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On radially symmetric vibrations of non-uniform annular sandwich plates

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ABSTRACT

Analysis and numerical results for the axisymmetric vibrations of annular sandwich plates with relatively stiff core of non-uniform thickness have been investigated using a refined theory. The face sheets are treated as membranes of constant thickness and the core is assumed to be solid as well as moderately thick of parabolically varying thickness. Due to this-type of variation in the thickness of the core, the face sheets take the shape of paraboloid of revolution and because of this, the face sheets membrane forces contribute to the bending and transverse shear stresses of the core of the plate. The equations of motion for such a plate have been derived using Hamilton's energy principle. The frequency equations for three different combinations of boundary conditions; clamped at the inner edge and clamped or simply supported or free at the outer edge are obtained employing differential quadrature method. The lowest three roots of these frequency equations have been reported as the frequencies for the first three modes of vibration. The effect of various plate parameters such as radii ratio, taper parameter, thickness of the facings and core at the centre on the natural frequencies has been studied. Three-dimensional mode shapes for the specified plates have been illustrated. A comparison of the results with published work has been made.

1. Introduction

A sandwich essentially consists of two thin faces sandwiching a light core between them. It is one of the most useful form of composite structures which has wide applications in aerospace and many other industries. Sandwich construction provides several key benefits over the conventional structures, such as very high bending stiffness, low weight, cost effectiveness, durability together with a very high stiffness-to-weight ratio and high bending strength. Due to these extra ordinary features, composite sandwich plates are used for both interior and exterior components of aircraft (e.g. overhead bins, floor panels, radome, aerodynamic fairings), space vehicles, trains, ships, boats, cargo containers and in residential construction [1,2].

In many practical situations, particularly in the design of aerospace vehicles such as wings, control surfaces (e.g. ailerons, elevators and rudders) and rotor blades of helicopter, it becomes essential to use tapered sandwich construction for greater structural and aerodynamic efficiency. It has necessitated to study the dynamic behavior of sandwich plates of non-uniform thickness with a fair amount of accuracy. Up till now, various theories for multilayered structures, particularly for composite and sandwich plates have been developed and given in Refs. [3–6]. In this regard, numerous studies have appeared in the literature and the work up to 1981 has been reported by Habip in their review/survey articles [7,8] and a series of papers by Bert [9–12]. Chang and Chen [13] investigated the free vibrations of circular and annular sandwich plates of variable thickness using finite element method. Axisymmetric vibrations of annular sandwich plates have been studied by Jain [14] using Chebyshev collocation technique. In a significant paper, Chang et al., [15] presented numerical and experimental studies on aluminum sandwich plates of variable thickness treating face plates as Marguerre shells, and the core is assumed to be an antiplane core providing resistance to transverse shear and normal stresses only. Recently, Carrera and Brischetto [16] have presented an excellent survey of the work up to 2008 on numerical assessment of classical and refined theories for the analysis of sandwich plates.

Very recent work dealing with static/dynamic behavior of sandwich/laminated plates has been reported in Refs. [17–30]. Among these, a variety of discrete singular convolution (DSC) method has been employed successfully for free vibration analysis of annular Mindlin plates by Civalek and Gürses [17], annular sector plates and laminated composite cylindrical shells by Civalek

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[18–22]. Zhen et al. developed [23] an eight-node C^0-continuous isoparametric finite element to predict the natural frequencies of sandwich plates with soft core. Free vibration behavior of symmetric laminated composite plates using different radial basis functions has been presented by Singh et al. [24]. Chalak et al. [25], proposed an improved C_0 two dimensional finite element model based on higher order zigzag plate theory to the analysis of laminated composite and sandwich plates. A Navier type and finite element solutions are proposed to obtain the free vibration response of laminated composite and sandwich plates by Grover et al. [26]. Versino et al. [27] developed six- and three-node, C^0-continuous, Refined Zigzag Theory based triangular plate finite elements for the analysis of multilayer composite and sandwich plates. Solution of the static buckling for a uniformly compressed rectangular sandwich plate having to parallel edges simply supported the generalized Galerkin method has been given by Lopatin and Morozov [28]. Peng et al. [29] used a meshfree Galerkin method based on first-order shear deformation theory for free vibration analysis of corrugated-core sandwich plates. Khalili et al. [30] used finite element procedure based on second-order Lagrangian elements and Galerkin-type formulation for the analysis of rectangular multilayered and sandwich plates.

