

Coarse-graining approaches for complex materials as multifield continua with applications to particle composites

P. Trovalusci

Department of Structural and Geotechnical Engineering,
Sapienza University of Rome, Italy

patrizia.trovalusci@uniroma1.it

Abstract

The mechanical behaviour of complex materials, characterized at finer scales by the presence of heterogeneities of significant size and texture, strongly depends on their microstructural features. By lacking in material internal scale parameters, the classical continuum does not always seem appropriate to describe the macroscopic behavior of such materials, taking into account the size, the orientation and the disposition of the micro heterogeneities.

Attention will be focused on multiscale approaches which aim to deduce properties and relations at a given macro-scale by bridging information at proper underlying micro-level via energy equivalence criteria. Focus will be on physically-based corpuscular-continuous models as originated by the molecular models developed in the 19th century to give an explanations ‘per causas’ of elasticity. In particular, will be examined the ‘mechanistic-energetic’ approach by Voigt and Poincaré who, when dealing with the paradoxes coming from the search of the exact number of elastic constants in linear elasticity, respectively introduced moment and multi-body interactions models which enabled to by-pass the experimental discrepancies related to the so-called central--force scheme, originally adopted by Navier, Cauchy and Poisson. Current researches in solid state physics as well as in mechanics of materials show that energy-equivalent continua obtained by defining direct links with lattice systems are still among the most promising approaches in material science. Aim of the presentation is pointing out the suitability of adopting discrete-continuous Voigt-like models, based on a generalization of the so-called Cauchy-Born rule used in crystal elasticity and in classical molecular theory of elasticity, in order to identify continua with additional degrees of freedom (micromorphic, multifield, etc.), which are essentially ‘non-local’ models with internal length and dispersive properties.

It will be shown as microstructured continuous formulations can be derived within the general framework of the principle of virtual works which, on the basis of a correspondence map relating the finite number of degrees of freedom of discrete models to the continuum kinematical fields, provides a guidance on the choice of non-standard continuum approximations for heterogeneous media. The circumstances in which the inadequacy of the classical hypothesis of lattice mechanics still call for the need of improved constitutive models which by-pass the hypotheses of lattice

homogeneous deformations or the central-force scheme via non-convex energy models or continua with additional degrees of freedom (multifield) will be also discussed. Some applications of such approaches will be shown with reference to microcracked composite materials, ranging from fiber-reinforced composites, or porous metal-ceramic composites and ceramic matrix composites up to masonry-like material. Further developments concerning the comparison with homogenization methods based on boundary problems solutions derived for generalized continua will be finally introduced.

Keywords: constitutive models, discrete to non-classical continua, homogenization