Abstract

Composite materials have made gigantic strides over the past few decades in engineering fields such as aerospace, civil, naval, automotive, and many other fields. The composite materials have distinguished characteristics such as high stiffness to weight ratio, high strength to weight ratio, and outstanding fatigue strength. The development of the composites significantly improves the structural performance of the components, which can be viewed by the Boeing 787 Dreamliner which has 50 weight % of polymeric composite, which results 20% saving in fuel economy and 20% reduction in emission due to lightweight. Further, the conventional polymer composites can be improved by nano reinforcement which has high mechanical, electrical, and thermal properties. These nano composites can be termed as polymer nanocomposites (PNCs). Thus, an accurate and effective mathematical model is necessary to encapsulate the structural response of the CNT-reinforced nanocomposites. Though, the number of models have been available, very few models have considered the most realistic analysis for the CNT reinforced composites. Thus, a computationally efficient model is necessary for the structural analysis of the FG-CNTRC plates. So, in this study, Mori–Tanaka micromechanical model has been coupled with a finite element representative volume element (RVE) approach to model functionally graded CNT reinforced (FG-CNTRC) plate. The coupled model also termed extended Mori–Tanaka (E-MT) effectively determines the mechanical properties of the CNT reinforced composite plates. The E-MT model has the provision to consider different types orientations of the CNT fibers in matrix phase with the incorporation of second order orientation tensor matrix. The solution of the E-MT model has been propagated to the FG-CNTRC structural model to obtain the geometrically nonlinear response. The nonlinear governing equations of motions are obtained using the Green–Lagrange strain field and solved using nonlinear Newmark's time integration and direct iteration method for the free and forced vibration of the FG-CNTRC plates respectively. The effect of various parameters like aspect ratio of CNT reinforcement, orientation of the CNT fibers, span thickness ratio of the plate, different types of edge constraints, and the gradation of the CNT fiber across the thickness of the plate have been studied in this work.

Keywords: Atomistic continuum model, RVE approach, Mori–Tanaka micromechanical model, Nonlinear structural response, Isogemetric finite element, Green–Lagrange nonlinearity, New higher order shear strain functions, FG-CNTRC.