A GMC-based Finite Element for Modeling the Finite Deformation of Composites Consisting of Hyperelastic Phases

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Finite element analysis of composite structures undergoing finite deformation (e.g., tires) requires constitutive laws that are capable of modeling the overall behavior of the composite material at any point. In the framework of the present research a finite element formulation is developed for the analysis of the large deformation of composite structures.

The finite element formulation employs a micromechanics model to compute the composite constitutive response at any material point. Within a chosen nonlinear solution strategy the micromechanics equations are solved locally at each integration point. The resulting mechanical tangent tensor, at the current state of deformation, and the stress tensor are utilized to set up the instantaneous tensor of elastic coefficients and internal force vector respectively.

We use the Generalized Method of Cells (GMC), a micromechanics model, as the constitutive law. GMC provides a nonlinear constitutive law of the finite deformation of fiber-reinforced composites from the knowledge of the properties of their nonlinear phases.

Two test cases are used to validate the formulation. In the first case we compare the constitutive response of the GMC-based finite element with a computationally intensive homogenization theory, suitable for finite deformation analysis of composites. Two types of hyperelastic matrix composites reinforced by continuous linear fibers are modeled. The fiber-to-matrix “small strain” stiffness ratio was 0.8 in one composite and 800 in the other. All the results obtained show good agreement between the two approaches. In the second case, a fixed-fixed plane strain rubber matrix beam reinforced by continuous nylon fibers is modeled with GMC-based elements and subjected to a uniform transverse load. Since no analytic solution is available, results are compared with a highly refined finite element model, which serves as a reference solution. Again, good agreement between the two methods is demonstrated.

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