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Hoff's Investigation of The Sandwich Panel with Honeycomb Core

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ABSTRACT

Recently, the use of sandwich panels has become increasingly important. This is due to its good mechanical properties and high strength-to-weight ratio. It is used in many fields, especially in aviation, construction and aerospace. It is necessary to know the behavior of the materials used, especially the free vibrations, to know the effect of external factors on the sandwich panels. The honeycomb core sandwich panel was studied. A model for analysis and modeling is proposed. A previous model was chosen for analysis and comparison. Hoff theory was applied to convert honeycomb sandwich panel into equivalent sandwich panel to facilitate the solution and save time. The limits were considered fixed on the one hand and moving on the other hand, and the ANSYS program was used to analyze and extract the results, and the results were compared and were promising and accurate, which proves to us the validity and accuracy of the proposed theoretical results.

1. Introduction

One of the biggest problems facing the business is how to make the structures lighter. Sandwiches are one structure that can fulfill this need. It is widely used in many industries, including the automotive, marine, construction, and aerospace industries, and has a high hardness-to-weight ratio. The basic characteristic of the sandwich structure is the type of metal and the type of substrate, which provide stiffness and shear resistance [1]. The casing consists of two thin, rigid plates, which act as the primary loading mechanism as in Figure 1 [1]. Various types of core layers, including rigid, foamed, truss, web, and honeycomb core, have been used to construct various sandwich structures. Composite sandwich structures have emerged as a desirable metal alternative as automotive design experts strive to reduce fuel consumption and increase safety.

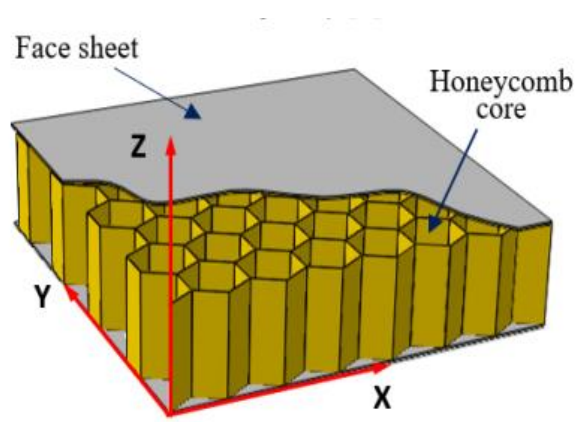

Figure 1: the sandwich panel honeycomb core [1]

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The significant loss of body weight has a positive effect on other components in the vehicle. As a result, the use of the sandwich structure helps reduce weight, increase fuel efficiency and increase payload capacity. It also enables the creation of aerodynamically stable, low-gravity vehicles [2]. The goal is to build insulating structures as efficiently as possible. Thus, we faced the challenge of creating a honeycomb core sandwich panel as well as the challenge of developing a honeycomb core in the same design process. To make it simpler and faster, some assumptions or shortcut rules are used [3]. The properties of sandwich composites have recently undergone further development and increased standardization as a result of recent developments in materials and manufacturing methods. Design of the optimal sandwich using computer assistance. Due to the high computational complexity and length, building CAD models and finite element analysis of the properties of these structures remains a major challenge. Before now, many technologies that are similar to honeycomb sandwiches have been researched. I have previously reported an equivalent sandwich solution that is both realistic and useful, according to Boudjemai et al. [4]. Only macro-level properties, not micro-level properties, can be described by technique. The damaging and high-speed deformation mechanisms of honeycomb sandwich panels were investigated by Shi et al. [5]. Jeong et al. [6] to generate the hexagonal honeycomb pulse pattern using the drop boundary method introduced an intensive mathematical model and numerical simulation. Allen [4] developed a honeycomb model that ignores the in-plane stiffness and bending stiffness. Gibson [7, 8] provided a theoretically equivalent parameter formula for honeycomb material. Xia and Jin [9] proposed three equivalent methods for calculating the natural frequencies of a honeycomb sandwich. Ref. [10] is a comprehensive FEA (finite element) structural analysis tool, which covers linear, nonlinear and dynamical investigations. Using the steel model instead of the actual honeycomb structure, ref [11] confirmed the design and analysis of honeycomb structures. Significant gains are achieved during finite element investigations in terms of model simplicity in use and model modification, resolution time, and hardware resources. Ref [12] considers how discharge affects the inherent frequencies of the dielectric sandwich. Nomenclature, materials, cell composition, production processes, and honeycomb uses are explained in reference [13]. For the first time, sandwich structures have been investigated to shed light on the fundamental size effects of periodic core cells in the context of free vibration analysis of an evolving lightweight structure [14]. An isometric finite element formula based on shear was introduced in reference [15].

In this research, we will study the effect of natural frequency on the structures of the sandwich panel with core Honeycomb. At first, Hoff theory [25], will be used to convert the base layer into equivalent by using theory equations, to derive the engineering parameters. The reason for converting the base layer from Honeycomb to parabolic is because the processing time and the time Building the model is much faster than the complex form. Then it will be compared with a researcher to verify and draw conclusions by simulation with the ANSYS program.

