COMPRESSION of HONEYCOMB PREFORM SANDWICH COMPOSITES

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SUMMARY

The effects of core structures on the compressive properties of sandwich composites have been studied in this paper. The three-dimensional multi-layer weaving technique was used to fabricate carbon and glass honeycomb performs for sandwich composites core materials by a modified Dobby loom. Three types of core materials, PU foam core, glass honeycomb core preform, and carbon honeycomb core preform were developed in current work.

Keywords: Honeycomb, Preform, Sandwich, Composite, Compression

INTRODUCTION

Structural sandwich beams are widely used because of their high specific stiffness and strength, noise reduction, thermal insulation, and impact energy absorption characteristics. Usually, high stiffness, high strength, and thin composites are used for faces to resist the in-plane and lateral loads, while light materials such as foam materials, honeycomb, and balsa wood are used for cores [1]. Thus, sandwich structures are used in many industrial fields such as aerospace, automobiles, machine tools and robot structures [2]. There are many wide varieties of core materials currently in use. Among them, honeycomb, foam, balsa and corrugated cores are the most widely used [3]. Usually honeycomb cores are made out of aluminum or out of composite materials: Nomex, glass thermoplastic, or glass-phenolic. One of the problems in the honeycomb sandwich constructions is the low surface area of the core for bonding. Weeks and Sun [4] considered the construction of multiple honeycomb core layers and additional reinforcing sheets. This construction provided better impact resistance and higher residual strength than traditional construction. The other most commonly used core materials are expanded foams, which are often thermoset to achieve reasonably high thermal tolerance, though thermoplastic foams are also used. The foam core has high surface area for bonding with skin or face sheet. The properties of foam core sandwich constructions are studied by many investigators [5–9]. The response of the foam core sandwich composites depends on the density and the modulus of the foam [6, 7]. Shear fracture was found to occur in PVC/PUR system based brittle core materials. In contrast, buckling failures in the uppermost composite skin were observed in the intermediate modulus systems, whereas initial damage in the higher modulus PVC/PUR systems took the form of delamination within the top surface skin. Torre and Kenny [10] reported the development of new type of sandwich construction which consisted of skins made from a glass fiber phenolic matrix composite laminate and a core formed by an internal corrugated structure of the same laminate used for the faces filled by a phenolic foam to improve crashworthiness for transport applications. The corrugated sandwich panels showed better performance in terms of impact energy absorbing properties and strength as in comparison to traditional sandwich structures. Hence, in the current study, a three-dimensional (3D) honeycomb preform has been developed. Additionally, the face sheets were strengthened by using woven plain S2-glass and carbon fabric layers. Furthermore, we modified a Dobby loom to weave the 3D honeycomb preform that can be used as core materials in sandwich composites. The loom has a multi-warp yarn supplier system and a multi-filling yarn mechanism. Each yarn has an individual tension control unit during weaving processes. Carbon and glass honeycomb preforms have been fabricated by the loom. Two bottom skin fabrics, the preform core fabrics and two top skin fabrics were consolidated with epoxy resin to form a sandwich composite material. Also, a traditional PU foam core sandwich composite was made in this study as a reference material. The longitudinal, lateral, and flat-wise compression tests were performed on these sandwich composites.

