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PII: S0045-7825(16)30310-3
DOI: http://dx.doi.org/10.1016/j.cma.2016.09.019
Reference: CMA 11131

To appear in: *Comput. Methods Appl. Mech. Engrg.*

Received date: 4 May 2016
Revised date: 14 September 2016
Accepted date: 20 September 2016

Please cite this article as: B. Staber, J. Guilleminot, Functional approximation and projection of stored energy functions in computational homogenization of hyperelastic materials: A probabilistic perspective, *Comput. Methods Appl. Mech. Engrg.* (2016), http://dx.doi.org/10.1016/j.cma.2016.09.019

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Functional approximation and projection of stored energy functions in computational homogenization of hyperelastic materials: a probabilistic perspective

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Abstract

This work is concerned with the construction of a surrogate model for the homogenized stored energy functions defining the effective behavior of nonlinear elastic microstructures. Here, a probabilistic standpoint is adopted and allows for the definition of a nonlinear mapping between the macroscopic deformations and the homogenized potential. This functional approximation is specifically obtained by means of a polynomial chaos expansion, the coefficients of which are computed through a Gauss-Legendre quadrature rule. By invoking well-known results related to projections in Hilbert spaces, closest approximations of arbitrary potentials to standard (*e.g.* Ogden-type) models are subsequently defined and characterized by appropriate residuals. Numerical illustrations on various microstructures are finally provided in order to discuss the relevance of the proposed framework. In particular, it is shown that the surrogate model compares very well with reference results at both the macroscale and the structural scale, even for moderate-order expansions, and that the aforementioned closest approximations constitute very accurate approximation provided that the subset onto which the homogenized response is projected is properly chosen. This result readily allows for nonconcurrent coupling using standard constitutive models available in commercial codes and therefore makes the approach very attractive for engineering applications.

Keywords: Computational homogenization, hyperelastic materials, nonlinear homogenization, polynomial chaos expansion, projection, surrogate model

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