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Research on the Impact of Honeycomb Sandwich Plates at Natural Frequency Changed with Geometric Parameters

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Abstract: In this paper, in order to find the impact of sandwich plates at natural frequency changed with its geometric and physical parameters, we deduced free vibration equation derived sandwich panels. We took the hexagonal honeycomb sandwich plates as example, and derived natural frequencies for each for use in the modeling and modal analysis, and then discussed the effect of skin thickness, core spacing and core height on the natural frequency of honeycomb sandwich plates. The result shows that the honeycomb sandwich plates have great rigidity, and compared to other parameters, the change of core height has a greater impact on the natural frequencies of honeycomb sandwich plates. When the surface thickness of quadrilateral honeycomb sandwich plates becomes thicker, its natural frequency increases with increasing length of core grid. When sandwich mesh length reaches a certain level, the natural frequency increased firstly and then decreased. When the sandwich mesh length is longer enough, the frequency decreased with the increase in the length. When the core height increased, the natural frequency increased. When the quadrilateral mesh becomes longer, its natural frequency appears to decline after the initial increase. The influence of geometric parameters on hexagonal honeycomb sandwich plates is same as on quadrilateral honeycomb and other soft sandwich plates. Later experiments confirmed some of above conclusions.

Keywords: ANSYS, geometric and physical parameters, honeycomb sandwich plates, modal, natural frequency.

1. INTRODUCTION

Composite laminate structures for static, dynamic theoretical analysis and computing applications, as well as viscoelastic polymer material in sandwich plates and shell structures, use a special method in mechanics applications. By selecting the appropriate surface and laminated materials, good vibration, heat insulation, sound insulation *etc*. can be achieved; it has thus broad application prospects [1-3], especially in the automotive, aerospace, construction, shipbuilding and mechanical construction fields [4, 5], in which the automotive and construction are two of the most promising fields. In the automobile industry, the quality of transport to reduce the honeycomb structure is widely used in aircraft, aerospace and aerospace industries. The new results enable the structural analysis to be decoupled from an analysis of shock propagation in the air [6]. The study complements the prior work on the role of fluid-structure interaction in the design and assessment of sandwich plates subject to water shocks [7]. Square honeycomb and folded plate core topologies are considered. Fluid-structure interaction enhances the performance of sandwich plates relative to solid plates under intense air shocks, Ashkan Vaziri investigates two methods for applying the loading to the sandwich plate [8, 9], responses are contrasted for loads applied as a time-dependent pressure history versus imposition of an initial velocity.

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2. INHERENT VIBRATION EQUATION OF HONEYCOMB SANDWICH PLATES

When the honeycomb sandwich panels undergo natural vibration in the absence of external force, the amplitude of the displacement of the plane is much smaller than the horizontal deflection amplitude. Therefore, you can ignore the inertial force generated by the intermediate displacement, using sandwich plate theory, so the basic equation can be derived based on the relationship between shear, load and moment [10-12].

$$M_x = -D\left(\frac{\partial \varphi_x}{\partial x} + v_f \frac{\partial \varphi_y}{\partial y}\right) - 2D_f\left(\frac{\partial^2 w}{\partial x^2} + v_f \frac{\partial^2 w}{\partial y^2}\right) \qquad (1)$$

$$M_y = -D\left(\frac{\partial \varphi_y}{\partial y} + v_f \frac{\partial \varphi_x}{\partial x}\right) - 2D_f\left(\frac{\partial^2 w}{\partial y^2} + v_f \frac{\partial^2 w}{\partial x^2}\right) \qquad (2)$$

$$M_{xy} = -\frac{1}{2}(1 - v_f)D\left(\frac{\partial \varphi_x}{\partial y} + \frac{\partial \varphi_y}{\partial x}\right) - 2(1 - v_f)D_f \frac{\partial^2 w}{\partial x \partial y} \qquad (3)$$

$$Q_x = C\left(\frac{\partial w}{\partial x} - \varphi_x\right) - 2D_f \frac{\partial}{\partial x}\left(\frac{\partial^2 w}{\partial x^2} + \frac{\partial^2 w}{\partial y^2}\right) \qquad (4)$$

$$Q_y = C\left(\frac{\partial w}{\partial y} - \varphi_y\right) - 2D_f \frac{\partial}{\partial y}\left(\frac{\partial^2 w}{\partial x^2} + \frac{\partial^2 w}{\partial y^2}\right) \qquad (5)$$

