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Studies on the Effect on Load Carrying Capacity of Composite Honeycomb Structures When Used in Layers

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Abstract

Honeycomb panels are widely used in aerospace applications to reduce the weight of the structure. It also increases the specific strength of the structure as a whole. They are commonly made by sandwiching a honeycomb core material between two thin layers that provide strength in tension. Honeycomb structure is modeled in ANSYS. This investigation focuses on the analyzing the load carrying capacity and energy absorption of the honeycomb structure when used in layers. Further geometric imperfections are also considered along with provision of layers. The peak load and the maximum energy absorption obtained is maximum for the honeycomb with two layers which are parallel to each other.

Keywords: *Honeycomb structure, Layers, Parallel, Staggered, Geometric Imperfections.*

1. Introduction

Honeycomb structures are natural or man-made structures that have the geometry of a honeycomb to allow the minimization of the amount of used material to reach minimal weight and minimal material cost. The strength of the sandwich panels depends on factors such as the size of the panel, facing material used and the number or density of the honeycomb cells within it. Honeycomb sandwich structures are widely used in applications such as in aircraft, railway industries, civil architecture and military industries. The investigation conducted by Tolga Topkaya et al [2] looked at how the cell diameter, core thickness and thickness of the skin material affected the fatigue behavior. The behavior of honeycomb core against compressive force along cell axis was investigated by M.R. Khoshravan et al [5]. K. Kantha Rao et al [7] conducted test on aluminum, titanium and high tensile steel honeycomb sandwich panels and it is observed that titanium alloy has more strength to weight ratio.

This proposed study focuses on analyzing the load carrying capacity and the energy absorbing capacity of the aluminum based honeycomb structure when used in parallel and staggered layers for uniform height. Further the effect of geometric imperfections leading to buckling are also considered along and a comparison is made.

2. Composite Honeycomb Structures

The sandwich panel consists of a light weight core and is covered by two thin face sheets as shown in Fig.1. Each face sheet may be an isotropic material while the core material may either be of metallic or metallic/polymeric foam. The structural performance of honeycomb sandwich plates depends on the properties of the skin layer and core layer, the adhesive bonding status and their geometrical dimensions.

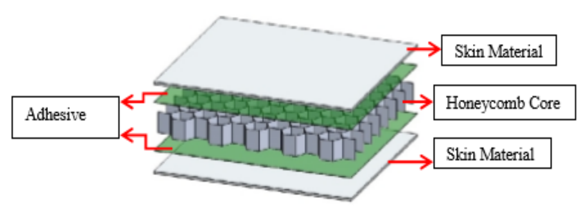


Fig. 1 Composite Honeycomb Structures

3. Objectives and Methodology

The main objective of the present study is to investigate the compressive load bearing capacity of honeycomb structure when used in layers.

1. To study the variation in load bearing capacity when used in parallel and staggered layers for uniform height.
2. To understand the effects of geometric imperfections leading to buckling along with layers.
3. To find the energy absorption characteristics.

The numerical analysis is to be performed in commercial software ANSYS. This software is based on finite element method. The Following procedure was adopted:

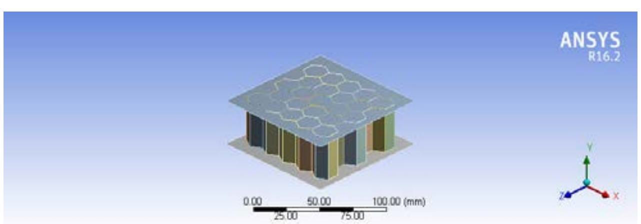
(1) Honeycomb structure is modeled in layers which are parallel as well as staggered.
(2) Selection of material properties, meshing size etc.
(3) Static structural analysis is done.
(4) Geometric Imperfections are considered.
(5) Energy absorption is calculated and the results are compared.