2.The Geometry for the study

The structure of the honeycomb core sandwich panel is composed of three layers, two face layers and the core layer as shown in Figure 2a and b. Where all sandwiches are feuding. Where the face serves to withstand axial loads, bending moments and internal shears, while the core bears normal bending shears. Because the core/laminate face assembly is not uniform, honeycomb structures are prone to failure caused by large local stress concentrations; As a result, frequency estimation is required [16].

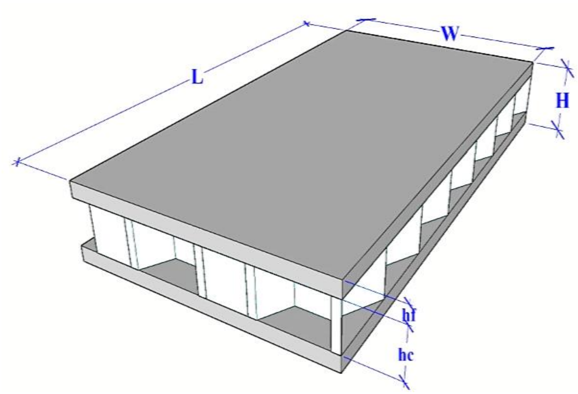

Figure 2a: The dimensions of sandwich panel with honeycomb core

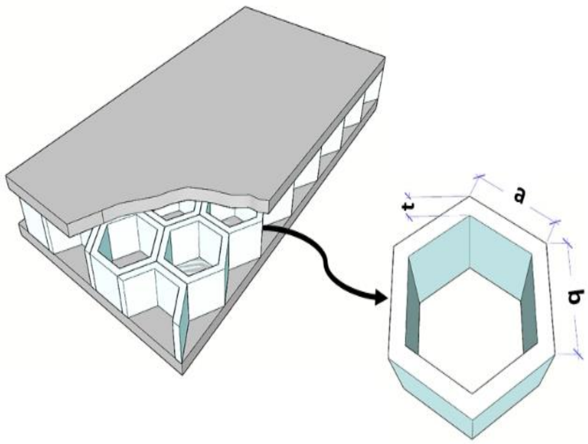

Figure 2 b: The dimensions of honeycomb core

where W is the width, L is the length, hc is the height of the substrate, hf is the height of the outer layer, a = b is the length of the cell rib and t is the thickness of the cell wall.

3.Finite element modeling

The problem of external vibration for isotropic plates with constant boundary conditions is more difficult, however it has been thoroughly studied. For orthodontic plates, there are many approximate solutions although an exact solution is not possible [17]. Lisa provided an excellent review of previous studies on this topic [18]. For both forced and free vibration analysis, Sakata and Hosokawa [19] provided a dual solution to the trigonometric sequence, while Gorman [20] used a superposition approach. Li [21] extended the last method to add strong vibration. To examine the response to free vibrations of fixed bony plates, the Kantorovich approach was developed [22, 23]. However, these studies only cover thin plates. In this work, Hoff theory will be used to convert a core sandwich panel into a equivalent sandwich panel to facilitate natural frequency solution and inference, as well as reduce time and effort as shown in Figure 3. Finite element techniques, such as parabola (two-dimensional model) and parabolic model are used Three-dimensional finite element study of the vibration properties of a honeycomb corrugated core dielectric beam (3D model) [24]. The profile of the mode is determined using the industry standard ANSYS commercial finite element product. Where aluminum will be used per sandwich panel with a density of 2800 kg/m3, Poisson's ratio of 0.33 and modulus of elasticity of 72 GPa.

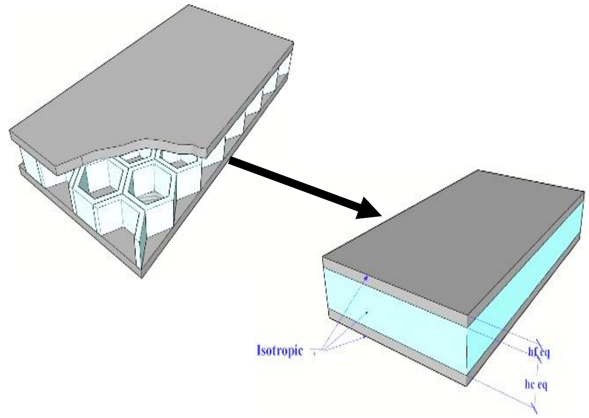

Figure 3: Converting the exact model to an equivalent

3.1 Hoff theory [25]

According to the hypothesis of Hoff theory:

1. The panels are thin, assuming they are ordinary sheets.

2.The internal stress component is omitted in the base layer since it is smooth, i.e.

$$\sigma_{cx} = \sigma_{cy} = \tau_{xy} = 0$$

3. Assume that σ_z is 0 in the outermost layer and the outer crust.

The Hoff hypothesis goes further than the Reissner theory, and the stress on the panel's surface is more complex when taking into account the panel's bending stiffness. The aforementioned equivalent stiffness approach based on the Reissner theory merely requires a few adjustments. The comparable parameters can therefore be solved as follows.