By introducing the sandwich plate surface stress-strain relation equation, the equation of motion into the sandwich board, after several parameter substitutions, acquired a sandwich board free vibration equation.

$$\frac{D}{2}\left(1-v_f\right)\nabla^2 f - Cf = 0 \tag{6}$$

$$\left(D+2D_f\right)\nabla^4\omega - \frac{2D_1 D_2}{C}\nabla^6\omega - \frac{1}{R}\frac{\partial^2\Phi}{\partial x^2} - \rho\bar{\omega}^2\left(\omega - \frac{D}{C}\nabla^2\omega\right) = 0 \tag{7}$$

3. HONEYCOMB SANDWICH PLATES MODELING PROCESS BASED ON ANSYS

The side length of the hexagonal honeycomb sandwich panels is 0.6m*0.6m, thickness is 0.003m, sandwich mesh side length is 0.03m, sandwich thickness is 0.001m, and mezzanine height is 0.03m. Create a hexagon, then copy it to extend to form a hexagon, beneath the newly generated long hexagonal surface to identify the key points to form a new hexagonal, as shown in Fig. (**1**). In the newly generated copy, extended hexagons form a new lengthy hexagon surface.
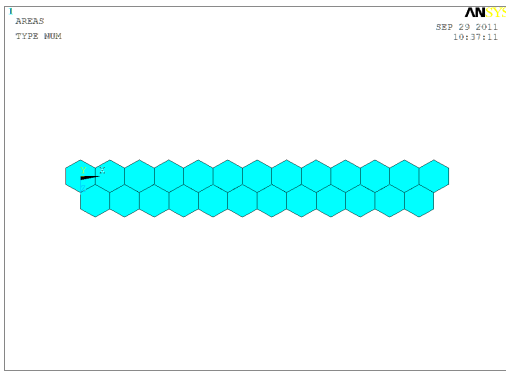

Fig. (1). Two-line hexagonal surface.

The new generation of multi-faceted hexagons replicate the formation of large multi-faceted hexagons, in the face of the origin of the four reference points that were selected (0,0), (0,0.6), (0.6,0), (0.6,0.6) *i.e.* four points together into a straight line, and then face segmentation, Pick a point above the origin, the origin is connected to form a baseline, then along the newly formed straight surfaces stretch this entry generating body, followed by removing the body, that will then leave the surface, it will be the model hexagonal honeycomb sandwich panels shaping up as shown in Fig. (**2**).
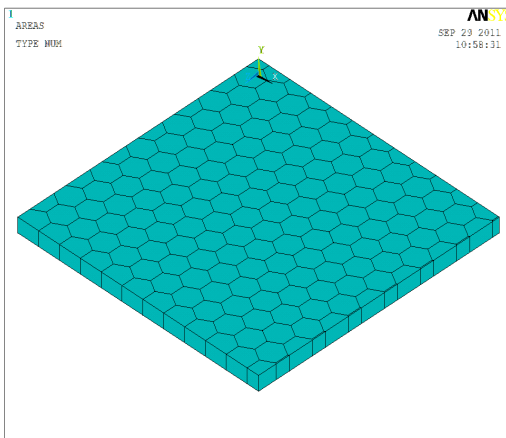

Fig. (2). Hexagon sandwich plates.