4. Structural Geometry and Material Property

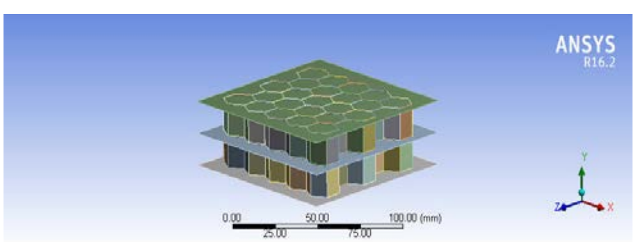
The strength and energy absorption characteristics of honeycomb structures may be varied accordingly with number of layers provided. In this study, the layers are considered in both parallel and in a staggered manner. A comparison of parallel layers and staggered layers are made. In each cases, 4 honeycomb structures are modeled without considering geometric imperfections and other 4 are modeled with geometric imperfections

4.1 Parallel Layers

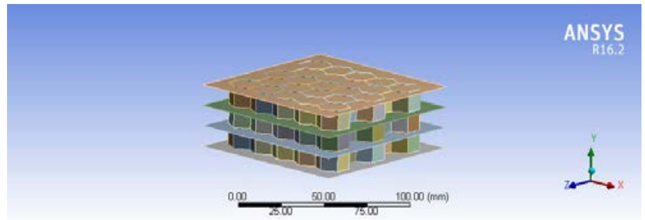
The honeycomb structures are modeled by increasing its layers for uniform height of 35 mm. Without changing total cell height, four models were prepared with one, two, three and four layers without geometric imperfections and other four with geometric imperfections. The layers are parallel to each other. The models are shown in Fig.2 (a), (b), (c) and (d) respectively.



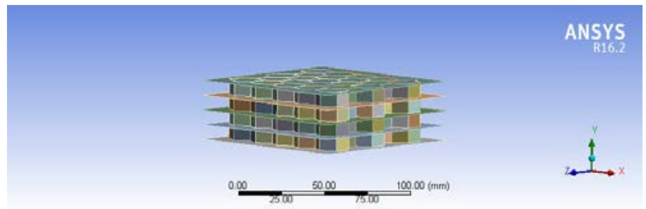
(a) One Layer



(b) Two Layers



(c) Three Layers



(d) Four Layers

Fig.2 Parallel Layered Models

The bottom plate is provided with fixed support as shown in Fig.3. Constant prestressing load of 1000N was applied on the top plate as shown in Fig.4.A meshing size of two is adopted and is shown in Fig.5.

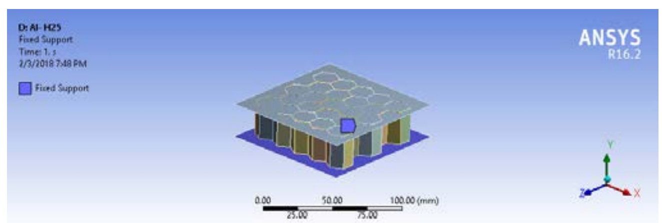


Fig.3 Boundary Condition

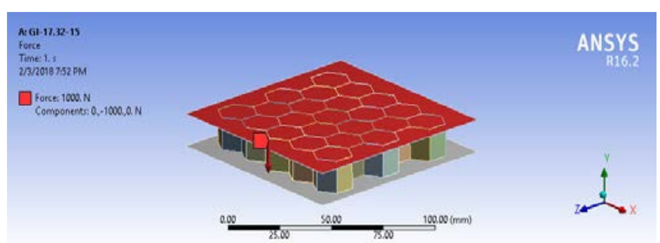


Fig.4 Loading

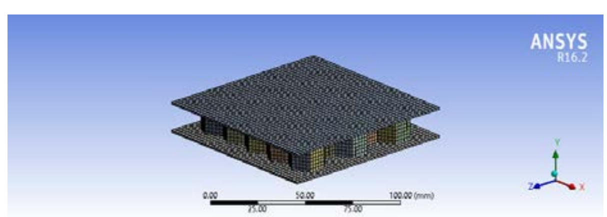


Fig.5 Meshing

The mechanical properties adopted for the honeycomb structures made of aluminium are shown in Table 1.

