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An isogeometric multimesh design approach for size and shape optimization of multidirectional functionally graded plates

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Abstract

This article firstly presents a novel numerical methodology to concurrently optimize material distribution (size) and thickness variation (shape) of multidirectional functionally graded (MFG) plates under free vibration within the isogeometric analysis (IGA) framework. An isogeometric multimesh design (IMD) approach is proposed to generate two distinct non-uniform rational B-spline (NURBS) surfaces via the $k-$refinement strategy. A finer analysis one relied upon a combination of the IGA and a generalized shear deformation theory (GSDT) is utilized for the unknown solution approximation in finite element analyses (FEAs). Whilst the other coarser design one is employed for the exact geometry representation as well as the optimal material and thickness depiction. Size and shape design variables are in turn the ceramic volume fraction and $z-$axis coordinate of the top side of the MFG plate coincidentally assigned to each of control points on this surface. Flexibly utilizing such two surfaces helps diminish a large number of design variables and considerably save the computational cost in optimization problems, yet still appropriately manifesting optimal material and thickness profiles. Additionally, this definition accurately simulates mechanical behavior of MFG plates in analysis ones as well. A recently developed derivative-free adaptive hybrid evolutionary firefly algorithm (AHEFA) is used to solve constrained frequency maximization problems. Several numerical examples are executed to verify the effectiveness and robustness of the present paradigm.

Keywords: Isogeometric multimesh design (IMD); Size and shape optimization; Multidirectional functionally graded (MFG) plates; Isogeometric analysis (IGA); NURBS; Adaptive hybrid evolutionary firefly algorithm (AHEFA).

1. Introduction

Since the pioneering work of Japanese scientists on discovering functionally graded materials (FGMs) [1] was released, a large number of scholars have focussed greatly on studying such materials and successfully applied them to a multiplicity of engineering areas such as aerospace, aircraft, nuclear plants and high-speed vehicles, etc. Among them, the metal-ceramic FGM has been very popular and has played a crucial role in various structural applications like beams [2, 3], plates [4–8]; shells [9–11], etc. owing to the fact that their predominant mechanical properties are properly produced from synergy. Indeed, the ceramic works very well in high temperature environments, meanwhile the metal owns salient fracture toughness. Its macroscopic material properties continuously alter in a certain spatial direction based on predefined mathematical functions to eliminate the discontinuities of strain and stress fields. These usually cause delamination and crack phenomena that lead to unpredictable behavior, even undesired failures of the overall structure. A more comprehensive review on FGMs was presented in Refs. [12, 13]. Nevertheless, as

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