Viscoplasticity of a Polymeric Composite

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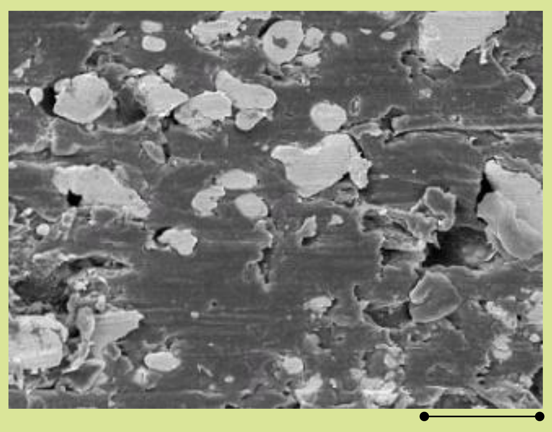
Introduction. The work is focused on the phenomenological modeling of the mechanical behavior of the polymeric material PTFE containing filler particles of bronze, which is done for the three-dimensional and quasi-static case within the theory of finite deformations. Furthermore the material response of the polymeric composite material is captured by a micro-macro simulation in form of a representative volume element (RVE).



50 µm

The compsite material consists of:

- a polymeric matrix material - **P**oly**t**etra**f**luoro**e**thylene – **PTFE**
- filler particles - bronze (25 volume percent)

Problem Definition

The inelastic material behavior of a polymeric composite in an industrial application as a sealing ring shall be modelled for simulations. The existing constitutive models are not exact enough for this particular class of materials. In addition we are seeking for more information about the interaction between both components on the microscale.

Objectives

Development of suitable constitutive equations to approximate the viscoplastic behavior of a polymeric material. The computational results are compared to cyclic tensile tests as well as a relaxation test. An RVE shall be generated to study the interaction of the filler particles with the matrix material.

Cooperation

Prof. Thomas Kletschkowski, Hochschule für Angewandte Wissenschaften Hamburg; Robert Bosch GmbH

Phenomenological Model for PTFE

The viscoplastic behavior of the polymeric matrix material is captured by the following constitutive equations :

isomorphy condition

$$\mathbf{S} = 2\,\rho_o \det \mathbf{P}\; \mathbf{P}\, \frac{\partial \psi}{\partial \underset{\sim}{\mathbf{C}}}\, \mathbf{P}^T$$

flow rule

$$d\mathbf{P}\,\mathbf{P}^{-1} = \mathbf{N}_1\, dz_1 + \mathbf{N}_2\, dz_2$$

flow directions

$$\mathbf{N}_1 = -\,dev\,(\mathbf{S}\mathbf{C})$$

$$\mathbf{N}_2 = -\frac{dev\,(\mathbf{D}_m)}{\|\, dev\,(\mathbf{D}_m)\,\|}$$

The scales dz_i include beside the integration paths the hardening and viscosity functions.The Neo-Hookean law is used for the hyperelastic response.

Micro-Macro Simulation

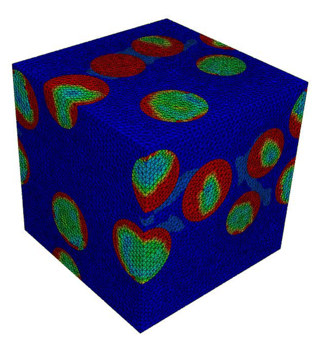
The numerical homogenization is done by performing a finite element calculation for an RVE with periodic boundary conditions with the assumptions listed below.

macro-micro transition

periodic displacement boundary conditions

$$\mathbf{u}_1 - \mathbf{u}_2 = \langle \mathbf{H} \rangle (\mathbf{X}_1 - \mathbf{X}_2)$$

RVE



- polymeric viscoplastic matrix material
- elastoplastic filler particles
- randomly distributed, spherical shape
- no debonding at the interface

