Available online at www.sciencedirect.com
ScienceDirect
Procedia Engineering 99 (2015) 405 – 412
Procedia Engineering
www.elsevier.com/locate/procedia

"APISAT2014", 2014 Asia-Pacific International Symposium on Aerospace Technology, APISAT2014

Stress Distribution on Composite Honeycomb Sandwich Structure Suffered from Bending Load

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Abstract

In this paper, we prepared a kind of carbon fibre/matrix composite honeycomb using carbon fibre and epoxy resin with compression molding technique. Composite Honeycomb Sandwich was prepared by gluing composite honeycomb with composite panels. Mechanical performance of the Composite Honeycomb Sandwich was characterized using finite element analysis (FEA) and three point bending performance. Results indicate that when suffering from bending loads, stress concentration is located at the loading zone as well as supporting zone. When bending load increases to 7200N, cracks occur on the interface between honeycomb and composite panel, the failure mode is interfacial de-bonding between honeycomb core and composite panel. Result of three-point bending performance indicates that composite honeycomb Sandwich breaks down when bending load increases to 6800N, which agrees with FEA results. Compared with traditional aluminum and Nomex honeycomb Sandwich, carbon fibre/epoxy Honeycomb Sandwich has higher bending strength. It can be used in aviation and aerospace industries.

Keywords: Honeycomb sandwich structure; Damage; Finite element Method; Composite

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doi:10.1016/j.proeng.2014.12.554

1. Introduction

The use of honeycomb sandwich structure is increasing rapidly due to their excellence strength to weight and stiffness to weight characteristics, such as aircrafts, ships, and bridges et.al [1-3]. The strength of honeycomb sandwich structure is a combination property of the skin, core and core-skin interfacial bonding. Any weak point in the three elements will reduce the performance of the structure. At present the skin of the sandwich structure is made of rigid fiber reinforce plastic composite, however, honeycomb cores are made of aluminum foil, Nomex paper [4, 5]. As a result mechanical performance of the sandwich structure is restricted by the performance of honeycomb core [6, 7].

In this paper, a carbon fiber/epoxy honeycomb core is prepared by compressing molding and gluing method. And sandwich structure is prepared by gluing the top-plate, core and bottom-plate together. Mechanical performance of the sandwich structure is studied by three-point bending test, and failure mechanism is analyzed by finite element analysis method (FEAM).

2. Experiment

CF/epoxy wave beam was prepared by compressing molding technique (wave length of the beam is 3cm, skin and core layer properties are listed in table 1), and composite honeycomb core was prepared by gluing the individual wave beams together. Sandwich structure was prepared by gluing the core and composite plates (top-plate and bottom plate) together.

Table 1 layer property of the structure

Component	Layer angle (deg)	Layer thickness (mm)	Sum of the layer
skin	0/90/0/90/0/90/0	0.15	7
honeycomb core	0/90/0/90/0/90/0/90/0/0	0.15	10

Stress distribution of sandwich structure was analyzed using finite element analysis method, and 7200N bending load is applied at the center of structure top-plate (1cm in width), a Z-direction displacement is applied at bottom-plate 8 cm from the center of the structure. Stress distribution on sandwich structure was characterized using Von • Mises stress definite as eq(1). Sandwich structure mechanical performance was studied according to Sandwich Bending Testing Method (GB/T1456-2005) on a universal testing machine.

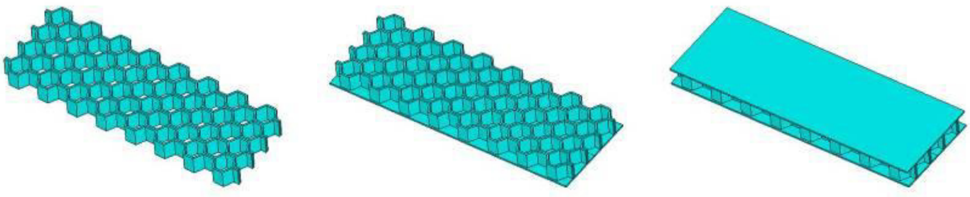

Fig.1 Finite element analysis model

Table 2 Material property for composite model [8, 9]