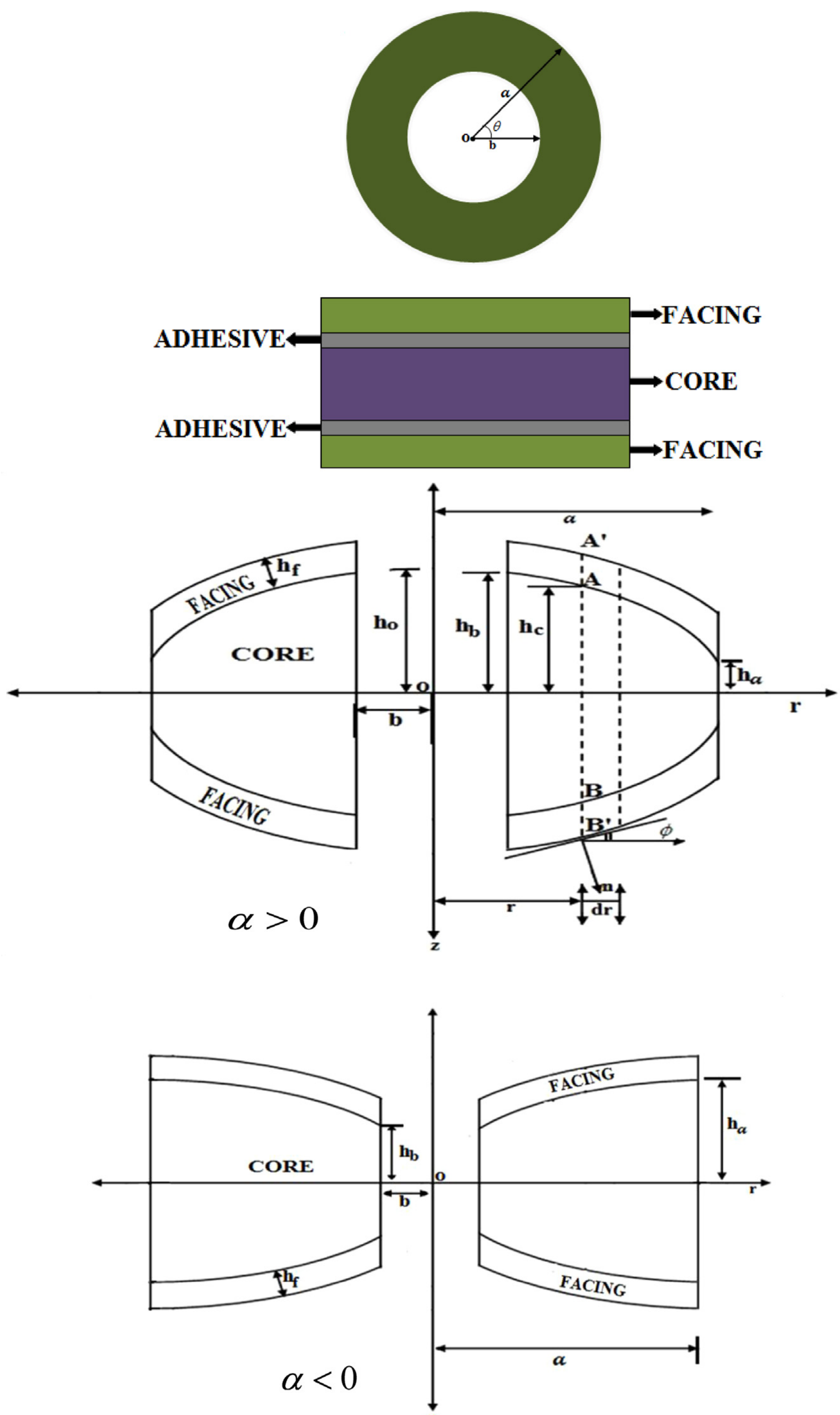

Fig. 1. Geometry and cross-section of the tapered annular sandwich plate with core of parabolically varying thickness i.e.$h_c = h_o\left[1-\alpha(r/a)^2\right]$.