Multi-level FEM

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**Introduction**

Almost all of the metals utilised in industry are microscopically heterogeneous (figure 1). Examples are
- **metal alloy** systems with the second phase in the form of precipitates and pores
- **polycrystals** with grains of different orientation
- **metal-matrix composites** containing fibers, whiskers or particles in the matrix

The mechanical and thermal behaviour at macrostructural level depends on the **size**, **shape**, **properties** and **spatial distribution** of the second phase.

**Objective**

It is the aim to include the properties of the microstructure into the modelling on the macro-level.

**MLFEM as homogenisation technique**

The Multi-Level Finite Element method (MLFEM) [1] is employed in the present work. The scheme of the MLFEM algorithm is presented in figure 2.

**Basic MLFEM hypotheses**

- spatial periodicity of the microstructure
- the microstructure is fully identified by a Representative Volume Element (RVE)
- local values at a macroscopic point \( P \) are determined by averaging the corresponding values over the RVE, attributed to that point
  - Cauchy stress: \( \sigma_{macro}(P) = \bar{\sigma}_{RVE}(P) \)
  - stiffness matrix: \( S_{macro}(P) = \bar{S}_{RVE}(P) \)

**Results**

As an example the method is applied to numerically simulate pure bending of microscopically heterogeneous aluminium AA 1050, which contains 10% volume fraction voids. The material behaviour is described by the visco-plastic Bodner-Partom model [2] with stress dependent viscosity. The results are presented in figure 3.

**Advantages of MLFEM**

- the method provides a **microscopically based** model of the macro-level behaviour
- the method enables the incorporation of **large deformations** and **rotations** (geometrical non-linearity) on both macro- and micro-levels
- **geometry** and **properties** of the microstructure are directly included into the calculations
- the **evolution** of the microstructure can be examined
- arbitrary material behaviour (including non-linear) at the micro-level may be used
- in general, **any modelling technique** may be used on the micro-level (finite elements, interaction simulations, cellular automata, etc.)

**Possible applications**

- macro behaviour of heterogeneous materials
- evolution of the microstructure, including phase transformations
- design of new materials

**References:**