{hs} + \boldsymbol{\epsilon}_{pl} + \boldsymbol{\epsilon}_{cr} + \boldsymbol{\epsilon}_{vp}$$

$$\boldsymbol{\epsilon} = \frac{1}{2} [(\nabla \mathbf{u})^T + \nabla \mathbf{u}]$$

$$\mathbf{C} = \mathbf{C}(E, \nu)$$

▼ Equation

Equation form:

Study controlled ▼

Show equation assuming:

Study 1, Time Dependent ▼

$$\rho c_p \frac{\partial T}{\partial t} + \rho c_p \mathbf{u} \cdot \nabla T + \nabla \cdot \mathbf{q} = Q + Q_{ted}$$

$$\mathbf{q} = -k \nabla T$$

▼ Study Settings

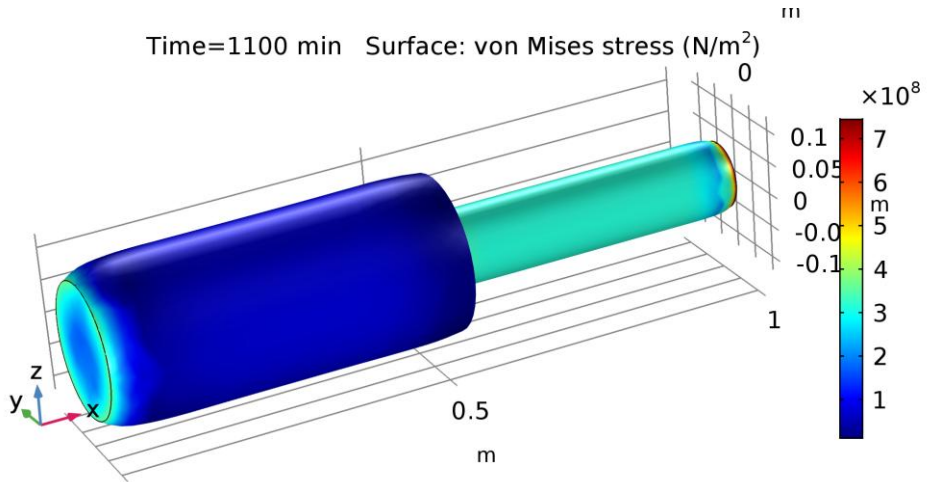
Time unit: min

Times: range(0,10,1100) min 

Tolerance: Physics controlled

Include geometric nonlinearity

RESULTS



Time=200 min Surface: Temperature (K)

