Structures 61 (2024) 106021

Contents lists available at ScienceDirect

Structures

journal homepage: www.elsevier.com/locate/structures

Stability analysis of imperfect FG sandwich plates containing metallic foam cores under various boundary conditions

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ARTICLE INFO

Keywords:
Stability
Sandwich plate
Functionally graded materials
Porosity

ABSTRACT

This research investigates the influence of porosity on the stability behavior of thick functionally graded sandwich plates subjected to mechanical loads, addressing a critical gap in current understanding. It employs a novel quasi-3D high shear deformation theory used here to study the behavior of multi-type sandwich plates. Unlike high-order deformation theories (HSDT), which require correction factors, this model introduces five variables without such adjustments. The current model employs a novel displacement field incorporating indeterminate integral variables, enabling a more accurate representation of complex deformation patterns. The mechanical properties of the FG layers are assumed to vary across their thickness according to a power law distribution (P-FGM). The FG layers' porosity and step functions are characterized in two models, while a third model includes a metal foam core. The concept of virtual work is applied to derive the governing equations for mechanical stability analysis, which are then solved using the Navier solution technique. The results are validated against existing data in the literature, and a detailed discussion explores the impact of side-to-thickness ratio, aspect ratio, material index, loading type, porosity, and various foam shapes on critical buckling behavior.

1. Introduction

High-level performance has been achieved with the development of composite materials. Because of the significant elastic deformation at the interfaces, the primary drawback of conventional laminates is the concentration of stress between the layers and the propagation of cracks. Hence, functionally graded materials (FGMs) are innovative, more advanced composites developed to overcome composites' limitations [1, 2]. FGMs are generally characterized by their two main properties: stiffness and high-temperature resistance. These unique properties make

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Abbreviations: Z, Thickness direction coordinate; *b,b,h*, Dimensions of the plate; k, Power-law index; V_c, Volume fraction of ceramic; E, Elastic modulus; ν, Poisson's ratio; u_0, v_0, w_0, θ, ϕ_z, Unknown displacements; fz, Shape function; *gz*, Derivative of the shape function; *n,m*, Real numbers; k_1, k_2 A',B', Coefficients; ε_x, ε_y, ε_z, Normal strains; ε_z, Transverse strain; *FFFF*, Plate with free edges; CCCC, Plate with clamped edges; γ_{xz}, γ_{yz}, γ_{xy}, Transverse shear strains; C_{ij}, Elastic constants; δU, Change of the total strain energy; N_x, N_y, M_{xx}, M_{yy}, P_{xx}, P_{yy}, N_{zz}, N_{xy}, M_{xy}, P_{xy}, Q_{xz}, Q_{yz}, S_{xz}, S_{yz}, Force and moment components; U_{mn}, V_{mn}, W_{mn}, θ, ϕ_{mn}, Unknown parameters; ζ, Porosity coefficient; Ω, Load coefficient; E_c, Characteristics of the ceramic; E_m, Characteristics of the metal; α_{ij}, variable parameter; D_c, Reference bending rigidity; η,η *,γ, Foam coefficient; E_1, Characteristics of the metal foam; *SSSS*, Plate with simply supported edges; *FFCC*, Plate with free-clamped edges.

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https://doi.org/10.1016/j.istruc.2024.106021
Received 3 October 2023; Received in revised form 9 January 2024; Accepted 5 February 2024