4. THE NATURAL FREQUENCY OF HONEYCOMB SANDWICH PLATES CHANGED WITH GEOMETRIC AND PHYSICAL PARAMETERS

In order to find the impact of sandwich plates at a natural frequency changed with its geometric and physical parameters, we deduced free vibration equation derived sandwich panels. The hexagonal honeycomb sandwich plates were taken as example, and natural frequencies were derived for each for use in modeling and modal analysis. Finally, the influence of skin thickness, core spacing and core height, on the natural frequency of honeycomb sandwich plates was discussed.

4.1. Plate Thickness Variation Affects the Natural Frequency

Hexagonal honeycomb sandwich panels studied under the free vibration, whose upper and lower plates are made of steel or aluminum. A modal analysis based on ANSYS software was conducted.

Examples: There is a 0.6m×0.6m hexagonal honey-comb sandwich plate, with sandwich height 0.03m, sandwich mesh sides 0.010m, 0.015m, 0.020m, 0.025m, 0.030m, 0.035m, 0.040m, 0.050m, 0.060m respectively. Each side of freedom, material parameters were: E_1=200GPa, E_2=90GPa, v=0.3, ρ=7800 kg/m^3. Skin thickness is 0.002m, 0.003m, 0.004m, 0.005m, 0.006m. These sandwich plates' first natural frequencies are given in Table **1**.

When mesh side is 0.01m, natural frequency of the sandwich plate with a thickness of the upper and lower thick plate increased. The rate of increase becomes smaller, that is, the slope becomes smaller.

When mesh side is 0.035m, 0.04m, 0.05m, 0.06m respectively, natural frequency of the sandwich plate with the thickness of the upper and lower thicker plates decrease linearly.

4.2. Sandwich Core Height Changed at Natural Frequency of Honeycomb Sandwich Plates

From the above chart presenting curve data analysis in Fig. (**3**), it has been identified that on the hexagonal honeycomb sandwich panels at the high fixed core sandwich, with the change in the thickness of the upper and lower plates, natural frequency change occurs more regularly.
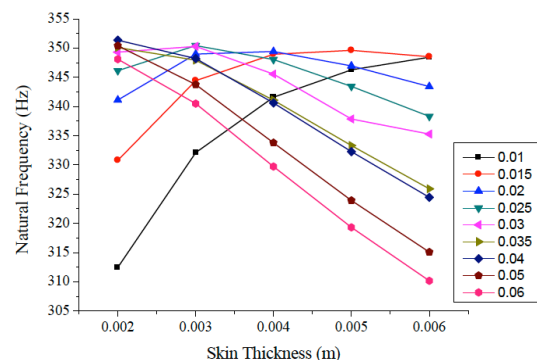

Fig. (3). Natural frequency changed with different skin thickness and mesh sides of hexagon sandwich plates.

Table 1.   Frequency at different skin thickness.

Frequency (Hz)	Skin thickness (m)				
Mesh length (m)	**0.002**	**0.003**	**0.004**	**0.005**	**0.006**
0.010	312.45	332.1	341.59	346.26	348.43
0.015	330.79	344.42	348.95	349.62	348.52
0.020	341.12	348.97	349.41	346.95	343.41
0.025	346.14	350.42	348.03	343.45	338.30
0.030	349.31	350.28	345.55	342.86	339.27
0.035	350.09	347.92	341.07	333.32	325.89
0.040	351.35	348.22	340.61	332.28	324.44
0.050	350.40	343.76	333.80	323.92	315.06
0.060	348.11	340.48	329.72	319.31	310.17
Mesh length (m)	0.002	0.003	0.004	0.005	0.006
Frequency (Hz)	Skin thickness (m)				

Table 2.   The natural frequency at different sandwich core height.

Frequency (Hz)	Sandwich core height (m)				
Mesh length (m)	**0.02**	**0.03**	**0.04**	**0.05**	**0.06**
0.010	245	332	404	466	520
0.015	252	340	415	478	543
0.020	254	348	428	497	557
0.025	255	350	431	500	561
0.030	255	350	431	500	561
0.035	254	348	428	497	557
0.040	242	348	427	496	557
0.050	250	343	420	485	545
0.060	250	340	416	479	539
Mesh length (m)	0.02	0.03	0.04	0.05	0.06
Frequency (Hz)	Sandwich core height (m)				

When mesh side is 0.015m, 0.02m, 0.025m, 0.03m, natural frequency of the sandwich plate with the upper and lower plate thickness after thickening and initial increase, decreased based on ANSYS software.

