NOVEL COMPUTATIONAL FRAMEWORK FOR THE AUTOMATED MULTISCALE MODELING OF CARBON FIBER-REINFORCED POLYMER COMPOSITES

Hossein Ahmadian[a], Soheil Soghrati[b]

[a]Department of Integrated Systems Engineering, The Ohio State University

[b]Department of Mechanical and Aerospace Engineering, The Ohio State University

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ABSTRACT

Carbon fiber reinforced polymer composites (CFRPCs) are widely used in the aerospace and automotive industry as structural components for fuselages, spars, skin elements, bumpers, and blades. Compared to metallic alloys, CFRPCs offer several advantages such as lightweighting, high fatigue resistance, chemical and corrosion resistance, and reasonable manufacturing cost. The optimal design of a CFRPC system requires quantifying the effect of its microstructural features (e.g. fibers volume fraction, size distribution, spatial arrangement, etc.) on the mechanical behavior of the material across different length scales. The main challenges involved in the treatment of this computational design problem are twofold: (i) creating realistic 3D geometrical models of the composite microstructure based on digital data such as micro-computed tomography (micro-CT) images and more importantly virtually changing this microstructure during the design process; (ii) constructing appropriate finite element (FE) conforming meshes to discretize the resulting geometrical model. In this work, we introduce a novel computational framework for the automated treatment of this problem. The proposed approach relies on a new microstructure reconstruction algorithm that implement the Centroidal Voronoi Tessellation (CVT), together with a multi-objective Genetic Algorithm (GA) to create realistic microstructural models of CFRPCs based on a set of statistical and morphological information extracted from imaging data. This algorithm can efficiently create virtual representative volume elements (RVEs) of the composite with desired volume fraction and size/spatial distribution of fibers. We then implement a non-iterative mesh generation algorithm, named Conforming to Interface Structured Adaptive Mesh Refinement (CISAMR), to create 3D FE models of resulting composite RVEs. CISAMR automatically transforms a simple structured grid into a high quality conforming mesh using a non-iterative algorithm capable of handling problems with complex geometries. We demonstrate the application of the proposed CVT-GA-CISAMR framework for simulating the multiscale failure response of a CFRPC system using continuum and cohesive damage models for the matrix and fiber-matrix interfaces, respectively.