Table 1 : Material properties

MATERIAL	PARAMETER	MAGNITUDE
Aluminium	Young's modulus	69 GPa
	Shear modulus	25 GPa
	Poisson's ratio	0.33
	Yield stress	160 MPa
	Tangent modulus	105 MPa

The geometrically imperfected honeycomb structure is shown in Fig.6. None of the honeycomb stuructre can be made as perfect avoiding slight geometric irregularities in actual cases. Imperfections like buckling of common edges or distorted corners can be occurred. Inorder to consider the geometric imperfections, the honeycomb is prestressed with a load and the buckled mode shape is obtained and that buckled shape is used for further modeling and analysis.

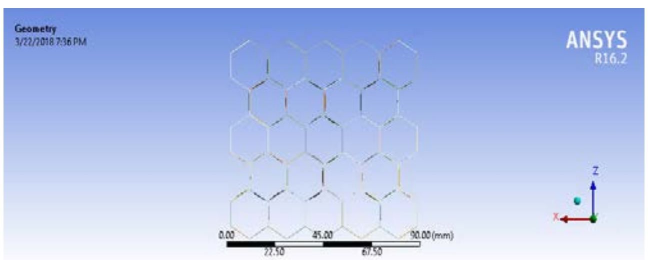


Fig.6 Geometrically Imperfected Honeycomb

The deformed structure of honeycomb when provided with two parallel layers is shown in Fig.7.

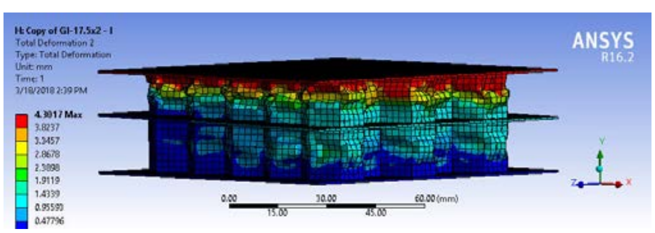
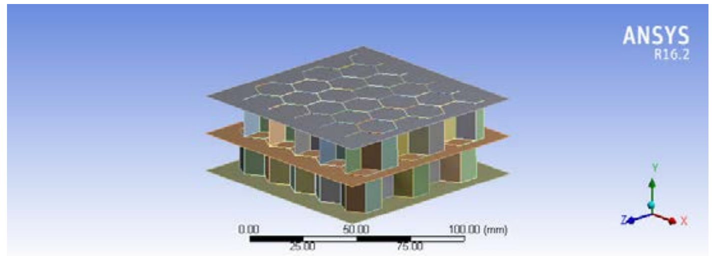


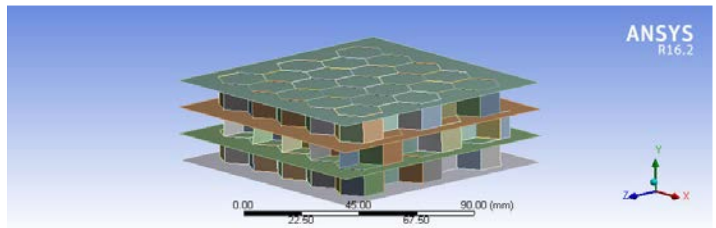
Fig.7 Deformed Structure of Two Parallel Layers

4.2 Staggered Layers

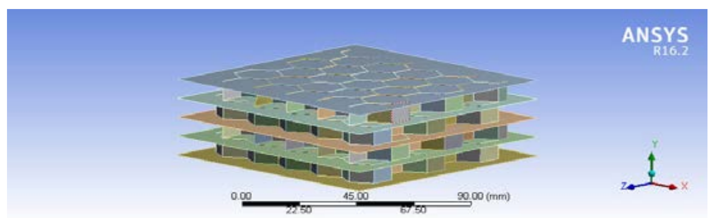
The honeycomb structures are modeled by providing layers in a staggered manner for a uniform height of 35 mm. Without changing total cell height, four models were prepared with one, two, three and four layers without geometric imperfections and other four with geometric imperfections. The models are shown in Fig.8 (a), (b), (c) respectively.