Examples: There is a 0.6m×0.6m hexagonal honey-comb sandwich plate, with the thickness of the upper and lower plates to be 0.03m. Sandwich mesh sides were: 0.010m, 0.015m, 0.020m, 0.025m, 0.030m, 0.035m, 0.040m, 0.050m, 0.060m. Each side of freedom, material parameters were: E_1= 200GPa, E_2=90GPa, v=0.3, ρ=7800 kg/m^3; sandwich height were: 0.002m, 0.003m, 0.004m, 0.005m, 0.006m. These sandwich plates' first natural frequencies are given in Table **2**.

Data from the Table **2** and Fig. (**4**). show that in a fixed timeframe and changes in the height, for hexagonal honeycomb sandwich panels with the upper and lower plates, sandwich plate's natural frequency also changes more regularly: With the increase in height of the sandwich core, hexagonal honeycomb sandwich panels natural frequency dramatically increases.
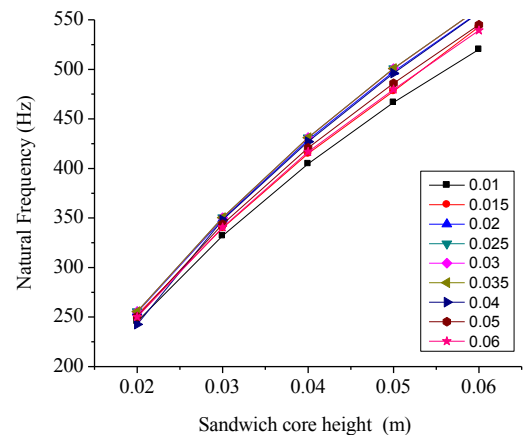

Fig. (4). Natural frequency with sandwich core height change and different mesh sides of hexagonal sandwich plates.

When the sandwich core height is 0.02m to 0.04m, the interlayer sheet's natural frequency increase is the greatest. When the sandwich core increased from 0.04m to 0.05m, sandwich plate natural frequency increase becomes smaller.

When mesh side lengths are 0.035m, 0.04m, 0.05m and 0.06m, showing the sandwich height variation, no significant difference is found between their natural frequency, until when the sandwich side length is 0.03m. But when the sandwich side lengths are 0.01m, 0.015m, 0.02m, 0.025m, the side of the sandwich becomes large along with the natural frequency of the interlayer sheet, and as the sandwich core height increases, the gap between also increases.

4.3. Sandwich Core Mesh Side Change at the Natural Frequency of Honeycomb Sandwich Plates

Data from the above two tables shows that the change in sandwich core height on a hexagonal honeycomb sandwich panel plate could help calculate the variation in the first-order natural frequency; we could draw a side length change on a hexagonal honeycomb sandwich plate.
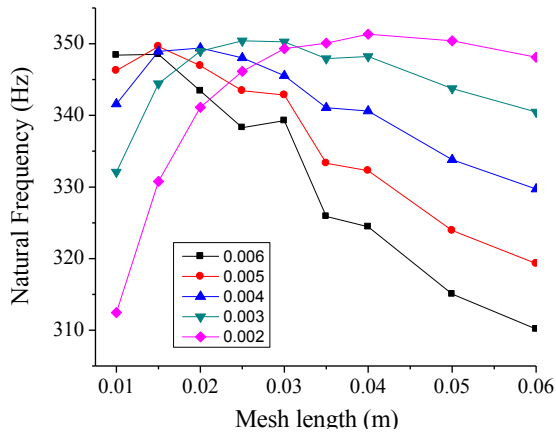

Fig. (5). Natural frequency with mesh length change and different skin thickness of hexagon sandwich plates.

