Asymmetric and anisotropic elasticity of contact-based architected materials

Vladislav Yastrebov*[1], Samuel Forest[2], and Djimédo Kondo[3]

[1]Centre des Matériaux, MINES Paris - PSL, CNRS UMR 7633 – CNRS : UMR7633, MINES ParisTech - École nationale supérieure des mines de Paris – France

[2]Mines Paris - PSL (École nationale supérieure des mines de Paris) – Université Paris sciences et lettres – 60, boulevard Saint-Michel 75006 Paris, France

[3]Institut Jean Le Rond d'Alembert, Sorbonne Université, CNRS – Institut Jean Le Rond d'Alembert, Sorbonne Université – France

Abstract

Architected materials with internal contacts (1) represent a relatively novel and still underexplored class of materials. In addition to exhibiting specific dissipative properties and path-dependent behavior, these materials possess a distinctive feature: elastic asymmetry (2), i.e., the dependence of elastic constants on the sign of deformation. The organization and orientation of contact interfaces make these materials not only asymmetric but also anisotropic. This combination of asymmetry and anisotropy poses significant challenges in constructing associated homogenized models. However, understanding their behavior can enable intelligent exploration of such properties at the structural scale. Specifically, the unique properties of anisotropic asymmetric - or asymmetrically anisotropic -materials can be utilized to design structures with tailored stress distributions. Furthermore, constructing accurate constitutive models may lead to advancements in continuum damage mechanics, particularly for materials for which the primary source of damage arises from oriented cracks.

Currently, there is no consensus in the existing constitutive models (3,4) on how to effectively account for this interplay of asymmetry and anisotropy. To address this question, our direct numerical homogenization approach, incorporating accurate modeling of contact interactions, enables a critical analysis of existing constitutive models and facilitates the development of a new thermodynamically consistent framework.

The identified constitutive model will be applied to analyze classical solid mechanics problems in both static and dynamic contexts, including a bar under tension/compression, bending, and torsion, as well as a plate with a hole and a notched plate.

(1) Yastrebov, V.A. CR Mécanique, 350(1):1-26, 2022.

(2) Monaldo, E., S. Brach, D. Kondo, G. Vairo. European Journal of Mechanics / A Solids, 81:103962, 2020.

*Speaker

(3) Ambartsumyan, S. Izvestiya Akademii Nauk SSSR, Mekhanika Tverdogo Tela, (3):51-62, 1969.

(4) Jones, R.M. AIAA Journal, 15(1):16-23, 1977.