$$\rho_{ceq} = \frac{2}{\sqrt{3}}\frac{hf}{a}\rho_c \tag{1}$$

$$v_{eq} = v_f \tag{2}$$

$$H_{eq} = \sqrt{{h_f}^2 + 3(hc + h_f)^2} \tag{3}$$

$$\rho_{eq} = \frac{2h_f\rho_f + hc\,\rho_{ceq}}{H_{eq}} \tag{4}$$

$$E_{eq} = 2\frac{E_f}{H_{eq}}h_f \tag{5}$$

where ρ_{ceq} is the basic layer equivalent density, h_f refers to is the thickness of the outer layers; v_f, ρ_f, and E_f refers to the outer layers ' Poisson's ratio, density, and elastic modulus, respectively; ρ_{eq}, v_{eq}, E_{eq}, and H_{eq} refers to the equivalent density, equivalent Poisson's ratio, equivalent elastic modulus, equivalent height.

Initially, a comparison is made with the researcher [25].by inserting the equations in MATLAB, the geometric parameters were deduced.

Table 1. The characteristics adopted by Ref. [25]

Young's modulus (GPa)	mass density (Kg/m³)	Poisson's ratio
72	2800	0.33

Table 1 shows the engineering properties adopted by the researcher [25], which are the properties of aluminum for all layers.

Table 2. Dimensions of the geometric shape of Ref. [25]

length (L)	Width (W)	thickness of cell (t)	cell size	core height (hc)	thickness of face skin (hf)	angle of cell (ϑ)
290 mm	40 mm	0.2 mm	2m m	9 mm	1 mm	60°

Table 2 shows the dimensions of the honeycomb sandwich panel that the researcher used [25].

Table 3. The results obtained by Ref. [25]

mode	Natural Frequencies (Hz) [25]
1	126.88
2	323.62
3	713.02

Table 3 shows the results obtained by the researcher [25] through careful analysis.

Table 4 .A comparison between the results of Natural Frequencies of Ref. [25] and 3D Finite Element Model

Mode	Natural Frequencies (Hz) [25]	3DFinite Element Model	Error rate
1	126.88	128.2	1.03
2	323.62	315.5	2.5
3	713.02	715.3	0.31

Table 4 shows the comparison of the results obtained by microanalysis after data entry with the results of the reference. [25], as the error rate was very low.

Table 5. The geometric parameters found by the Hoff theory

The equivalent density (Kg/m³)	The equivalent elastic modulus (MPa)	The equivalent height (mm)	The equivalent Poisson's ratio
0.0177	8325	500.5	0.33

Table 5 shows the conversion of a honeycomb-core sandwich panel into an equivalent sandwich, as shown in Figure 3. Through Hof's theorem, where the geometrical properties were deduced, and they will be included in ANSYS for simulation, analysis, deduction of natural frequency and mode shape.

Table 6. A comparison between the results of Natural Frequencies

Mode	Hoff theory (Hz)	3D Finite Element Model (Hz)	Error rate
1	130.48	128.2	1.74
2	301.41	315.5	4.46
3	740.55	715.3	3.40

Through the error rate in Table 6, where it shows us the comparison between the results of the natural frequency between the Hoff theory and the careful analysis using the ANSYS program, it was found that the theory is promising, as the highest error rate was 3.7 and the lowest was 1.88, which proves the correctness of the used theory. Figure 4 shows the mode shape of the proposed model.

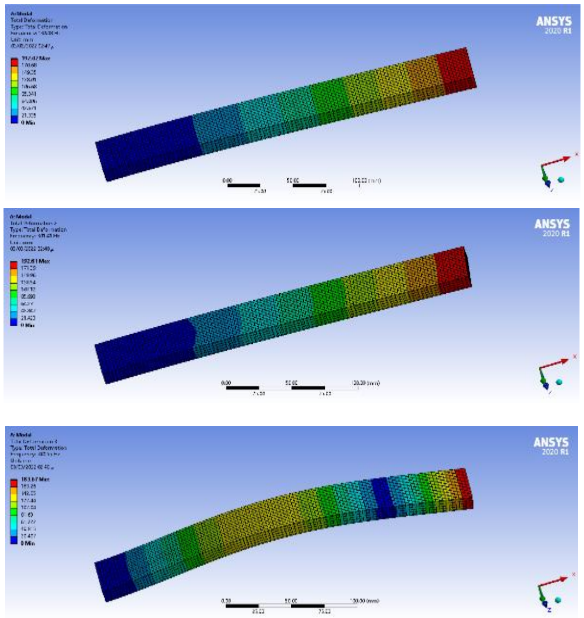

Figure 4: The modal shape of equivalent sandwich panel

4.Conclusion

Honeycomb core sandwich panel is designed and converted into a parabolic sandwich. Aluminum was used for all layers of the sandwich. Hoff theory was used to convert the honeycomb core sandwich into a parabolic one by using the theory equations to analyze the free vibration. The results of Hoff theory were compared with the results of the parabolic model. [25] After comparison, it was found that the method used was correct, which had the lowest error rate. In the first model it was 1.74 and the highest error rate in the second model was 4.46. Hoff's theory is used to extract the equivalent material coefficients, and show that the material coefficients are directly proportional to the natural frequency.

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