Figs. (**5** & **6**) show that on hexagonal honeycomb sandwich panels with the upper and lower plates having high fixed core length/thickness, side length changes with time and the natural frequency change occurs more regularly.

When the core height is fixed, hexagonal honeycomb sandwich panels having different thickness of upper and lower plate sides with a grid showing changes in its natural frequency shows decreasing trend after the first growth. And with the increase of the mesh side length, its inherent frequency reduction rate increases.

When the upper and lower plate thickness is fixed, different height hexagonal honeycomb core sandwich panels with mesh side, change its natural frequency initially and then show increasing or decreasing trend. However, the changes are not significant.

5. SANDWICH PLATE MODAL TEST

Modal shows the overall characteristics of the inherent elasticity of the structure. If you figure out the structure within a frequency range of each susceptible modal characteristic at the main stage by modal analysis method, it is possible to predict the actual vibrational response of the structure inherent in this band under the action of various external or internal vibration sources. Therefore, modal analysis is an important method for fault diagnosis, structural dynamic design and equipment analysis. Modal analysis provides a practical study of structural vibration in an effective way. Modal parameters can be achieved by calculation or experimental analysis, which is known as modal analysis. If this analysis is done by the finite element method to obtain modal parameters, then it is known as modal analysis calculation. After parameter identification, modal parameters are obtained through the system if the input and output signals of the test will be collected, this process is called experimental modal analysis.
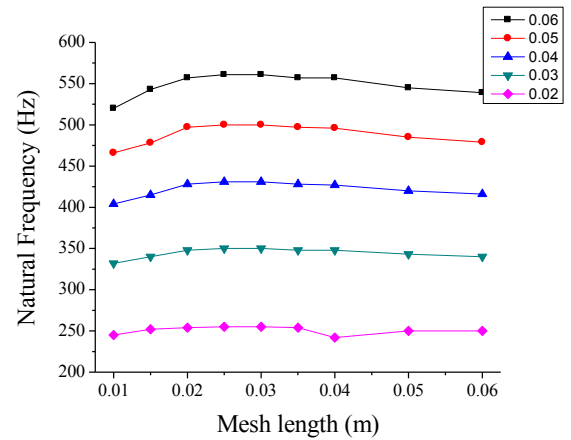

Fig. (6). Natural frequency with mesh length change and different core height of hexagon sandwich plates.

Testing Examples: There is a 0.3m×0.2m hexagonal honeycomb sandwich plate with upper and lower plates having thickness: 0.001m and 0.002m and 0.003m. Sandwich mesh side is 0.010m, and sandwich core height were 0.015m,0.020m and 0.030m. Each side of freedom, material parameters were: E_1=200GPa, E_2=90GPa, ν=0.3, ρ_1=7800 kg/m^3, ρ_2=2700 kg/m^3 and mesh side length is 6 mm.

We adopted INV1601B vibration type tester and INV1601 DASP software in order to perform model analysis of sandwich plate. In the process of analysis, we tested sandwich plate by adopting the experimental methods that is the multipoint excitation and taking a single point under free constraint conditions. Its stationing way uses 4×5 units, a total of 30 points, table board and sandwich connected by gluing way. And freedom constraint condition uses 4 angle soft underlay like sponge *etc*., simulation, as shown in Figs. (**7** & **8**).