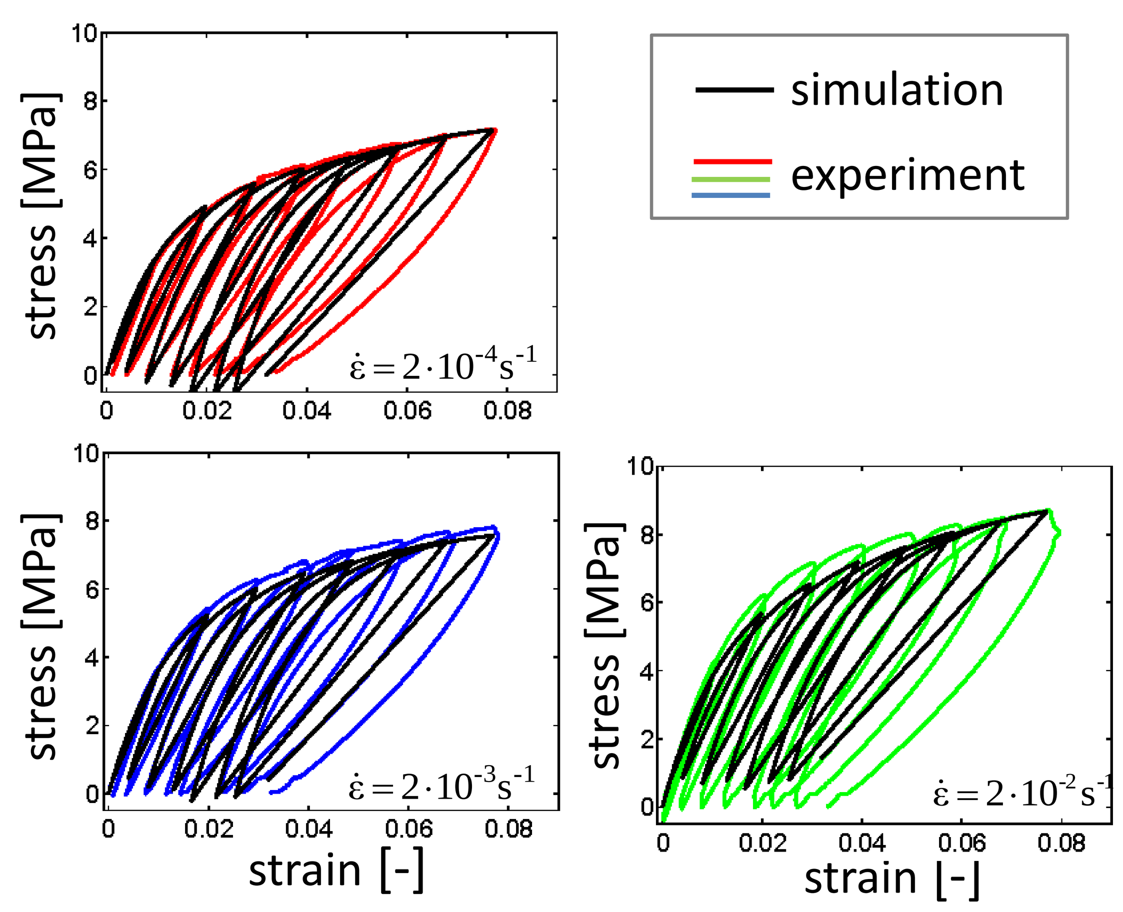
micro-macro transition

volume average of nominal stress

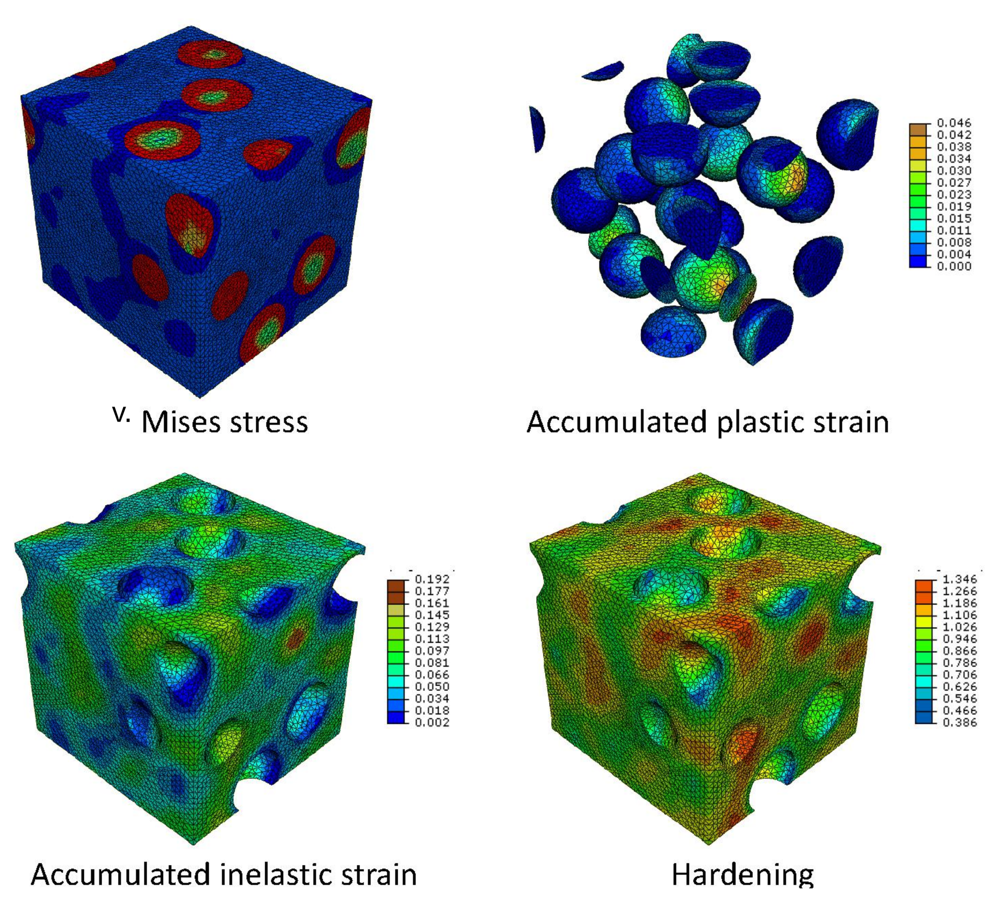
$$\langle \mathbf{T}^{1PK} \rangle = \frac{1}{V_o} \int_{B_o} \mathbf{T}^{1PK}\, dv_o$$

