Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 144 (2016) 1397 – 1402

Procedia Engineering

www.elsevier.com/locate/procedia

12th International Conference on Vibration Problems, ICOVP 2015

Effect of Core Topology on Vibro-Acoustic Characteristics of Truss Core Sandwich Panels

M. P. Arunkumar[a], Jeyaraj Pitchaimani[a*], K. V. Gangadharan[a] , M. C. Leninbabu[b]

[a]*National institute of technology Karnataka, Surathkal,575025, India*
[b] *VIT University, Chennai Campus, Tamilnadu,600127, India*

Abstract

This paper presents numerical simulation studies on effect of core topology on vibro–acoustic behaviour of truss core sandwich panels with metal facings. Free and forced vibration responses of the panels are obtained using finite element method based on the equivalent 2-dimensional models. Sound radiation characteristics of the panel are obtained using Rayleigh integral. It is found that influence of nature of core topology on sound radiation is significant in lower frequencies. It is observed that compared to trapezoidal and rectangular core, triangular core is more suitable for low frequency application and also it radiates less sound compare to trapezoidal and rectangular core.

Peer-review under responsibility of the organizing committee of ICOVP 2015

Keywords: Sandwich panel; Vibration response; Acoustic response; Equivalent model; Rayleigh integral

1. Introduction

Sandwich panels with metal/laminated polymer composite stiff facing as outer skin relatively soft material as the core are used as structural members in several engineering applications. This kind of sandwich construction offer significant advantage in structural and acoustical performance of structures during their service. Due to these advantages, sandwich constructions are used in many aircraft and space structures where weight saving and good acoustical properties is an important consideration in their design along with high stiffness and strength.

* Corresponding author. Tel.: +91-7795858559.
E-mail address: pjeyaemkm@gmail.com

Peer-review under responsibility of the organizing committee of ICOVP 2015
doi:10.1016/j.proeng.2016.05.170

Sandwich constructions are composed of top and bottom face stiff layers that are separated by a core layer. The faces are thin panels of aluminium, steel or fibre reinforced laminated composites. Material in the core can be selected from metals, composites plastics or wood. They are usually designed in such a way that the core carries the shear load and the face plate carries the bending and in-plane loads, resulting in high bending stiffness and resistance to buckling in relation to their weight.

Various core topologies can be used for sandwich construction like aluminium honeycomb, rigid or flexible polymer foam, aluminium foam solid balsa wood and corrugated or cellular core with a variety of corrugation geometries like sinusoidal, triangular, trapezoidal and rectangular shaped core. This type of sandwich panels are used to construct the fuselage for passenger aircraft where comfortable is required. These panels during their services are subjected to external excitations which causes vibration. This vibration has its effect on sound radiation. [1] derived the equivalent elastic stiffness properties for c-core sandwich panel.

The 2D equivalent properties of truss core sandwich panel are derived by [2]. [3] investigated the free vibration of clamped truss core sandwich panel. [4] analysed the vibration and sound radiation from sandwich beams with truss core. A finite element model is developed to evaluate the structural and the acoustic behaviour of the considered class of sandwich beams. [5] evaluated the equivalent stiffness properties of corrugated board; he derived the equivalent stiffness properties based on detailed micro mechanical representation of a region of corrugated board modelled by means of finite elements. [6] performed wave number analysis and compared the coincidence frequency to investigate acoustic performance on bamboo with balsa, cotton with Rohacell foam, epoxy carbon fibre with Rohacell foam, cotton with pine were used for the analysis. [7] investigated the acoustic power radiated by aluminium foam sandwich panel. Two different aluminium foams with different thickness and foam density are used.

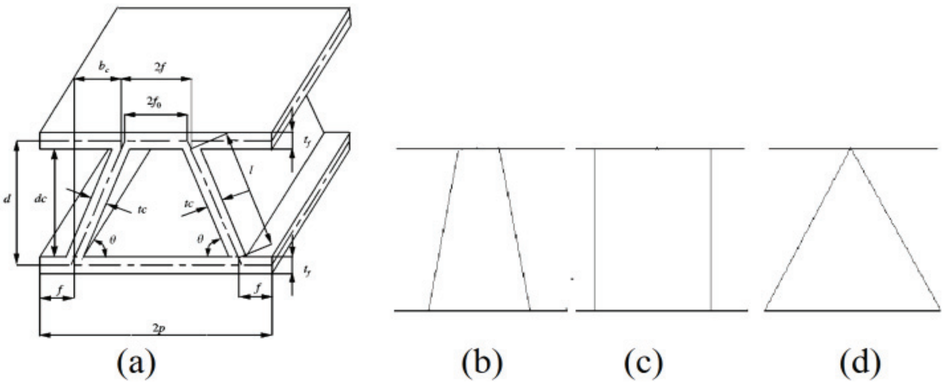


Fig. 1 (a) Dimension of a truss core unit cell [3]. Different topology of truss core sandwich panel, (b) trapezoidal truss core, (c) cellular truss core, and (d) triangular truss core

