Séminaire PIMM

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Design of Novel Materials and Structures Based on Topological Interlocking Principle

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A continues demand from different industries is pushing materials engineers to find a new ways of designing new materials and improving their properties. A relatively new way of creating materials with superior properties is by combining two or more existing materials to a hybrid materials. In this talk, a new way of designing novel materials and structures using identical fragments assembled to single structures will be presented. The fragments are held in place by its neighbours kinematically using matching surfaces rather than through a binder phase or connectors [1]. The advantages of such interlocking-based materials lie in their high resistance to catastrophic crack propagation, tolerance to local failures, high energy dissipation and ease with which they can be assembled and dismantled.
This talk will illustrate the principle of topological interlocking and demonstrate that interlocking ensembles of blocks having the shape of one of the five platonic solids, and blocks with concavo-convex surfaces (osteomorphic blocks) are possible and possess favourable properties such as controllable bending stiffness, high energy and sound absorption and a great tolerance to local failures. Application of this principle to the design of the novel sandwich structures [2] as well as ceramic materials with improved sound absorption properties [3] will be presented, along with our recent results on biomimetic approach to create abalone shell-inspired structure with improved fracture toughness.

[1] Y. Estrin, A.V. Dyskin, E. Pasternak, Materials Science and Engineering: C, 31 (2011) 1189-1194.
[2] A. Molotnikov, R. Gerbrand, O. Bouaziz, Y. Estrin, Adv. Eng. Mater., 15 (2013) 728-731.
[3] M. Carlesso, A. Molotnikov, T. Krause, K. Tushtev, S. Kroll, K. Rezwan, Y. Estrin, Scripta Mater., 66 (2012) 483-486.

Modelling of Deformation Behavior of Gradient Materials

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Many materials found in Nature have shown the ability to maximize their structural performance by implementing a gradual change in composition from the core to the surface. The advances in several manufacturing techniques such as surface mechanical attrition treatment (SMAT) are a driving force for development of new materials which are mimicking such naturally architectured materials. However, the prediction of the mechanical behavior of such materials is challenging and new computational models are required to better understand the mechanisms responsible for the improvement of mechanical properties and accelerate the design of new materials with architectured microstructure.

One potent model, which can be adopted for modeling such metallic gradient materials is based on microstructure-related constitutive description in which the dislocation cell walls and the dislocation densities cell interior, entering the model as scalar internal variables, [1]. The resulting 'phase mixture' model can be extended to include the strain gradient theory that allows to account for a strengthening effect associated with microstructural gradient present in the material. Two types of strain gradient model are proposed arising from two distinct physical mechanisms. One is associated with the occurrence of geometrically necessary dislocations and inclusion of the gradient of first order in the Taylor type flow stress formulation [2]. The second one is associated with the reaction stresses due to plastic strain incompatibilities between neighbouring grains and incorporate strengthening effect due to second Laplacian of the equivalent strain, [2]. Both models have the advantage that the intrinsic length scale parameter depends on microstructural features. The numerical results will be validated by comparison with experimental data from high pressure torsion [2]. Other case studies related to materials processed by surface mechanical attrition treatment (SMAT) and three roll planetary milling [3] will also be presented.

[1] L.S. Tóth, A. Molinari and Y. Estrin, Journal of Engineering Materials and Technology, Vol. 124, p. 71, 2002

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