(a) Two Layers



(b) Three Layers



(c) Four Layers

Fig.8 Staggered Layered Models

The bottom plates are kept fixed and the loading conditions are similar as that of previous models. Material properties of the structures is also same as that of previous models.

The deformed structure of honeycomb when provided with two staggered layers is shown in Fig.9.

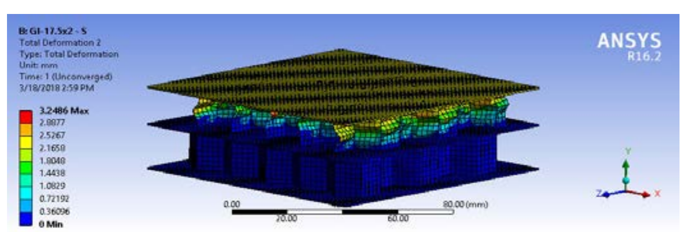


Fig.9 Deformed Structure of Two Staggered Layers

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5. Results and Discussions

5.1 Parallel Layers without Geometric Imperfections

The load carrying capacity variation when the honeycomb structure is modeled with parallel layers for uniform height without geometric imperfections is shown in Table 2.

Table 2: Peak Load Variation for Parallel Layers

Number of Layers	Peak Load (kN)
One	11.05
Two	11.9
Three	11.84
Four	11.80

The variation of the peak load obtained for various layers are slightly varied without much more differences in the absence of geometric imperfections. Even though there is no greater improvement, can be say that multiple layers are better than single layer.

5.2 Parallel Layers with Geometric Imperfections

The changes in the load bearing capacity of the Aluminium honeycomb structures when provided with parallel layers considering geometric imperfections are shown in the Fig.10.

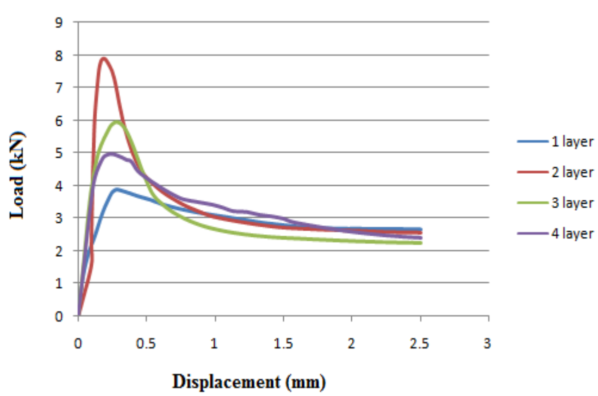

Fig.10 Load- Displacement Curves for Parallel Layers

The comparison of Load-Displacement curves of parallel layered honeycomb models shows that the peak load obtained is maximum for two layered model. As the number of layers increased, the peak load has decreased, even though the multiple layered models shown better result than single layered models.

The total energy absorption of the four models are shown in Table 3. Double layered model has the highest energy absorption capacity than 3 layered and four layered honeycomb models. Single layered model has the least energy absorption characteristics.

Table 3: Total Energy Absorption for Parallel Layers

Number of Layers	Energy Absorption (Nmm)
One	7380.57
Two	8323.61
Three	7973.96
Four	7449.7

5.3 Staggered Layers without Geometric Imperfections.

The load carrying capacity variation when the honeycomb structure is modeled using staggered layers for uniform height is shown in Table 6.4.

Table 4: Peak Load Variation for Staggered Layers

Number of Layers	Peak Load (kN)
One	11.05
Two	11.54
Three	11.4
Four	11.25

In the absence of geometric imperfections, the variation of the peak load obtained has less variations. In case of staggered layers also, multiple layers are better than single layer.

