Advanced computational strategies
ECCM19-ABS-273

Investigation on fiber packing geometries towards efficient and realistic prediction of elastic properties of continuous fiber-reinforced composite materials

Arada Jamnongpipatkul* [1, 2], Ruben D. Sevenois[1, 2], Wim Desmet[3, 4], Wim Van Paepegem[1], Frank Naets[3, 4], Francisco A. Gilabert[1]
[1]Department of Materials, Textiles and Chemical Engineering, Ghent University, [2]SIM M3 program, Zwijnaarde, [3] Department of Mechanical Engineering, KU Leuven, [4]DMMS Core Lab, Flanders Make, Leuven, Belgium

Preferred presentation method: ORAL
Second topic: 3.2 Material and Structural Behavior - Simulation & Testing: Multiscale modeling

Abstract text: Multiscale modeling is in great use for understanding and predicting the mechanical behavior of composite materials. However, this powerful approach still poses issues in practicality due to large computational cost, especially when numerous simulations are to be performed in the material-by-design setting varying design parameters [1]. To alleviate the problem of computational feasibility, model order reduction (MOR) methods have been used successfully to accelerate simulations at only a marginal accuracy cost in many other engineering fields [2]. However, MOR techniques are still in the initial stage of research for the prediction of macro-mechanical properties of fiber-reinforced composite materials from microscale simulations. In the work of Radermacher et al. [3], they used MOR to accelerate nonlinear multiscale simulation of fiber-reinforced composites with promising results. However, its applicability for the parametric studies of composite materials is still missing.

In this work, we therefore explore the applicability of MOR for parametric studies of fiber-reinforced composite materials. We propose the use of the proper orthogonal decomposition (POD) approach for setting up the reduced order basis which can be exploited to construct a reduced order model (ROM) for accelerating numerical simulations [4]. In order to construct a representative ROM to predict the response of composite materials, an appropriate set of parameters needs to be included in the POD procedure. Common parameters encountered in the design of fiber-reinforced composite materials include material properties of the constituents, microstructural geometries, and external boundary conditions typically applied to the microstructures as uniform or periodic displacement boundary conditions. Parameter selection remains one of the critical questions in practice [5,6].

Besides the aforementioned issue regarding the selection an appropriate set of parameters, varying microstructural geometrical parameters raise another issue in MOR with respect to the treatment of variable meshes. Since the randomness of the composite microstructure has a significant influence on the composite elastic constants [7], the fiber arrangements shown in Figure 1 are proposed to solve the problem of mesh variations. The mesh on the left in Figure 1 represents the simple microstructure to investigate the effect of varying fiber volume fraction only. The mesh on the right in Figure 1 represents the more realistic microstructure to investigate the coupled effect of varying fiber volume fraction and fiber distribution. The proposed meshes allow the incorporation of varying fiber packing in MOR.

A number of numerical simulations on the microscale volume elements of unidirectional fiber-reinforced composites were performed under uniform and periodic boundary conditions. To assess the applicability of the MOR in parametric studies of fiber-reinforced composite materials, this study presents the comparison of the homogenized elastic properties obtained from the full order model, reduced order model, and analytical homogenization models [8]. Reduced order model allows the consideration of realistic microstructures in the prediction of linear elastic behavior of fiber-reinforced composite materials when compared to analytical expressions commonly employed and without increasing computational cost when compared to performing full order model simulation.

Acknowledgement
The work leading to this abstract has been funded by the SBO project "MOR4MDesign", which fits in the MacroModelMat (M3) research program, coordinated by Siemens (Siemens PLM software, Belgium) and funded by SIM (Strategic Initiative Materials in Flanders) and VLAIO (Flanders Innovation and Entrepreneurship).

References

1. Chinesta F, Leygue A, Bordeu F, Aguado JV, Cueto E, Gonzalez D, Alfaro I, Ammar A, Huerta A. PGD-based computational vademécum for efficient design, optimization and control. Arch Comput Methods Eng, 2013, 20(1): 31-59.
2. Besselink B, Tabak U, Lutowska A, van de Wouw N, Nijmeijer H, Rixen DJ, Hochstenbach ME, Schilders WHA. A comparison of model reduction techniques from structural dynamics, numerical mathematics and systems and control. J Sound Vib, 2013, 332(19): 4403-4422.
3. Radermacher A, Bednarcyk BA, Stier B, Simon J, Zhou L, Reese S. Displacement-based multiscale modeling of fiber-reinforced composites by means of proper orthogonal decomposition. Adv Model and Simul in Eng Sci, 2016, 3-29.
4. Quarteroni A, Manzoni A, Negri F. Reduced basis methods for partial differential equations: An introduction. Vol. 92 of Unitext, Springer 2015.
5. Goury O, Amsallem D, Bordas SPA, Liu WK, Kerfriden P. Automatised selection of load paths to contruct reduced-order models in computational damage micromechanics: from dissipation-driven random selection to Bayesian optimization. Comput Mech, 2016, 58:213-234.
6. Paul-Dubois-Taine A, Amsallem D. An adaptive and efficient greedy procedure for the optimal training of parametric reduced-order models. Int J Num Meth Eng, 2014, 1-31.
7. Gusev AA, Hine PJ, Ward IM. Fiber packing and elastic properties of a transversely random unidirectional glass/epoxy composite.
8. Nemat-Nasser S, Yu N. Bounds and estimates of overall moduli of composites with periodic microstructure. Mech Mater, 1993, 15(3):163-181.

Image:

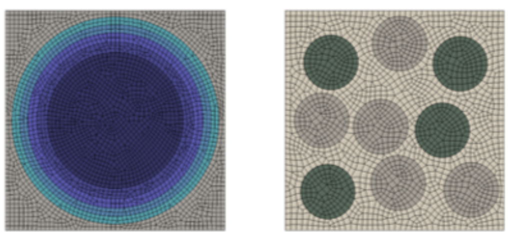

Figure 1 Meshes proposed to incorporate varying volume fractions (left) and varying fiber distribution (right)

Disclosure of Interest: Aucun conflit à déclarer

Keywords: Computational homogenization, Fiber-reinforced polymer composite, Multiscale modeling