## **Bone Remodeling**

We will use COMSOL to implement a simple bone remodeling simulation, more precisely a simplified version of the model described by <u>Mullender & Huiskes, 1995</u>. The evolution of "relative bone density" m shall be governed by

$$\dot{m}(\boldsymbol{x},t) = \tau \cdot (S(\boldsymbol{x},t) - k)$$

with the strain energy density (SED) *S*, a reference SED *k* and a remodeling rate constant  $\tau$ . In this simplified model, the remodeling stimulus is thus simply the deviation of the SED at the current location from a reference value, *but not* the weighted influence of surrounding "osteo-cytes".

Mechanical loads, boundary conditions and other parameter values should generally correspond to those described in the paper. Only for the parameter k we recommend a slightly different value of k = 0.05 MPa.

## Tasks

- 1. Implement the model using COMSOL (2D, time-dependent).
- 2. Compare your results to those presented by Mullender & Huiskes 1995.
- 3. Investigate the influence of the parameters.

## Suggestions

- Your model should consist of two "physics" components: "Solid Mechanics" to compute the SED and a "Coefficient Form PDE" to describe the evolution of *m*.
- Initial conditions: Instead of a homogenous density distribution, we recommend using a simple initial structure, e.g. a "trabecular grid", instead.
- It is critically important to ensure  $0 < m \le 1$ . Hint: The if-operator may proof useful.
- For a more stable solution, choose "discontinuous Lagrange" with a "constant" Ansatz for the discretization of *m* (meaning that *m* is considered to be piecewise-constant).

