Two-scale homogenization in solid mechanics: on 1^{st}-order, 2^{nd}-order, discontinuous, thermal & shell problems

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Abstract

In the past decades, considerable progress had been made in bridging the mechanical engineering aspects of materials to the field of materials science. This is mainly due to a fruitful combination of micromechanics and multi-scale approaches, with a steadily increasing multi-disciplinary character. Several improved micromechanical theories and associated numerical models have been proposed and implemented, where a lot of interaction with materials science is involved. The developed understanding of single phases and complex interfaces in materials is optimally used in multi-scale homogenization techniques, where it is aimed to predict the collective multi-phase response of materials. Large deformations, damage and cracking, phase transformations, etc. can thereby be taken into account.

Among the variety of multi-scale techniques nowadays available, attention is here focused on computational homogenization techniques. Within this context, several topics will be addressed:

- First-order computational homogenization: key principles
- Second-order computational homogenization: key principles, micro-macro kinematics, solution of the micro-scale boundary value problem, higher-order macro-continuum, example in localisation, first-order versus second-order
- Continuous-discontinuous multi-scale approach for damage: the coarse scale is modelled discretely or with a discrete band (weak discontinuity), whereas the fine scale is modelled with a continuum.
- Thermo-mechanically coupled computational homogenization: homogenization of the thermal problem, coupling to mechanical homogenization.
- Computational homogenization of structured thin sheets and shells: application of second-order homogenization principles to through-thickness representative volume elements, enabling its application to shell-type continua.

Illustrative examples are given for each of the topics addressed, with a particular emphasis on the applicability, and possible limitations of each. The work presented in this seminar is largely covered in the papers [1–10]. Interested readers will find more details therein.

Literature

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