

Computational homogenization of cellular materials with propagation of instabilities through the scales

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The aim of this work is to develop an efficient multi-scale finite element framework to capture the buckling instabilities in cellular materials.

As a classical multi-scale computational homogenization scheme loses accuracy with the apparition of the macroscopic localizations resulting from the micro-buckling, the second-order multi-scale computational homogenization scheme¹ is considered. This second-order computational framework is herein enhanced with the following novelties so that it can be used for cellular materials.

First, at the microscopic scale, the periodic boundary condition is used because of its efficiency. As the meshes generated from cellular materials exhibit a large void part on the boundaries and are not conforming in general, the classical enforcement based on the matching nodes cannot be applied. A new method based on the polynomial interpolation² without the requirement of the matching mesh condition on opposite boundaries of the representative volume element (RVE) is developed.

Next, in order to solve the underlying macroscopic Mindlin strain gradient continuum of this second-order scheme by the displacement-based finite element framework, the treatment of high order terms is based on the discontinuous Galerkin (DG) method to weakly impose the C1-continuity³.

Finally, as the instability phenomena are considered at both scales of the cellular materials, the path following technique is adopted to solve both the macroscopic and microscopic problems⁴. The micro-buckling leading to the macroscopic localization and the size effect phenomena can be captured within the proposed framework. In particular it is shown that results are not dependent on the mesh size at the macroscopic scale during the softening response, and that they agree well with the direct numerical simulations.

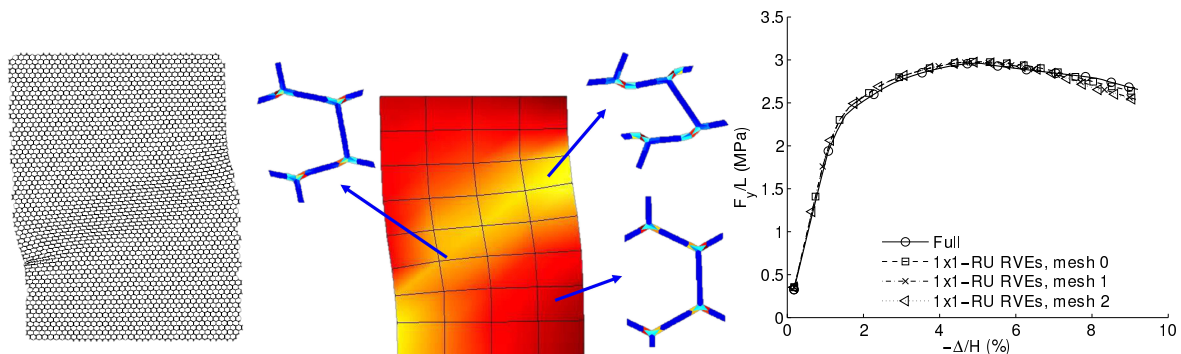


Figure 1: Compression of a honeycomb structure. (a) Full numerical simulation (b) Second-order multi-scale simulation. (c) Comparison of results for different macro-mesh sizes.

¹V. G. Kouznetsova, M. G. D. Geers, W. A. M. Brekelmans, *Comput. Meth. in Appl. Mech. and Eng.*, **193**, 5525, (2004)

²V.-D. Nguyen, E. Béchet, C. Geuzaine, L. Noels, *Comput. Mat. Sci.*, **55**, 390, (2012)

³V.-D. Nguyen, G. Becker, L. Noels, *Comput. Meth. in Appl. Mech. and Eng.*, **260**, 63, (2013)

⁴V.-D. Nguyen, L. Noels, *Int. J. of Sol. and Struct.*, (Submitted)