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Material Distribution and Sizing Optimization of Functionally Graded Plate-Shell Structures

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Abstract

A high order shear deformation theory is used to develop a discrete model for the structural and sensitivity analyses allowing for the material distribution and sizing optimization of functionally graded material (FGM) structures. The finite element formulation for general FGM plate-shell type structures is presented, and a non-conforming triangular flat plate/shell element with 24 degrees of freedom for the generalized displacements is used. The formulation accounts for geometric and material nonlinear behaviour, free vibrations and linear buckling analyses, and their analytical gradient based sensitivities. The p-index of the power–law material distribution and the thickness are the design variables. Mass, displacement, fundamental frequency and critical load are the objective functions or constraints. The optimization solutions, obtained by a Feasible Arc Interior Point gradient-based algorithm, for some plate-shell examples are presented for benchmarking purposes.

1. Introduction

In an effort to develop the super heat resistant materials, Koizumi [1] first proposed the concept of Functionally Graded Material (FGM). Typical FGM plate-shell type structures are made of materials characterized by a continuous variation of the material properties over the thickness direction by mixing two different materials, metal and ceramic. The metal–ceramic FGM plates and shells are widely used in aircraft, space vehicles, reactor vessels, and other engineering applications.
Structures made of composite materials have been widely used to satisfy high performance demands. In such structures, stress singularities may occur at the interface between two different materials. In contrast, in FGM plate-shell structures the smooth and continuous variation of the properties from one surface to the other eliminates abrupt changes in the stress and displacement distributions.

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