5.4 Staggered Layers with Geometric Imperfections.

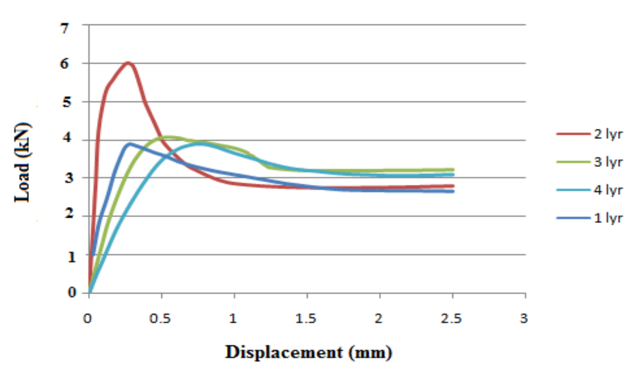

Fig.11 Load- Displacement Curves for Staggered Layers

The changes in the load bearing capacity of the Aluminium honeycomb structures when layers are provided in a staggered manner considering geometric imperfections are shown in the Fig.11. The total energy absorption of the four models is shown in Table 5.

Table 5: Total Energy Absorption for Staggered Layers

Number of Layers	Energy Absorption (Nmm)
One	7380.57
Two	8238.21
Three	8224.77
Four	7721.24

In case of staggered layered models, similar as in parallel layered models, double layered honeycomb model shows better result. Both the peak load and the total energy absorption are maximum for double layered models compared with three layered and four layered models. However, multiple layered models have better performance than single layer.

5.5 Comparison of Parallel Layers and Staggered Layers

While considering the effect of number of layers when provided in parallel as well as staggered manner, both cases shows better results for double layered honeycomb model. A comparison is made between the parallel and staggered layers for double layered models and shown in Fig.12 and Table 6.

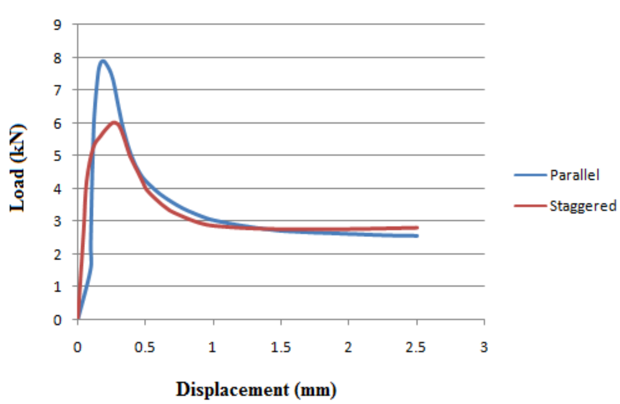

Fig.12 Comparison of Load- Displacement Curves for Parallel and Staggered Layers

Table 6: Comparison of Total Energy Absorption for Parallel and Staggered Layers

Layers	Energy Absorption (Nmm)
Parallel	8323.61
Staggered	8238.21

Considering both the peak load and total energy absorption, parallel layered models shows better result than staggered layered models. Thus, it can be concluded that, two parallel layered honeycomb model is considered as the best model.

In cases such as space craft, pressure hull etc. even a small crack may lead to complete failure of the structure. In such cases, honeycomb structures with maximum peak load are preferred. While in applications such as earthquake dampers, bridge panels, slabs etc. which are continuously using structures, more energy absorption is needed. Therefore, in such cases honeycomb structures with maximum energy absorption is preferred rather than high peak value. Considering both types of applications, two layered honeycomb structure is the best option.

6. Conclusions

The use of honeycomb structures has increased drastically in last few decades in aerospace applications due to their high load bearing capacity and less weight. The load carrying capacity of honeycomb structures with parallel and staggered layers is studied and the effects of geometric imperfections are considered. With the presence of geometric imperfections, peak load decreases. Multiple layers are better than single layer. Among multiple layers two layered honeycomb shows better results. Also, parallel layered honeycombs are better than staggered layered honeycomb structures. Thus, two parallel layered honeycomb model is considered as the best model.

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