Material Property	EX	EY	EZ	PRXY	PRYZ	PRXZ	GXY	GYZ	GXZ
Composite	1.26E+11	1.10E+10	1.10E+10	0.28	0.30	0.30	6.60E+09	6.60E+09	6.60E+09

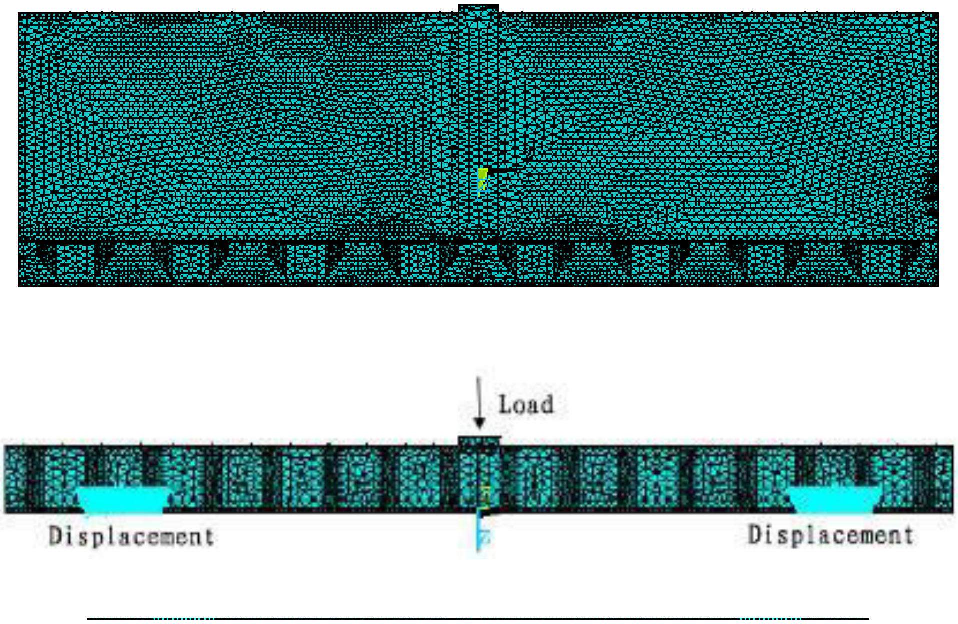

Fig.2 Bending load and displacement on the F.E.A model

Structure failure mechanism was analized according to parabolic failure criterion [9, 10, 11] (Eq.1). Where $R=\sigma_{Cb}/\sigma_{Tb}$, σ_{Cb} is compression strength of epoxy matrix; σ_{Tb} is tension strength of epoxy matrix, in our experiment σ_{Cb} and σ_{Tb} are 165 MPa and 90MPa respective.

$$(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_1-\sigma_3)^2+2(\sigma_{Cb}-\sigma_{Tb})(\sigma_1+\sigma_2+\sigma_3)-2\sigma_{Cb}\sigma_{Tb}=0 \quad (1)$$

Take parameter：

$$\sigma_0=\frac{\sigma_1+\sigma_2+\sigma_3}{3}$$

$$\tau_0=\frac{\sqrt{(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2}}{3}$$

$$\tau_0^2=a_1-a_2\sigma_0 \quad (2)$$

where：

$$a_1=\frac{2R}{9}\sigma_{Tb}^2;\quad a_2=\frac{2}{3}(R-1)\sigma_{Tb} \quad (3)$$

3. Results and discussion

Stress distribution on sandwich structure is indicated in Fig.3, when suffers from a 7200N bending load. The maximum stress is 156 MPa, located at both side of the cross head on the top-plate, maximum stress at composite core is 129 MPa, and maximum stress at bottom-plate is 121 MPa. The stress on top-plate is higher than composite core and bottom-plate, as can be seen stress on top-plate is higher than core and bottom-plate, as a result, composite will break down at top-plate at first.

