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Sound radiation and transmission loss characteristics of a honeycomb sandwich panel with composite facings: Effect of inherent material damping

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ABSTRACT

This paper presents the results of numerical studies carried out on vibro-acoustic and sound transmission loss behaviour of aluminium honeycomb core sandwich panel with fibre reinforced plastic (FRP) facings. Layered structural shell element with equivalent orthotropic elastic properties of core and orthotropic properties of FRP facing layer is used to predict the free and forced vibration characteristics. Followed by this, acoustic response and transmission loss characteristics are obtained using Rayleigh integral. Vibration and acoustic characteristics of FRP sandwich panels are compared with aluminium sandwich panels. The result reveals that FRP panel has better vibro-acoustic and transmission loss characteristics due to high stiffness and inherent material damping associated with them. Resonant amplitudes of the response are fully controlled by modal damping factors calculated based on modal strain energy. It is also demonstrated that FRP panel can be used to replace the aluminium panel without losing acoustic comfort with nearly 40 percent weight reduction.

1. Introduction

A sandwich panel, with thin and stiff top and bottom face skins separated by thick and relatively less stiff core, is a common structural member used in several engineering applications. Most generally used core in aerospace industry is aluminium honeycomb core. A light weight, stiff and strong sandwich structure can be obtained by using FRP laminates as stiff layers and non-corrosive hexagonal aluminium honeycomb as core material. Also the usage of composites could be very much useful in future aircraft structures to build the smart materials [1]. Structures made up of this material experiences mechanical excitation (time-harmonic) during their service which leads to structural vibration, sound radiation and transmission issues. Apart from structural strength and stiffness requirements, the sandwich structure should have desirable vibration and acoustic response characteristics also. It is very important to analyse vibration and acoustic response characteristics of a structural member made up of a new advanced material. Damping is an important factor to be considered while analysing the dynamic behaviour of composite sandwich structures. FRP composites have better inherent material

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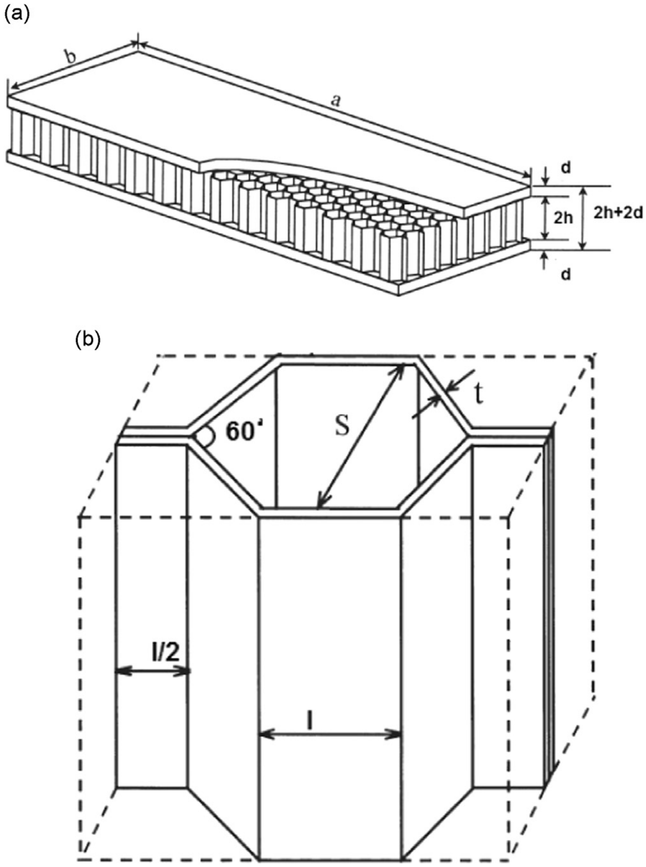

Fig. 1. (a) Dimension of honeycomb core sandwich panel and (b) dimension of unit cell honeycomb core [3].

damping due to fibre–matrix interaction compared to conventional metals used in aerospace applications. Mellert et al. [2] proved that the impact of sound and vibration on health, travel comfort and performance of flight attendants and pilots has significant effect.

Typical honeycomb core sandwich panel used as a structural member is shown in Fig. 1 [3] with dimensions h, l, t, s, d, a, and b, where h is one half of the core height, l is the side wall length, t is the cell wall thickness, s is the cell size, d is the thickness of face sheet, and a and b are the length and width of the honeycomb core sandwich panel respectively. Chandra et al. [4] reviewed the damping studies in fibre reinforced composites. Rikards [5] used a modal strain energy-based finite element method to obtain the loss factors of a laminated composite plate. Numerical methods are commonly used to predict the dynamic response from vibrating structures with complex geometry [6]. Three dimensional (3D) exact solution for the study of vibration and acoustic characteristics of aluminium honeycomb core with FRP composite facings does not exist. Two dimensional (2D) model with equivalent elastic constants is preferred for the simplified numerical investigation of these complex sandwich panels [7], thereby the computational cost is greatly reduced [8].

Ichchou et al. [9] derived the equivalent properties based on wavenumber space analysis. Hao et al. [7] studied about the suitable method to derive the equivalent properties of honeycomb core sandwich panel. In order to derive the equivalent elastic properties of honeycomb structure, sandwich plate theory, equivalent plate theory, and honeycomb plate theory can be used. Boudjemai et al. [10] conducted a numerical study on natural frequency evaluation of honeycomb panels using equivalent model. Lim et al. [11] analysed the dynamic behaviour of delaminated honeycomb panels by both theoretical and experimental methods. Setoodeh and Karami [12] analysed the free vibration behaviour of thick laminated plates using a three dimensional elasticity based layerwise theory. Kim [13] studied the free vibration characteristics of laminated and sandwich plates using enhanced plate theories. The accuracy and efficiency of the enhanced plate theories are demonstrated by comparing their results with the 3D exact elasticity solutions for the plates. Kumar et al. [14] studied the free vibration response of laminated composite and sandwich shell using a 2D FE model based on higher order zigzag theory.

Jeyaraj et al. [15,16] studied the vibration and acoustic response of a composite plate and visco-elastic sandwich plate in a thermal environment with inherent material damping. Chao et al. [17] proved that the technique of using added-on facings on a honeycomb core structure has significant effect on the noise transmission loss. Sandwich panel with honeycomb core in its back cavity has excellent sound absorption characteristics [18]. Ruzzene [19] investigated the sound radiation characteristics of sandwich beams with truss core. A finite element model is developed to evaluate the structural and

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