Composite Sandwich Structure Design Requirements

Composite Engineer's Viewpoint
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Part 8 – Panel Vibration Behaviour

The vibration of sandwich structures with metal skins is well established (see Allen[1]). The difficulty with composite skins is that they have orthotropic properties and these complicate the analysis somewhat. For orthotropic skins the natural frequency of a simply supported sandwich panel can be expressed as:

$$\omega_{mn} = \left(\frac{\pi}{Rb}\right)^2 \sqrt{\frac{1}{\rho}} \sqrt{\left(D_{11}m^4 + 2\left(D_{12} + 2D_{66}\right)R^2m^2n^2 + D_{22}R^4n^4\right)}$$

Where: *Dij* = Sandwich Panel Flexural Stiffness Constants

$$D_{ij} = \begin{bmatrix} \frac{E_{f_1}t_fh_c^2}{2\left(1-\upsilon_{21}\upsilon_{12}\right)} & \frac{\upsilon_{21}E_{f_1}t_fh_c^2}{2\left(1-\upsilon_{21}\upsilon_{12}\right)} & 0 \\ \frac{\upsilon_{21}E_{f_1}t_fh_c^2}{2\left(1-\upsilon_{21}\upsilon_{12}\right)} & \frac{E_{f_2}t_fh_c^2}{2\left(1-\upsilon_{21}\upsilon_{12}\right)} & 0 \\ 0 & 0 & \frac{G_{f_{12}}t_fh_c^2}{2} \end{bmatrix}$$

Note for the first mode of vibration $m = n = 1$. The natural frequency can be converted to a frequency in cycles per second (*Hz*) using:

$$f_{mn} = \frac{\omega_{mn}}{2\pi}$$

There are several modes of vibration in a structure and the mode shape is defined by integer values in the longitudinal direction (*m*) and the transverse direction (*n*) in the plane of the plate. The natural frequency over a range of vibration modes for a specially orthotropic laminated sandwich plate (i.e. the laminate is symmetric and specially balanced such that $A_{16} = A_{26} = D_{16} = D_{26} = 0$) is given by (Whitney, 1987[2]):

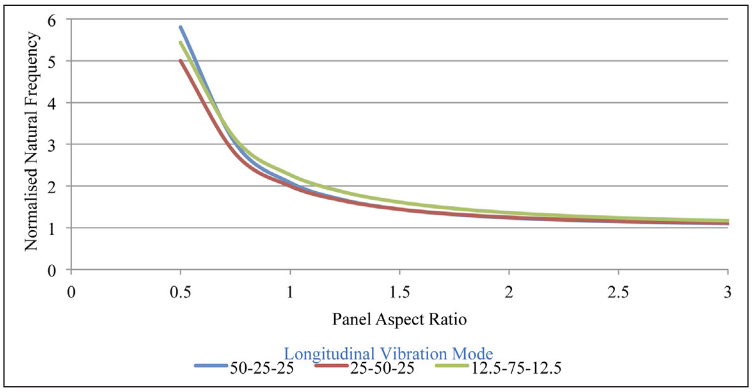
Hence, there are a lot of potential variables in the development of the plate natural frequency. The panel aspect ratio (*R*) has a major role to play in determining the natural frequency of the structure, as does the panel density (ρ) (controlled by fibre/resin type and the fibre volume ratio to some extent). Also, the factor in defining composite plate natural frequency is the flexural rigidity of the panel (D_{ij}) and thus the through-the-thickness position of the contributing plies.

For $n = 1$ (first transverse frequency mode) and the sandwich panel expressions for D_{ij} substituted into the terms stiffness properties of the composite laminate into the natural frequency equation we have:

$$\frac{\omega_{mn}}{h_c}\left(\frac{b}{\pi}\right)^2 \sqrt{\frac{2\rho\left(1-\upsilon_{21}\upsilon_{12}\right)}{E_2t_f}} = \sqrt{\frac{E_1}{E_2}\left(\frac{m}{R}\right)^4 + \frac{2\left\{\upsilon_{21}E_1 + 2G_{12}\left(1-\upsilon_{21}\upsilon_{12}\right)\right\}}{E_2}\left(\frac{m}{R}\right)^2 + 1}$$

This expression can be plotted for a couple of composite skins with percentages of plies as follows:

a. [0/±45/90] = [50%/25%/25%],
b. [0/±45/90] = [25%/50%/25%],
c. [0/±45/90] = [12.5%/75%/12.5%],



Simply Supported Sandwich Panel with Orthotropic Facings with Natural Frequencies under Mode 1,1 conditions

From this plot the normalised natural frequency basically asymptotes at an aspect ratio above 2. We can also see that the facing have a limited effect on the normalised natural frequency. But the core thickness will play a key role to normalised natural frequency.

In the next article we will discuss structural detail in sandwich panels. Specifically, we will discuss facing and core depth holes, joining sandwich structures, the attachment of fittings and sandwich structure edge requirements.

References:
1. Allen H.G., Analysis and Design of Structural Sandwich Panels, Pergamon Press, Sydney, 1969.
2. Whitney J.M., Structural Analysis of Laminated Anisotropic Plates, Technomic Publishing Co., Lancaster PA, 1987.

All articles published in Engineer's Viewpoint are available on the Composites Australia website (www.compositesaustralia.com.au/industry). Rik welcomes questions, comments and your point of view by email to rikheslehurst@gmail.com