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Abstract

A multi-scale model is proposed to investigate arbitrarily functionally graded hollow cylinders (discs), with fibers, particles, or disc-shaped reinforcements, subjected to harmonic loading conditions. The stress analyses are performed by dividing the cylinders (discs) into several layers each with homogeneous properties, which are functionally graded through the thickness of the structures, with varying microstructural details. Good agreement can be obtained by comparing the present stress distributions against other analytical solutions used as boundary conditions or obtained for homogeneous and continuously graded structures. Furthermore, the Mori-Tanaka model is used to generate effective properties of each layer reinforced with fibers, particles or disc-shaped inclusions. The stress distributions in the cylinders along the radial direction are effectively investigated with the influence of either the shape or the volume fraction of reinforcements. Finally, the particle swarm optimization technique is combined with the present framework to provide inverse calculations for microstructural details, in the effort of finding proper inclusion volume fractions or minimizing the shear stress along the radial direction, which are necessary for the design of functionally graded structures. The present analysis for arbitrarily FG cylinders under arbitrary loading conditions provides benchmark solutions for other future analytical and numerical methods.

Keywords: Multi-scale analysis; arbitrarily functionally graded layered cylinders; harmonic loading; Mori-Tanaka homogenization; Particle Swarm Optimization