EXPERIMENT

Preform Weaving

To weave a 3-D honeycomb preform as shown in Figure 1, a Dobby loom has been modified. The modified mechanisms of the loom are 24-shaft with Teflon coated heddle eyes, multi-warp yarn supply system, multi-filling yarn mechanism, warps yarns tension control system for each warp yarn and exclusive take-up mechanism. The weaving principle of honeycomb preform is derived from the weaving principle of multilayer fabric. In this study, a 8-layer fabric has been modified to form the honeycomb preform with a design interlock technique. As shown in figure 1, the preform has 8 layers and the 8-layer has to weave according to the two interlaced structures to form the honeycomb configuration. A unit configuration derived from figure 1 is shown in Figure 2. The unit configuration of honeycomb preform has three weaving units. The first weaving unit is non-interlacing configurations. The non-interlacing area is original weaving pattern with 8 layers. The 8 layers do not interlace with each other. The second weaving unit is an interlacing weaving pattern. In this pattern, the odd layers are interlaced with the even layers. That is, the warp yarns of the odd layers move down to the positions of adjacent even layers to weave each other. On the contrary, the third weaving unit is another interlacing pattern – the even layers are interlaced with the odd layers. In other words, the warp yarns of even layers move up to the position of adjacent odd layers to weave each other. After the three weaving unit, a basic structure of honeycomb configuration can be gained. Repeat these processes several times to get the length of preform that you want. The above mentioned is the design concept and procedure to that the honeycomb preform can be made. In the weaving procedure, we, first, weave the preform with acrylic fiber to check the mentioned weaving patterns and weft yarn filling processes. After the weaving pattern and weft yarn filling process was right, we began to weave the preform with glass and carbon fibers. Figure 3 shows the honeycomb preform that weave with acrylic fiber. Details of weaving principle can be found in author' articles [14-15]. The preforms weaved with carbon and glass yarns are shown in Figure 4. In current experiment, the preform is 10 cm wide, 1 cm thick and 30 cm long.

Composites Manufacturing and Testing

The epoxy resin that can be cured at room temperature was used as a matrix material. The resin has low viscosity and possesses good impregnated capacity with 3D preform. Figure 5 shows the manufacture procedure of sandwich composites with a honeycomb preform core material. In the first step, we fold a release paper to form a box, and then we put the box into a steel mold. Furthermore, we put the bottom face sheet fabrics into the box and then impregnate with epoxy resin (second step). In third step, the 3D honeycomb preform, which was filled with PU foams in the gaps of honeycomb structure, was put into the box onto the bottom face sheet fabrics and then impregnate with epoxy resin. The fourth step, we put the top face sheet fabrics onto the core layer and then impregnate with resin. The top and bottom skins are two layers of E-glass or Carbon woven plain fabrics. Finally, the box was covered with a top mold and then put into a vacuum oven to cure the impregnated materials. Moreover, traditional sandwich composites with PU foam core had been made with the same procedure as mentioned above. Figure 6 shows the sandwich composites with various core materials, PU form (Figure 6a, 6b), carbon honeycomb core (Figure 6c), and glass honeycomb core (Figure 6d). Table 1 lists the details of sandwich composite structures, densities and their nomenclature. We used an A-B format to name the samples, that is, A indicates the type of face sheet materials and B is the type of core materials. The abbreviated letters C, G, PU and H mean carbon fabric, glass fabric, PU foam and honeycomb preform, respectively. For examples, the named C-PU sample, the sample has carbon fabric face sheet and PU foam core materials.

Flat-wise, lateral, and longitudinal compression tests were conducted on a MTS 810 system. The compressive loading directions and the dimension of specimens are shown in Figure 7. As shown in the figure, aa-loading is flat-wise compression, bb-loading is lateral compression, and cc-loading is longitudinal compression.

RESULTS and DISCUSSION

The compression peak stresses are shown in Table 2. The flat-wise compression peak strength of the 3D honeycomb preform core sandwich composites was about 7000% higher than that of the traditional PU foam core sandwich composites. This is due to the honeycomb structure that enhanced the ability to against the flat-wise compression loading. For flat-wise compression in sandwich composites, the compression loading is mainly resisted by core materials. So, the 3D honeycomb preform core sandwich composites have much greater strength in flat-wise compression.