As can be observed from Fig. (**9**), the stiffness of pic2 was higher than pic1, which coincides with result of the above study. We had recorded data in the Table **3** and then drew the curves as shown in Fig. (**9**).
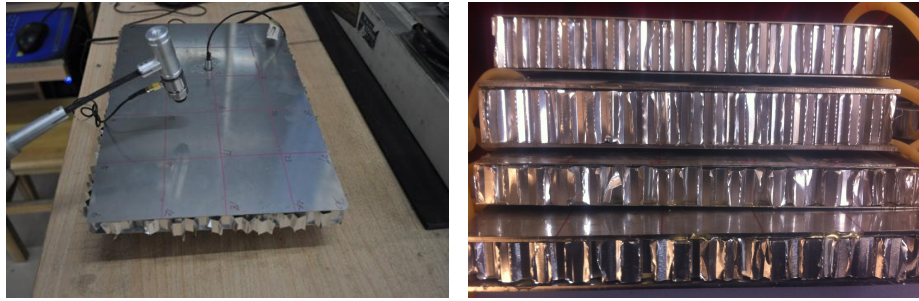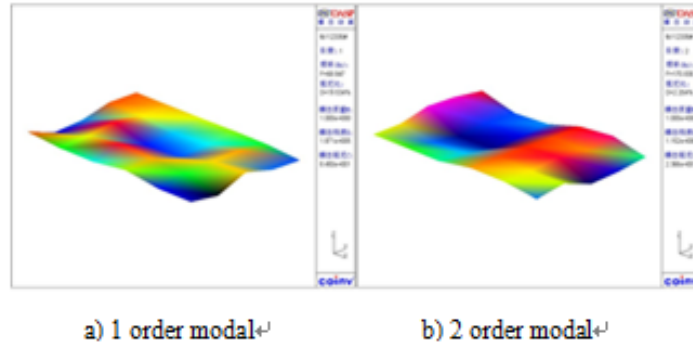
Fig. (7). Sandwich plate experiment.

a) 1 order modal   b) 2 order modal

Fig. (8). Sandwich plate modal experiment.

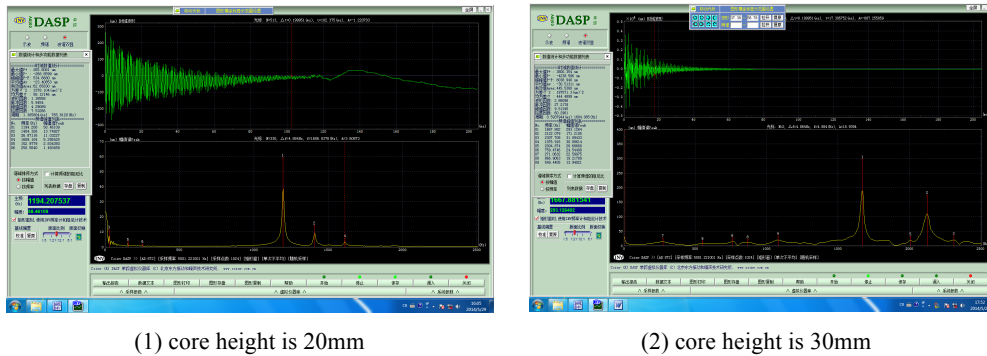(1) core height is 20mm   (2) core height is 30mm

Fig. (9). Frequency response curve of experiment.

Table 3.   The natural frequency of different sandwich core height.

Skin Thickness (mm)	Core Height (mm)	Weight (g)	Frequency (Hz)
1	15	984	1076
1	20	1024	1194
1	30	1052	1167
3	15	2688	865
3	20	2706	999
3	30	2749	1263

Mesh side length is 6 mm.

CONCLUSION

The result shows that the change of core height has a greater impact on the natural frequencies of honeycomb sandwich plates. When the surface thickness of quadrilateral honeycomb sandwich plates becomes thicker, its natural frequency increases with increasing length of core grid. When sandwich mesh length reaches a certain level, the natural frequency increased firstly and then decreased. When the sandwich mesh length is longer enough, the frequency decreased with the increase in the length. When the core height increased, the natural frequency increased. When the quadrilateral mesh becomes longer, its natural frequency appears to decline after the initial increase. The influence of geometric parameters on hexagonal honeycomb sandwich plates is same as on quadrilateral honeycomb and other soft sandwich plates.

Our experiment verify the results of the study, that is sandwich plate geometric changes at the natural frequency influence honeycomb panels trend; provide reference data for the manufacture and application of sandwich panels.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

ACKNOWLEDGEMENTS

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