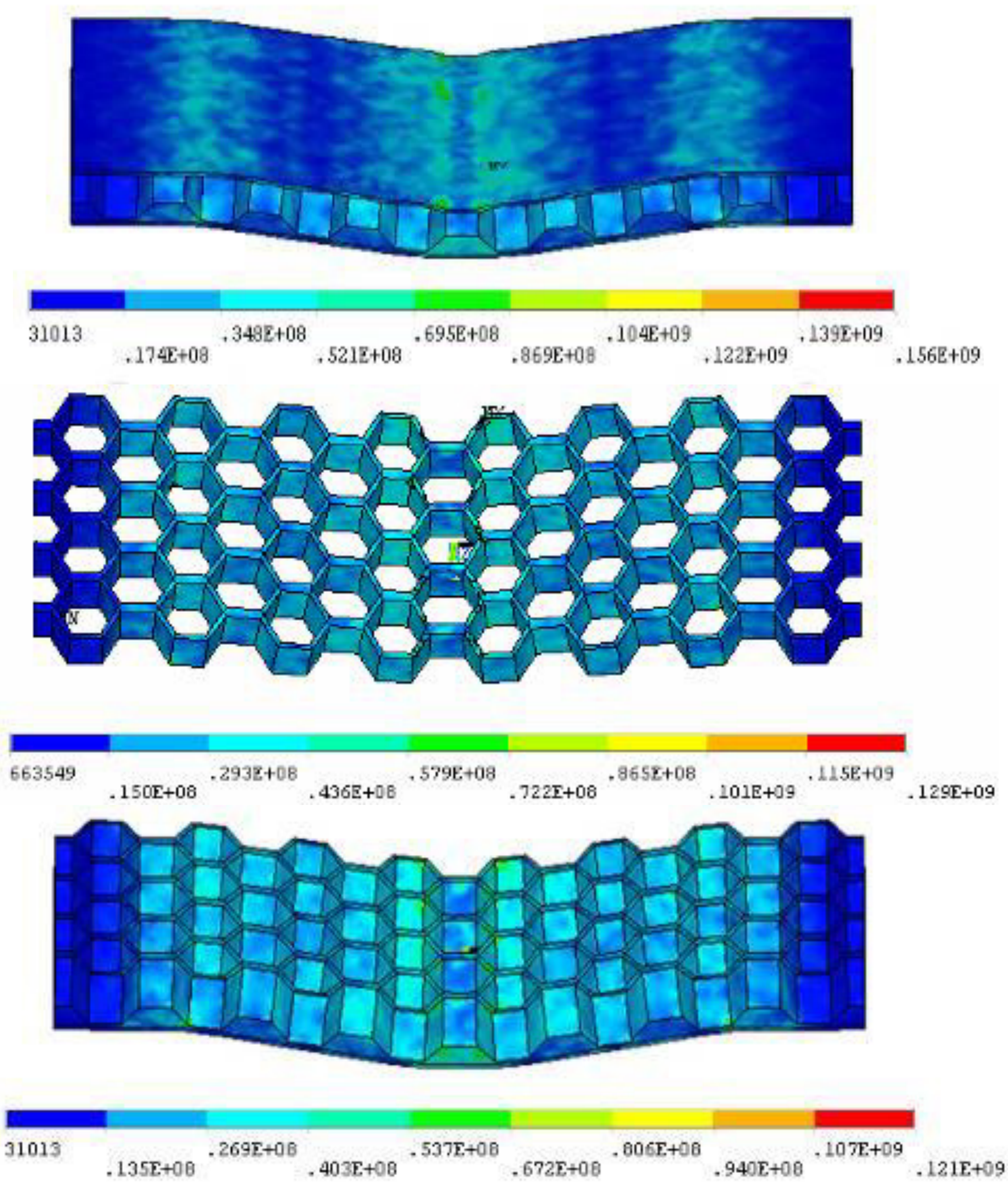

Fig.3 Stress distribution on honeycomb structure

We analyzed composite failure mechanism using parabolic failure criterion, the result is showed in Fig.4 and Fig.5. The octahedral shear stress and octahedral normal stress on nodes of the top-plate and core have exceed the failure surface (Fig.4 (a) and (b)), while stresses on a few nodes of bottom-plate have exceed the failure surface(Fig.4 (c)), as a result structure destruction takes place at top-plate and core initially.

