Equivalent Laminated Model of the Aluminum Honeycomb Sandwich Panel

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Abstract. In order to improve quality, safety and dependability, researches on the mechanical characteristics of the aluminum honeycomb sandwich panel have been given more prominence. In the present study, an equivalent laminated model with three layers is presented to simulate the behavior of the aluminum honeycomb sandwich panel with positive hexagon core. In the equivalent model, upper and lower layers are the same as that of the aluminum honeycomb sandwich panel, the middle honeycomb core is equivalent to a layer with isotropic properties. The elastic parameters of each layer are not necessarily the same. Examples indicate that the present model is reasonable and credible.

Introduction

The aluminum honeycomb sandwich panel is a kind of special compound materials. Because of its excellent material function, it is widely used in aerospace, aviation and ship manufacturing. In order to improve product quality, ensure the sandwich panel safety and reliability, it is necessary to study its mechanical property. Jeyakrishnan et al [1] carried out an avant-garde study on Buckling of honeycomb sandwich panel of hexagonal cell considering simply supported boundary constraints. Luca Guj and Aldo Sestieri [2] established a mathematical model based on a multi-scale asymptotic technique for the dynamic description of honeycomb structures. Chen Jun et. al [3] put out an experiment measurement method of the metal honeycomb core sandwich panel. Liang Sen et al [4], Fu Minghui [5], studied the equivalent elastic parameters of regular hexagonal honeycomb. Xu Sheng-jin introduced a method of equivalent analysis for dynamic and statics behavior of honeycomb sandwich plates with orthotropic materials. In various forms of aluminum honeycomb core, positive hexagon core is applied most extensively. The aim of the present study is to establish an equivalent laminated model of the aluminum honeycomb sandwich panel with positive hexagon core. Each layer of the laminated plate is isotropic properties.

Equivalent Model

In order to facilitate the analysis, unified symbols are necessary. The honeycomb sandwich panel is composed of a upper and lower isotropic aluminum skin layer with plane stiffness and smaller thickness, and a middle honeycomb core. The sketch of the honeycomb sandwich panel is shown in Fig.1, where h_f is the thickness of a skin layer, h_c the thickness of honeycomb core. The total thickness of the aluminum honeycomb sandwich panel is

$$H = 2h_f + h_c \quad (1)$$

Fig.1 Sketch of the honeycomb sandwich panel

The sandwich core (shown in Fig.2) with positive hexagon can be equivalent to a single plate with isotropic function. A laminated model with three layers is introduced to calculate the mechanical behaviors of the whole aluminum honeycomb sandwich panel. In the model, each layer is isotropic properties. The elastic parameters of each layer are not necessarily the same. The stress-strain relationship can be written as:

$$\begin{Bmatrix} N_x \\ N_y \\ N_z \\ M_x \\ M_y \\ M_z \end{Bmatrix} = \begin{bmatrix} A_{11} & A_{12} & & & & \\ & A_{11} & & & & \\ & & 2A_{66} & & & \\ & & & D_{11} & D_{12} & \\ & & & & D_{11} & \\ & & & & & 2D_{66} \end{bmatrix} \begin{Bmatrix} \varepsilon_{x0} \\ \varepsilon_{y0} \\ \varepsilon_{xy0} \\ \kappa_x \\ \kappa_y \\ \kappa_{xy} \end{Bmatrix} \quad (2)$$

where the coefficients of Eq.(8) can be see in book [5].

The Young's modulus of the equivalent center layer can be written as:

$$E_{cef} = \gamma \frac{4}{3\sqrt{3}} \frac{t}{l} E_f \quad (3)$$

where t and l are the cell thickness and size (shown in Fig.2); γ the relaxation coefficient with value of 0.8 in the present study.

Fig.2 Sketch of the honeycomb core

Examples

There are two rectangular aluminum honeycomb sandwich panels, one is a plate with length of 500mm and width of 400mm, and the other is a square with length of 300mm. The skin-layer thickness h_f of both panels is 3mm, the thickness of honeycomb core h_c is both 44mm. Panels can be calculated with FEM for 3D model and the equivalent laminated model. The following three cases are considered:

- (1) One Side is fixed support, and a skin layer bears surface pressure of 1MPa;
 - (2) One Side is fixed support, and a corner is under the concentrated load of 10kN;
 - (3) The two opposite edges are imply supported, and a skin layer bears surface pressure of 1MPa.
- The results are shown in Fig.3 to Fig.8.

Fig.3 Calculation results of square panel with the two models in case (1)

Fig.4 Calculation results of square panel with the two models in case (2)

Fig.5 Calculation results of square panel with the two models in case (3)

Fig.6 Calculation results of rectangular panel with the two models in case (1)

Fig.7 Calculation results of rectangular panel with the two models in case (2)

Fig.8 Calculation results of rectangular panel with the two models in case (3)

Contrasts of the maximum displacements with the two models in any cases are shown in table 1. The results by the present equivalent laminated models are identical to the value by the 3D solid FEM models. With the increase of the board size, the error of the two models is more and more small.

Tab.1 The maximum displacements

Case	FEM of 3D model /mm	FEM of the equivalent laminated model /mm	Deviation /%
The square panel in case(1)	5.0398	5.0742	0.6826
The square panel in case(2)	2.2874	2.3159	1.246
The square panel in case(3)	0.3124	0.3455	10.5954
The rectangular panel in case(1)	33.7606	33.7772	0.0492
The rectangular panel in case(2)	6.0347	6.0785	0.7258
The rectangular panel in case(3)	0.9882	1.0597	7.2354

Conclusion

An equivalent laminated model with three layers is introduced to calculate the behavior of the aluminum honeycomb sandwich panel with positive hexagon core, in which upper and lower layers

are the same as that of the aluminum honeycomb sandwich panel, the middle honeycomb core is equivalent to a layer with isotropic properties. The elastic parameters of each layer are not necessarily the same. Examples indicate that the present model is reasonable and credible. With the increase of the board size, the error of the two models is more and more small.

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