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Homogenized and localized stress reconfigurations of solid or hollow fiber reinforced materials in a multi-scale framework

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Abstract

A multi-scale model is proposed in the present work based on the effort of reducing the stress concentrations in an infinite aluminum homogeneous plate with a hole that is subjected to several types of far-field loading conditions. A set of concentric composite layers reinforced using solid or hollow fibers are employed to replace the homogenous material in the vicinity around the hole. The homogenized moduli of each layer can be easily calculated from the proposed locally exact homogenization theory. The continuity equations and boundary conditions are applied to solve the boundary value problems at structural level using assumed displacement field in terms of complex potentials, then the stress distributions at the local microstructures are investigated. It is found that the hollow fibers are more efficient than solid ones in reducing the stress concentrations at both homogenized and microstructural levels. The particle swarm optimization technique is finally introduced to search for the optimal design parameters to reduce the stress concentrations. It can be concluded that the local stresses in the matrix phase of the innermost layer are still very large and prone to suffer cracks even if the homogenized stress concentration factors are significantly reduced.

Keyword: Kirsch problem; stress concentration; functionally graded materials; Locally exact homogenization; Particle Swarm Optimization.