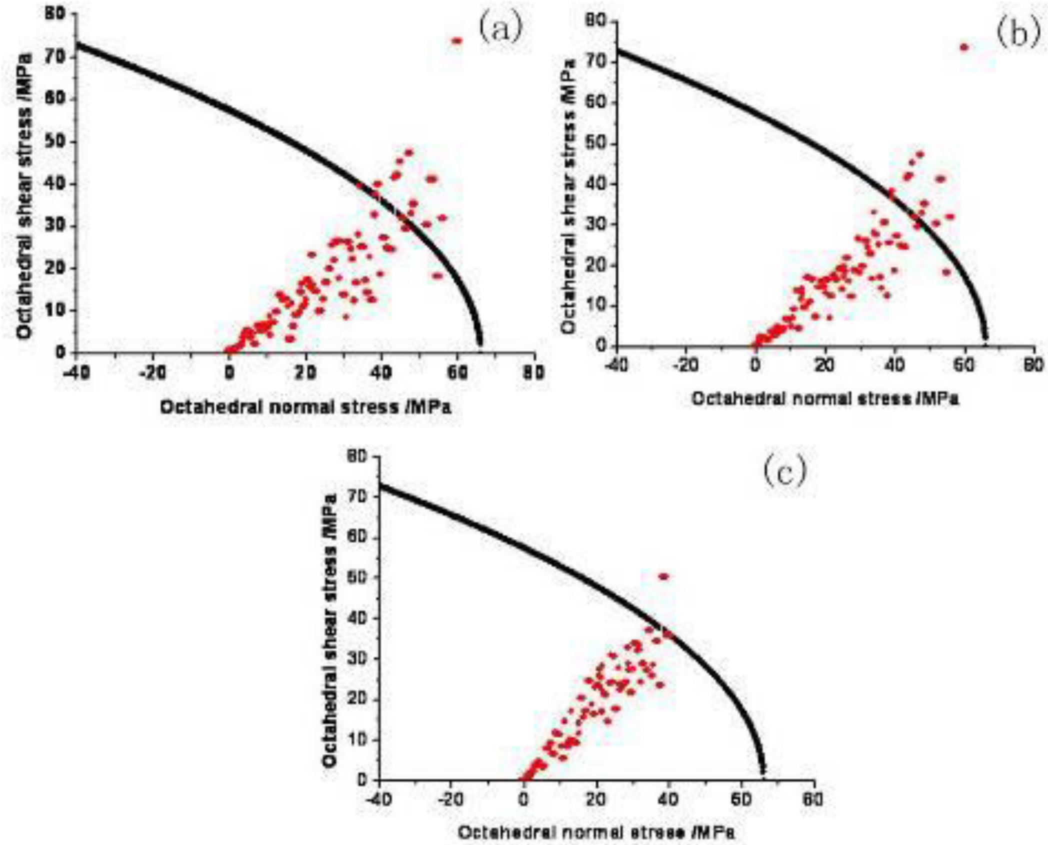

Fig.4 Parabolic failure criterion of Honeycomb Sandwich Structure: (a) top-plate; (b) core; (c) bottom-plate

