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Micromechanics code: beam modeling of periodically heterogeneous composites

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The code herein described serves as a micromechanics tool for the efficient computation of the effective stiffness matrix and the recovering of the local fields of periodically heterogeneous composite structures. The main novelty of the proposed tool is that refined beam models are employed to analyze the representative volume element of composites with no loss of accuracy and great advantages in terms of modeling and computational efforts. The Mechanics of Structure Genome (MSG) [1] is chosen to define the micromechanics problem for 3D structural analyses and the Carrera Unified Formulation (CUF) is used to solve the governing equations.

The code makes use of standard 1D elements to discretize the various constituents along the longitudinal direction and sets of 2D Hierarchical Legendre Expansions (HLE) [2] to expand the unknowns of the problem over the remaining two directions. In this manner, the unknown functions of the MSG problem, also known as fluctuations [1], can be expressed as follows,

$$\boldsymbol{\chi} = F_\tau N_i \boldsymbol{\chi}_{\tau i} \,,$$

where $\boldsymbol{\chi}_{\tau i}$ is the vector of the generalized fluctuation unknowns, F_τ, are the expansion polynomials and N_i are the beam shape functions. The code employs a higher-order mapping technique to model the exact geometry of the different constituents (fibers, matrix, particles, plies, etc…) over the cross-section of the beam, whereas heterogeneities along the beam axis, if any, are captured by the finite element discretization. In this manner, the geometrical description is fixed at the beginning of the analysis and the accuracy of the solutions is controlled by the polynomial order of the expansions, p, which is an input of the analysis.

A representation of the code operation is illustrated in Figure 1. The user defines the section geometry, the beam discretization (only for particle inclusions), the properties of the different constituents, the boundary constraints and the polynomial order of the HLE model. Then, according to the CUF statements [2], the code computes the fundamental nuclei of the problem arrays and generates the system of governing equations. Periodic Boundary Conditions are applied in all cases over the faces of the volume. Once the system is solved and the fluctuation variables are calculated, the effective stiffness matrix is straightforwardly computed with no need of further loading steps. If the local fields are required, the user must only input the values of the global displacements and strains, and the code automatically provides the local solutions using the same fluctuation unknowns. This process can be repeated indefinitely without launching the tool again.

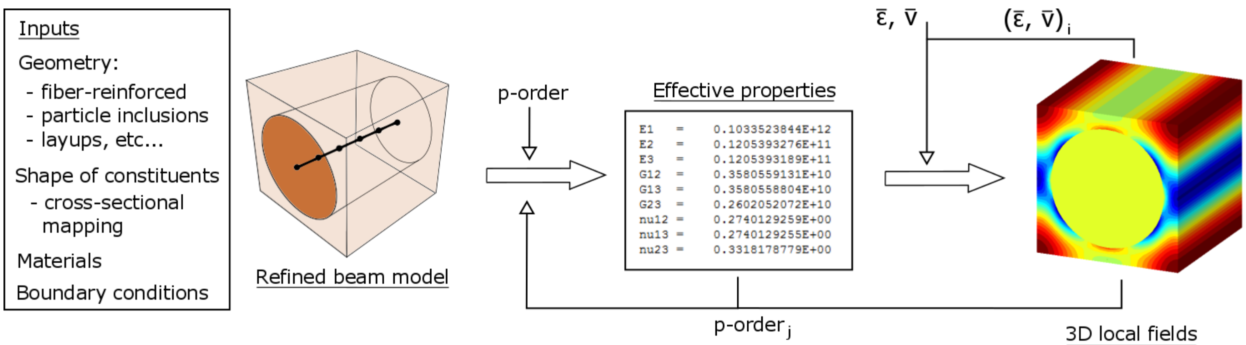

Figure 1. Micromechanics analysis using MSG and CUF beam models.

The code is entirely written in Fortran 77/90 and the outputs, i.e. effective properties and local fields (displacements, strains and stresses), are presented in files '.dat'. A Gmsh file is also generated so as to allow the post-processing of the local fields in a more user-friendly environment. For the purposes of the present competition, several pre-arranged models will be available for any user to easily test the code, such as lay-ups, fiber-reinforced composites featuring typical packs and particle inclusions with variable geometries.

The present code couples the already established capabilities of MSG for the accurate micromechanics analysis with the efficiency of refined beam models for representative volumes in which the heterogeneities are predominant in one or two directions, such us clusters of fibers. In these cases, but not limited to, refined beam models are very convenient in terms of computational efforts and can provide the same accuracy in the micromechanics study as commonly used 2D or 3D models. In addition, the exact geometry of the constituents can be represented regardless of the size of the discretization, for instance, the fiber section can be represented by only a single HLE domain (see Fig. 1). Once the geometry is fixed, the accuracy of the model can be enhanced by increasing the order of the HLE polynomial expansions, *p*, with no need of iterative and time-consuming refinements of the mesh.

References

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