2. Methodology

To start with, the sandwich panel is converted to its equivalent 2D model. Secondly, modal analysis is carried out to find the natural frequencies and mode shapes of the structure by solving the Eigen value problem as given below:

$$(K - \omega_k^2 M)\varphi_k = 0 \tag{1}$$

Where, *K* is the structural stiffness matrix, *M* is the mass matrix, while ω_k is the circular natural frequency of the structure and φ_k the corresponding mode shape. After the computation of the natural frequencies and mode shapes a harmonic response analysis is carried out to find the vibration response of the structure. The general equation of motion for a structure is

$$M\ddot{U} + C\dot{U} + KU = F(t) \tag{2}$$

Where, [*C*] is the damping matrix, *F*(*t*) the applied load vector (assumed time-harmonic), $\ddot{U}$, $\dot{U}$, and *U* are the acceleration, velocity and displacement vector of the panel. In this work vibration responses are calculated using commercial finite element solver ANSYS. SHELL 181 is used to carry out the analysis. Forced vibration response of the structural member is given as an input to the Rayleigh integral.

$$p(r) = \frac{j\omega\rho_0}{2\pi}\int W(r_s)\,\frac{e^{-jk|r-r_s|}}{|r-r_s|}\,ds$$
(3)

Where, $p(r)$ is the complex pressure amplitude, ρ_0 is the density of the medium, $W(r_s)$ is the particle velocity at the surface point, *k* is the acoustic wave number, $|r - r_s|$ is the distance between the surface and the field point. MATLAB code developed for the Rayleigh integral is used to obtain sound radiation characteristics.

3. Results and discussion

In this paper, an Aluminum trapezoidal truss core sandwich panel of size 2 m X 1.2 m is considered for detailed investigation. The panel width implies an assembly of eight identical truss core sandwich units. The dimension as shown in Fig. 1 and properties of the unit cell are: p = 75 mm, f_0 =25 mm, d = 46.75 mm, t_f = t_c= 3.25 mm, E = 80 GPa, poisons ratio γ = 0.3 and material density ρ = 2700 kg/m^3. It is assumed that f/p varies from 0 ≤ f/p ≥ 0.5. In that, the ratio f/p = 0 corresponds to a triangular truss core, and f/p = 0.5 represents a cellular truss core with vertical webs. The equivalent elastic constants: E_x and E_y are the elastic modulus and G_{xy}, G_{xz} and G_{yz} are the shear modulus are calculated. To solve Eq.1 and Eq. 2 commercial finite element solver ANSYS is used. Convergence study is done on modal analysis and spatially averaged RMS velocity to get the mesh size to be used for detailed analysis. Vibration response obtained is given as an input to Eq. 3 to obtain the sound radiation characteristics.

Equivalent elastic constants are calculated for all the three cases and shown in Table 1. From Table 1, it is clear that the transverse shear stiffness of triangular core is high compared to other sandwich panels. The free vibration response results are shown in the Table 2. From Table 2, it is clear that natural frequency varies with core topology. The natural frequency of triangular core is high compared to other sandwich panels because of its high stiffness. From Fig. 2, it is clear that the core topology has the influence on average RMS velocity. It is observed that core topology influences the average RMS velocity in terms of increasing free vibration frequencies as seen in Fig. 2. The sound power level of trapezoidal, rectangular and triangular are calculated and shown in Fig. 3. From the Fig. 3 it is clear that compare to triangular core trapezoidal and rectangular core radiates more sound because of its high stiffness to weight ratio compare to triangular core. The stiffness of triangular core is high compare to trapezoidal and rectangular but in the same way it has more equivalent density compare to trapezoidal and rectangular core because of this property it radiates less sound compare to trapezoidal and rectangular core sandwich panel. From Fig. 3, one can select triangular core for low frequency applications compared to trapezoidal and cellular core.