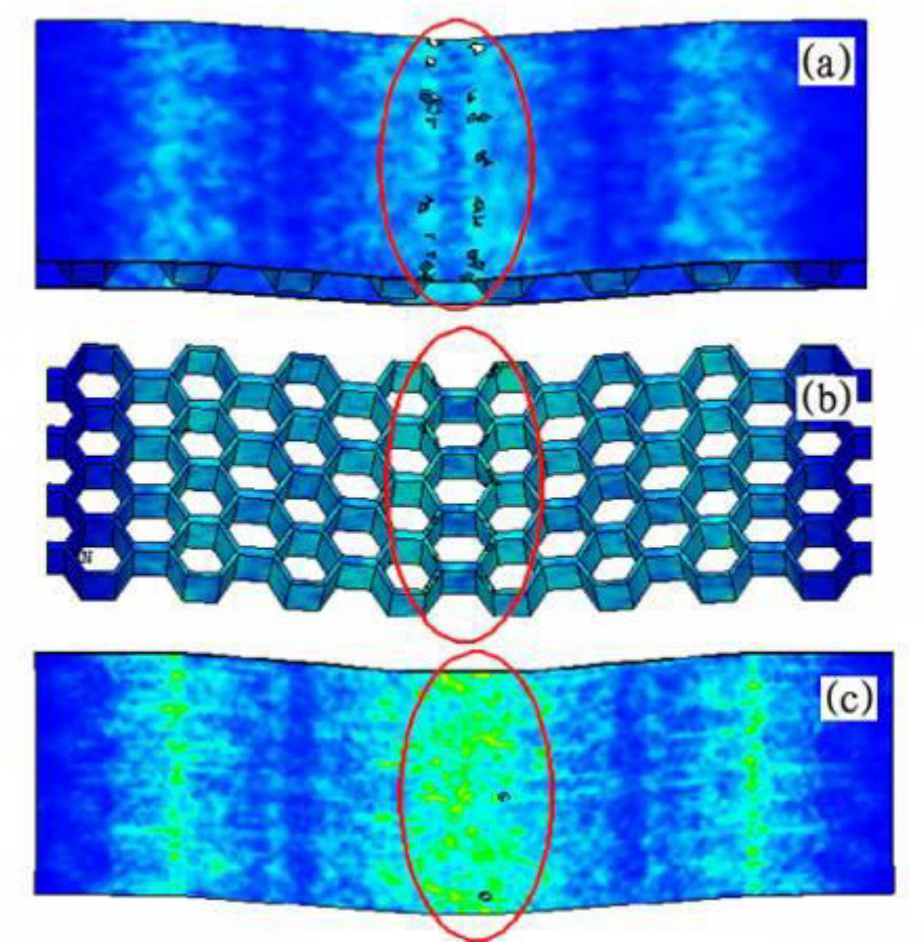

Fig.5 Crack distribution in sandwich structure: (a) Top-plate; (b) Core; (c) Bottom-plate

From Fig.5 it can be seen that on top-plate cracks are located at both side of the loading zone; in core, cracks are located at both side of the loading zone between top-plate and core, while a few cracks can be seen at bottom-plate. It can be seen from the analysis above the failure mechanism at top-plate is surface cracking; in honey core, the failure mechanism is interfacial de-bonding between top-plate and core.

We analysis the bending performance of honeycomb structure according to GB/T 1456-2005, when bending load increases from zero to 6272N cracks take place. The morphology of the honeycomb structure is indicated in Fig.6. It can be seen on top-plate cracks is located on both side of the loading zone, in core failure mechanism is interfacial de-bonding between top-plate and core. The result is in accordance with the analysis result above.