In lateral compression, the 3D honeycomb preform core sandwich composites have higher resistance capacity. The lateral compression peak stresses were 68.6 MPa and 903.2 MPa for the carbon/PU foam core sandwich materials and the carbon 3D honeycomb preform core materials, respectively. Even the loading acts in the lateral direction, the honeycomb structures have good strengths in lateral compressions. As shown in Figure 7, even thought, the loading worked on lateral direction, the honeycomb core sandwich composites, still, have the reinforced effect in loading direction. It is quite different than that of sandwich composites with PU foam core materials. For a sandwich composite with foam cores, the skin (face sheet) materials will bear the major loading in lateral compression. But, in the same condition, the sandwich composites with honeycomb preform core materials, both the face sheet materials and the structure of honeycomb core materials have, also, contributed the ability to resist the lateral compressive loading. However, in the longitudinal compression test, both the PU-foam core sandwich composites and honeycomb core sandwich composites have the equivalent strength. This is due to the face sheet materials dominate the capacity to resist the longitudinal compressive loading. In the meantime, the core materials only pay a role to hold the top and bottom face sheet layers. Most of the longitudinal compressive loading bears down on the top and bottom face sheet materials. Figure 8 (a), (b) and (c) show the flat-wise, lateral, and longitudinal compression modulus, respectively. The carbon honeycomb sandwich composites have higher compression modulus than the glass sandwich composites in three compression directions. We, also, found that the honeycomb sandwich composites have good compression resistance than the PU-foam core sandwich composites.

Typical compression stress-strain relations for glass sandwich composites are shown in Figure 9. The peak stresses of various samples have been indicated by solid circles. The specimens begin to reduce thickness after the peak stress under the flat-wise or lateral compression. The specimen's thickness could be reduced with increasing the compression loading and the stress could be increased with increasing the loading. The flat-wise and lateral compression test finished when the specimen's thickness reduces to the half of its original thickness. Therefore, the maximum stress (indicated by solid star) cannot be recorded for the specimen's final strength. After observing the tested specimens, we found that the core materials failed in a crush mode under flat-wise or lateral compression. For longitudinal compression, the face sheets failed in a buckling mode as the loading reached to the peak stress.

CONCLUSION

1. This paper developed a new weaving method of multi-warp supplying and multi-weft yarn filling techniques to weave the 3D honeycomb preforms.
2. The flat-wise compression peak strength of the 3D honeycomb preform core sandwich composites was higher than that of the traditional PU foam core sandwich composites.
3. In lateral compression, the 3D honeycomb preform core sandwich composites had higher resistance capacity.
4. The 3D honeycomb preform sandwich composites and the PU-foam core sandwich composites have the same ability to bear the longitudinal compressive loading.

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References

1. Zenkert D. The handbook of sandwich construction. London: EMAS Publishing; 1997.
2. "DIAB Sandwich Handbook", Diab Co.
3. Karssson KF, _Astr€om T. Manufacturing and application of structural sandwich components. Composite Part A, 1997; 28A: 97–111.
4. Weeks CA, Sun CT. Multi-core composite laminates. J Advancese Materials 1994:28–37.
5. Wu CL, Sun CT. Low velocity impact damage in composite sandwich beams. Compos Structure 1996; 34: 21–27.
6. Hazizan AM, Cantwell WJ. The low velocity impact response of foam based sandwich structures. Compos: Part B: Eng 2002; 33: 193–204.
7. Caprino G, Teti R. Impact and post impact behavior of foam core sandwich structures. Compos Struct 1994; 29: 47–55.
8. Anderson T, Madenci E. Experimental investigation of low velocity impact characteristics of sandwich composites. Compos Structure 2000; 50: 239–47.
9. Mines RAW, Worrall CM, Gibson AG. Low velocity perforation behavior of polymer composite sandwich panels. Int. J Impact Eng 1998; 21(10):855–79.
10. Torre L, Kenny JM. Impact testing and simulation of composite sandwich structures for civil transportation. Composite Structure, 2000; 50: 257–67.
11. Farnk K. Ko, "An outlook to the future work of textile composites", TEXCOMP-2 Symposium, May 19, 1994.
12. A. W. van Vuure etc., "Mechanical properties of composites panels based on woven sandwich-fabric preforms", Composites: Part A, 31, 2000, pp. 671-680.
13. U. K. Vaidya etc., "Impact response of integrated hollow core sandwich composite panel", Composites: Part A, 31, 2000, pp. 12-24.
14. Yu-Chih Chen, Jieng-Chiang Chen, "Mechanical properties of Textile Honeycomb Sandwich Composites", Thesis for Master of Engineering, Vanung University June 2007.
15. Jieng-Chiang Chen etc., "Fabrication of 3-D Sandwich Core Preforms" , 2009 International Workshop on Procession and Properties of Reinforced Polymers Composites, 2009 June15-16.