Table 1. Equivalent elastic constant for different cores

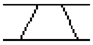
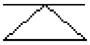
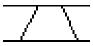
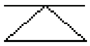
		Equivalent elastic constants		
Material properties	Elastic constants (Pa)	Trapezoidal truss core 	Cellular truss core 	Triangular truss core 
$E = 80$ GPa	E_x	3.3.6536e+10	3.6162e+10	3.8935e+10
$\gamma = 0.3$	E_y	3.3631e+10	3.3603e+10	3.3804e+10
$\rho = 2700$ kg/m^3	G_{xy}	1.2834e+10	1.2837e+10	1.2837e+10
	G_{yz}	2.376e+07	1.3856e+06	8.7110e+08
	G_{xz}	1.397e+09	1.6005e+08	75087e+08
	γ_{xy}	0.3	0.3	0.3
	γ_{yz}	0.2761	0.2788	0.2605
	ρ_{eq} (kg/m^3)	498.86	484.26	592.38

Table 2. Free vibration response for different cores

Mode	Different types of core		
			
	(Hz)	(Hz)	(Hz)
1	137.89	129.46	259.86
2	210.93	186.16	365.74
3	292.86	253.32	534.06
4	295.15	292.77	577.81
5	350.69	322.64	659.39
6	381.43	337.91	744.65
7	430.71	391.90	793.28
8	467.99	406.22	970.52
9	518.90	460.52	977.26
10	520.78	482.44	983.55

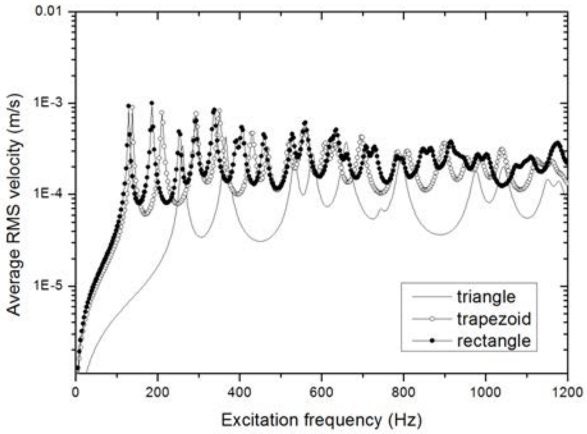


Fig. 2. Influence of core topology on average RMS velocity

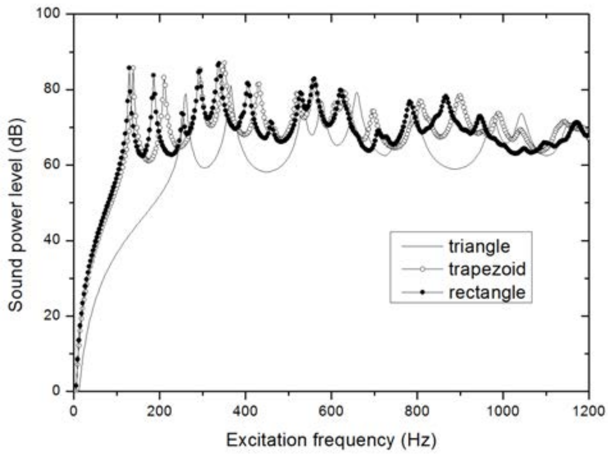


Fig. 3. Influence of core topology on sound power level

4. Conclusions

In this paper, the free and forced vibration responses, acoustic responses of triangular, trapezoidal and cellular core sandwich panel are studied. Equivalent elastic properties are calculated to convert 3D sandwich panel in to its equivalent 2D model. Using 2D model vibration and acoustic responses are calculated for trapezoidal, cellular and triangular core. The pre processing time for modelling sandwich panel is greatly reduced by using 2D equivalent model. From results, it is clear that the triangular core radiates less sound compared to trapezoidal and cellular core and also it is more suitable for low frequency applications.

References

[1]T. C. Fung, K. H. Tan, T. S. Lok, Shear stiffness for c-core sandwich panel, Journal of Structural Engineering, 120 (1996) 958-966.

[2]T. S. Lok, Q. H. Cheng, Elastic stiffness properties and behaviour of truss core sandwich panel, Journal of Structural Engineering. 126 (2000) 552-559.

[3]T. S. Lok, Q. H. Cheng, Free vibration of clamped orthotropic sandwich panel, Journal of Sound and Vibration, 229 (2000) 311-327.

[4]M. Razzen, Vibration and sound radiation of sandwich beams with honeycomb truss core, Journal of Sound and Vibration, 277 (2004) 741-763.

[5]M. E. Biancolini, Evaluation of equivalent stiffness properties of corrugated board, Composite Structures, 69 (2005) 322-328.

[6]J. Sargianis , H. I. Kim , E. Andres, J. Suhr, Sound and vibration damping characteristics in natural material based sandwich composites, Composite Structures, 96 (2013) 538-544.

[7]G. Petrone , S. Rao , S. D. Rosa, B. R. Mace, F Franco, D. Bhattacharyya, Initial experimental investigations on natural fibre reinforced honeycomb core panels, Composites: Part B, 55 (2013) 400-406.