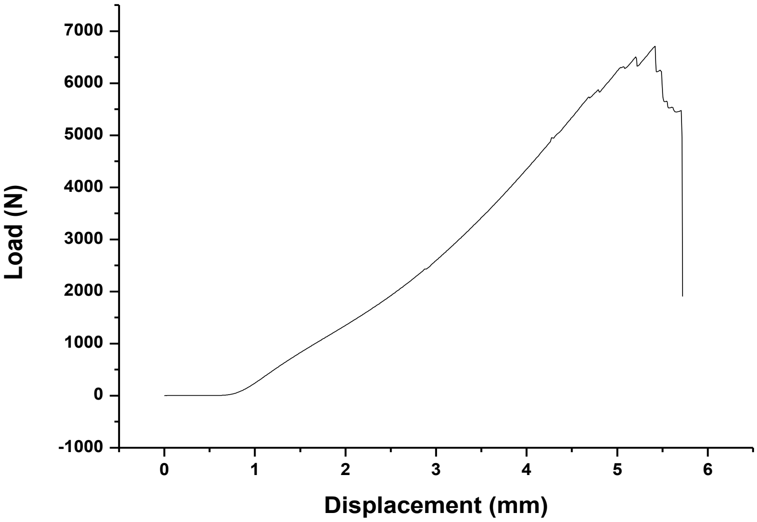

Fig.6 composite honeycomb sandwich structure after bending test

Table 3 Mechanical performance of composite honeycomb

	Composite honeycomb	Aluminium honeycomb[13]	Nomex honeycomb[14,15]
Density(kg/m^3)	260	21-166	48-80
Bending strength($N\cdot mm^2$)	2.86×10^8	1.00×10^8	3.6×10^7

4. Conclusion

Results of finite element analysis indicate that stress distribution on structure top-plate is much higher than core and bottom-plate, the failure mechanism of composite honeycomb structure is top-plate cracking or de-bonding between surface plate and honeycomb structure.

References

[1]Nicolas J. Lombardi, Judy Liu. Glass fiber-reinforced polymer/steel hybrid honeycomb sandwich concept for bridge deck applications. Composite Structures. 93(2011), 1275-1283.

[2]A. Zinno, A.Prota, E.Di Maio. Experimental characterization of phenolic-impregnated honeycomb sandwich structures for transportation vehicles. Composite Structures. Composite Structures. 2011, 93: 2910-2924.

[3]D.H. Chen. Bending deformation of honeycomb consisting of regular hexagonal cells. Composite Structures. 2011, 93:736-746.

[4]X. Frank Xu, Pizhong Qiao. Homogenized elastic properties of honeycomb sandwich with skin effect. International Journal of Solids and Structures. 2002, 39: 2153-2188.

[5]H.X. Zhu. Size-dependent elastic properties of micro- and nano-honeycombs. Journal of the Mechanics and Physics of Solids 58 (2010) 696-709.

[6]W. Miller, C.W. Smith, K.E. Evans. Honeycomb cores with enhanced buckling strength. Composite Structures. 2011, 93: 1072-1077.

[7]V.N. Burlayenko, T. Sadowski. Effective elastic properties of foam-filled honeycomb cores of sandwich panels. Composite Structures 92 (2010) 2890-2900.

[8]Carlos Santiuste, Xavier Soldani, Maria Henar Miguélez. Machining FEM Model of Long Fiber Composites for Aeronautical Components. Composite Structures. 2010. (92): 691−698.

[9]Chun Lu, Ping Chen, Gao Yu. Thermal Stress Distribution in CF/EP Composite in Low Earth Orbit. Journal of Composite Materials, 2010, 14: 1729-1738.

[10]Fiedler, B., Hojo, M., Ochiai, S.: The influence of thermal residual stresses on the transverse strength of CFRP using FEM. Compos. Part A 33, 1323-1326 (2002).

[11]Fiedler, B., Hojo, M., Ochiai, S., Schulte, K., Ochi, M.: Finite-element modeling of initial matrix failure in CFRP under static transverse tensile load. Compos. Sci. Technol. 61, 95-105 (2001).

[12]Chun Lu, Ping Chen, Qi Yu. Thermal Residual Stress Distribution in Carbon Fiber/Novel Thermal Plastic Composite. Applied Composite Material. 2008, 15: 157-169.

[13]Qiu Yuhong, Liu Bingli. Experimentation Study for Carbon/Epoxy Network Facings-Aluminous Honeycomb Sandwich Construction's Flexural Rigidity. SPACE CRAFT RECOVERY & REMOTE SENSING.2004. 25(3)：44-46.

[14]Di Xiyan, Wei Borong, Lan Liwen. Study on performance of 1581 type epoxy glass-cloth/Nomex homeycomb sandwich composite plate. Glass fiber composite. 2000,3:16-18.

[15]HaoWei, Li Yong, Luo Yuqing, Study on the mechanical properties of the moderate and high density Nomex honeycomb. Journal of Aeronautical Material. 2002.22(2):41-43.