Results

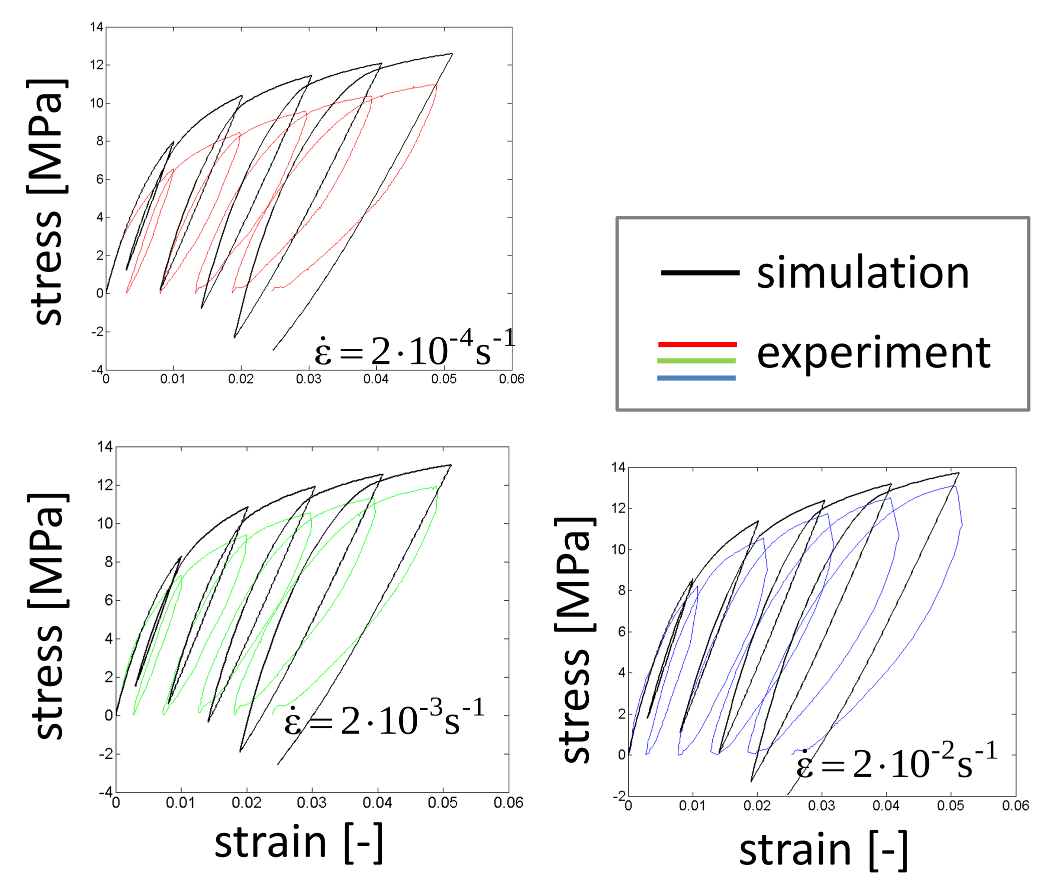
cyclic tensile tests of PTFE



fields on the microscale



cyclic tensile tests of the composite



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