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Material optimization of functionally graded plates using deep neural network and modified symbiotic organisms search for eigenvalue problems

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Abstract

The paper is aimed at improving computational cost enhanced by a new combination of deep neural network (DNN) and modified symbiotic organisms search (mSOS) algorithm for optimal material distribution of functionally graded (FG) plates. The material distribution is described by control points, in which coordinates of these points are located along the plate thickness using B-spline basis functions. In addition, DNN is used as an analysis tool to supersede finite element analysis (FEA). By using DNN, solutions can directly be predicted by an optimal mapping which is defined by learning relationship between input and output data of a dataset in training process. Each of dataset is randomly created from analysis through iterations by using isogeometric analysis (IGA). The mSOS being a robust metaheuristic algorithm is employed to solve two optimization problems: buckling and free vibration with various volume constraints. Moreover, the power of mSOS is verified by comparing to other algorithms in the open literature. Finally, optimal results in all examples generated by the proposed method are compared to those of a combination of IGA and mSOS to demonstrate its effectiveness and robustness.

Keywords: Deep neural network; Modified symbiotic organisms search; Functionally graded plates; Buckling; Free vibration.

1. Introduction

Functionally graded materials (FGMs) are a kind of smart materials and their properties change continuously along certain directions. FGMs are usually made from two distinct component materials such as metal and ceramic, in which ceramic phase is perfectly efficient in withstanding high temperatures while metal phase is of excellent fracture toughness. Overcoming limitations of laminated composites, the FGMs perfectly discard undesired stress discontinuity appearing between two layers in laminated composites. For these reasons, FGMs are widely used in many various fields such as aircraft engineering, nuclear plants, electrical engineering, etc. A large number of research publications could be easily found in the literature as Refs. [1–18]. The effective material properties of the FGMs can be defined by different rules such as the three-phase model by Frohlich et al. [19], Mori-Tanaka technique [20], or mixture [21], etc.

Recently, IGA was proposed by Hughes et al. [22] to integrate computer aided design (CAD) and FEA. In IGA, the same non-uniform rational B-spline (NURBS), which is smoother and higher, is used for symbolizing exact CAD geometry and approximating to FEA solution fields.

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