# A multifield continuum model for the description of wave propagation in microcracked composite-material plate waveguides

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**Abstract**. The description of the mechanical behavior of composite materials is an open challenge in engineering. The focus of this work is on microcracked/microporous composites, whose grains interact through boundaries of micrometric size with pores localized at the interfaces, which reduce the contact area between grains. We apply a two-scale modeling strategy based on a discrete-continuum equivalence procedure. The constitutive relationships of the resulting microcontinuum are identified requiring equivalence, in terms of virtual work, with a lattice description of the given material. Linear and nonlinear phenomena, also due to states of prestress, occurring in wave propagation in a microcracked composite plate are considered, and parametric investigations are conducted by varying size and density of the pores. The response of the equivalent model is compared to that obtained from a fine model, which employs the Virtual Element Method, and to experimental results available in the literature.

## Introduction

The investigation of the mechanical behavior of composite materials presenting different kinds of heterogeneities requires the development of appropriate models bridging several scales of observation. The design of such materials and the understanding of their macroscopic properties relies on the ability to describe their internal structure, and motivates the interest for the identification of suitable constitutive laws of continua with microstructure, capable to account for the relevant microscopic features, avoiding a direct modeling of the microstructure. The purpose of this work is to contribute to the advancement in the field of microcracked/microporous composite modelling. The modelling is approached here applying a two-scale discrete-continuum equivalence procedure developed within the framework of the principle of virtual work, which enables us to obtain continuum approximations for such heterogeneous media, and leads to continua with additional kinematical and dynamical descriptors (micromorphic, multifield, etc.) [1, 2]. In particular, we address the modelling of microcracked composite materials, which consist of grains interacting through boundaries of micrometric size with pores localized at the interface, which reduce the contact area (Fig. 1 a). The presence of voids is accounted for by means of an additional displacement field [1, 3], leading to a multifield, non–local equivalent model [4].

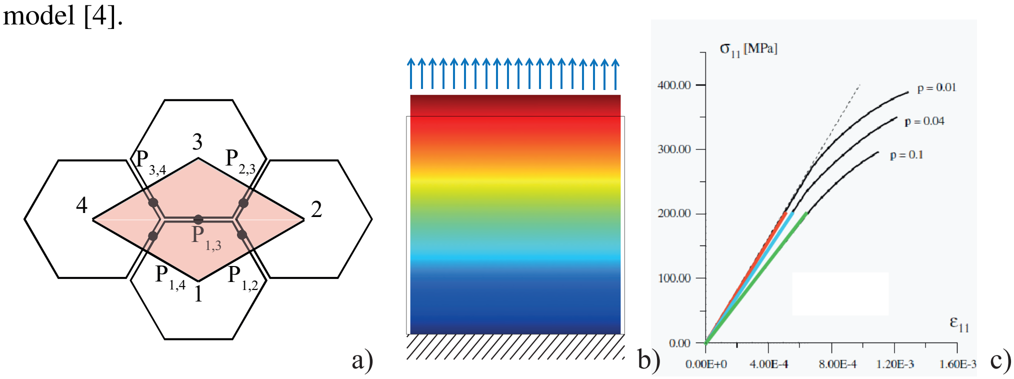


Figure 1: Sketch of the microcracked material (a), numerical vertical displacements (b) and numerical vs experimental results (c).

## Results and discussion

The constitutive relationships of this microcontinuum are identified by requiring the equivalence in terms of virtual work with a lattice description of the given material. The results of a parametric study made by varying the size and density of the pores as well as the size of the grains relative to the sample size are compared to experimental results [5] (Fig. 1 b and c presenting good agreement) and to a fine Virtual Element Method. The model described is further employed to investigate linear and nonlinear phenomena occurring in wave propagation, due to the prestressed, extending the theory of acoustoelasticity to the mutifield continuum [6], which enables to describe the change in wave speed as well as to observe the occurrence of higher-order harmonics in relation to prestress and microporosity.

## References

[1] Trovalusci P., Varano V., Rega G. (2010) A generalized continuum formulation for composite materials and wave propagation in a microcracked bar. *J. Appl. Mech.-T ASME*, Vol. **77** (10): 061002/1-11.

[2] Trovalusci P., Pau A. (2014) Derivation of microstructured continua from lattice systems via principle of virtual works. the case of masonry-like materials as micropolar, second gradient and classical continua. *Acta Mech.*, Vol. **225**: 157–177 .

[3] Nunziato J.W., Cowin S. (1979) A nonlinear theory of elastic materials with voids. *Arch. Rantion. Mech. An.*, Vol. **72**: 175-201.

[4] Kunin, I. (1984), On foundations of the theory of elastic media with microstructure. *Int. J. Eng. Sci.*, Vol. **22** (8): 969 - 978.

[5] Sadowski T., Samborski S. (2013) Prediction of the mechanical behaviour of porous ceramics using mesomechanical modelling. *Comp. Mater. Sci.*, Vol. **28**: 512-517.

[6] Murnaghan F. D. (1951) Finite Deformation of an Elastic Solid. Wiley, New York.