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COMPUTATIONAL MULTISCALE MODELLING OF MICROSTRUCTURED MATERIAL LAYERS

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INTRODUCTION

In the modelling of thin material layers situated within a continuum, an underlying microstructure can yield size effects. These are captured by a micromorphic continuum to model the material layer. Towards an efficient computation of this thin micromorphic layer, a multiscale approach is pursued. At the macro scale, the material layer is modelled as a cohesive interface embedded into the bulk material. Its constitutive behaviour is evaluated in a multiscale approach from a micromorphic representative volume element accounting for both the underlying meso- and microstucture.

HOMOGENISATION FRAMEWORK

The macroscopic response of the material layer is obtained based on its underlying meso- and microstructure via computational homogenisation. At the macroscale, the material layer is treated as a cohesive interface $\widehat{\Gamma}_0$. For the underlying mesostructure, a micromorphic representative volume element (RVE) is used, which captures size-dependent effects that occur when considering a relatively large intrinsic microstructure.

The material layer at the macro level transmits cohesive tractions that obey the Cauchy theorem:

$$\{\widehat{\boldsymbol{P}}\} \cdot \widehat{\boldsymbol{N}} = \widehat{\boldsymbol{t}}_0 \quad \text{on } \widehat{\Gamma}_0 \,. \tag{1}$$

The micromorphic continuum within the RVE, see Hirschberger et al. [1], is characterised by microcontinua being attached to each material point within the interfacial meso-continuum. The kinematically independent deformation of these microcontinua is described by the micro-deformation map $\bar{\boldsymbol{F}}$. Meso

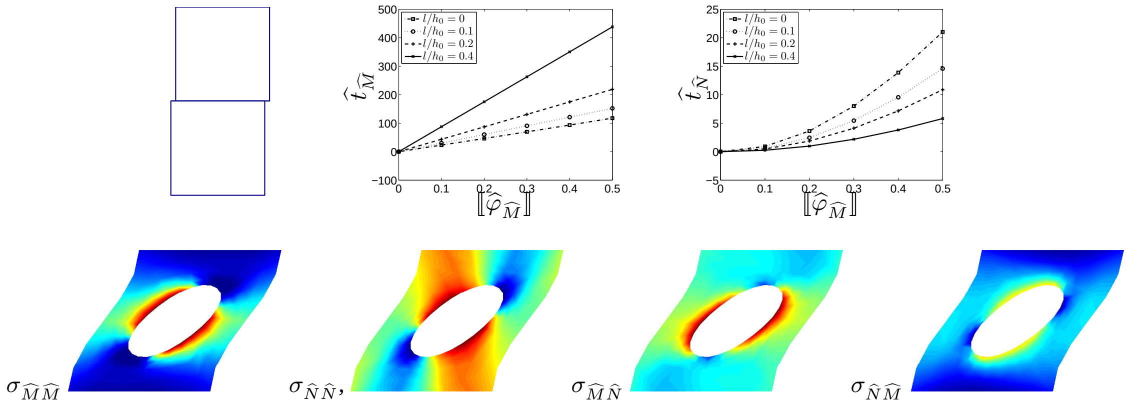

Figure 1: Interface under fully prescribed shear: macro mesh, macro traction separation curves and Cauchy-type macro stress components in the deformed RVE.

and micro deformation are only coupled at a constitutive level and the constitutive relations depend on the standard deformation gradient $\boldsymbol{F}$, the micro-deformation map $\bar{\boldsymbol{F}}$, as well as on the gradient of the latter, $\bar{\boldsymbol{G}}$.

Following the procedure presented in Reference [2], the meso–macro transition is achieved via a homogenisation of the deformation gradient, the stress, and the virtual work over the RVE occupying $\mathcal{B}_0$. Particularly, the virtual work equivalence, coined as the Hill condition [3], is postulated as:

$$\widehat{\boldsymbol{t}}_0 \cdot [\![\delta\widehat{\boldsymbol{\varphi}}]\!] \equiv h_0 \langle \boldsymbol{P} : \delta\boldsymbol{F} + \bar{\boldsymbol{P}} : \delta\bar{\boldsymbol{F}} + \bar{\boldsymbol{Q}} \because \delta\bar{\boldsymbol{G}} \rangle \, . \tag{2}$$

The finite height h_0 of the mesostructure is given by the thickness of the material layer. To account for both the Hill condition and the intefacial deformation modes, hybrid boundary conditions are chosen. These consist of prescribed displacements at the edges of the material layer to the bulk, while periodicity along the material layer is assumed.

Within a finite-deformation finite-element framework, a nested multiscale solution involving both the macro and the meso boundary value problem is employed, compare Reference [4]. At each integration point of an interface element, the material behaviour is evaluated within the micromorphic RVE. From the solution of the RVE system under the boundary conditions imposed by the macro level, both the homogenised macro traction and the macro tangent are obtained.

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