

Abstract

Functionally Graded Materials (FGMs) have a gradual material variation from one material character to another throughout the structure. Applications of these types of materials have significant advantages in civil and mechanical systems including thermal systems. Analyzing the FGMs at the microstructure level with the conventional Finite Element Method (FEM) takes enormous pre-processing and computational time due to the complex material characteristics at the microstructure level. Essentially, the model contains too many degrees of freedom to be solved economically.

The homogenization method has been successfully applied to solve periodic microstructure problems. However, the development of analysis procedures for structures with nonperiodic material or cell geometry, as occurs in graded materials, has turned out to be a significant challenge.

A new method is developed which accurately models the nonperiodic microstructure in FGMs. This method allows the efficient solution of nonperiodic problems without requiring the simplification of the original models. The performance of the developed theory is verified through the solution of appropriate nonperiodic problems associated with graded materials. In the nonperiodic 1-D cases, the global displacement $U(\mathbf{x})$ was obtained and compared with the exact solution. At the same time, the proposed data collection point method was investigated. In the nonperiodic 2-D cases, the global displacement $U(\mathbf{x})$ and the microstructural level displacements were computed. In the program, the Von-Mises Stress computation process was included to evaluate the local stress values at the microstructure level and the results were compared with very fine scale finite element calculations.

The performance of the developed nonperiodic homogenized (NPH) algorithm indicates that it is a promising tool for estimating the FGMs characteristics in loaded conditions. The method can be applied to estimate the global and local displacements in nonperiodic geometries which contain continuously decreasing and/or increasing microstructures.