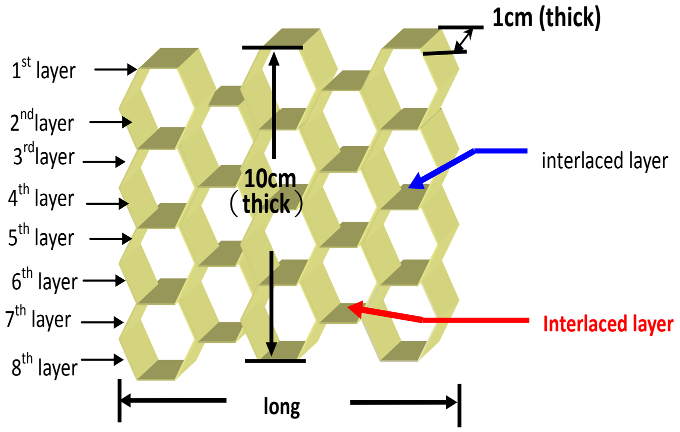


Figure 1 Schematic of 3D honeycomb preforms.

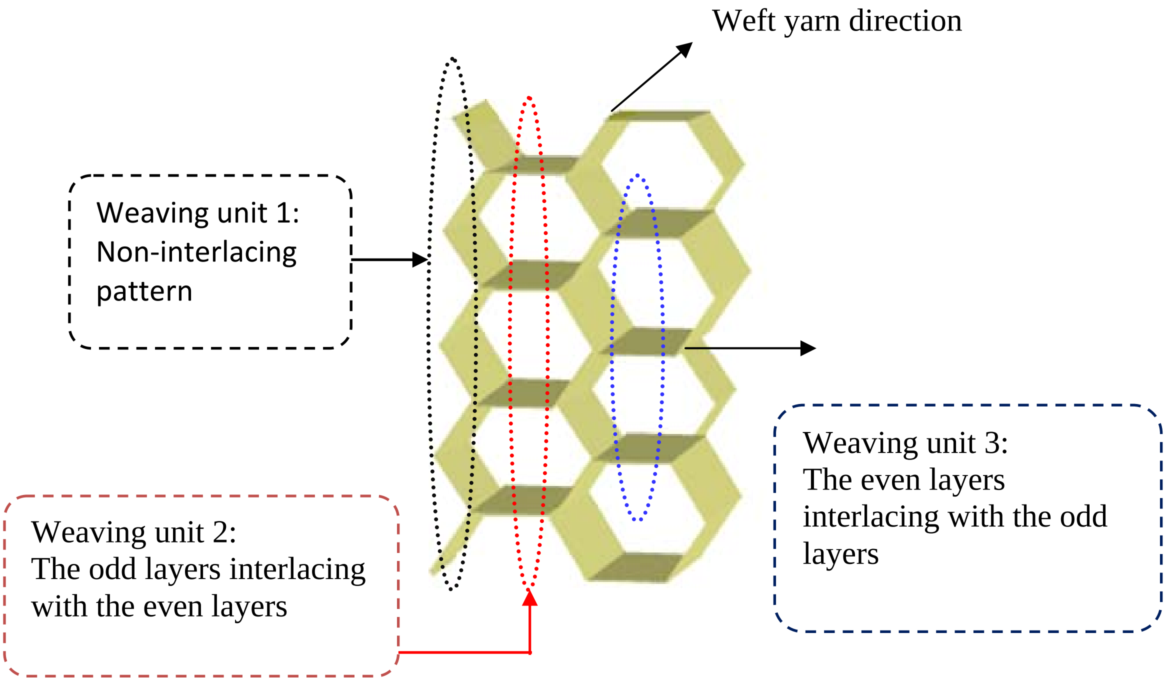
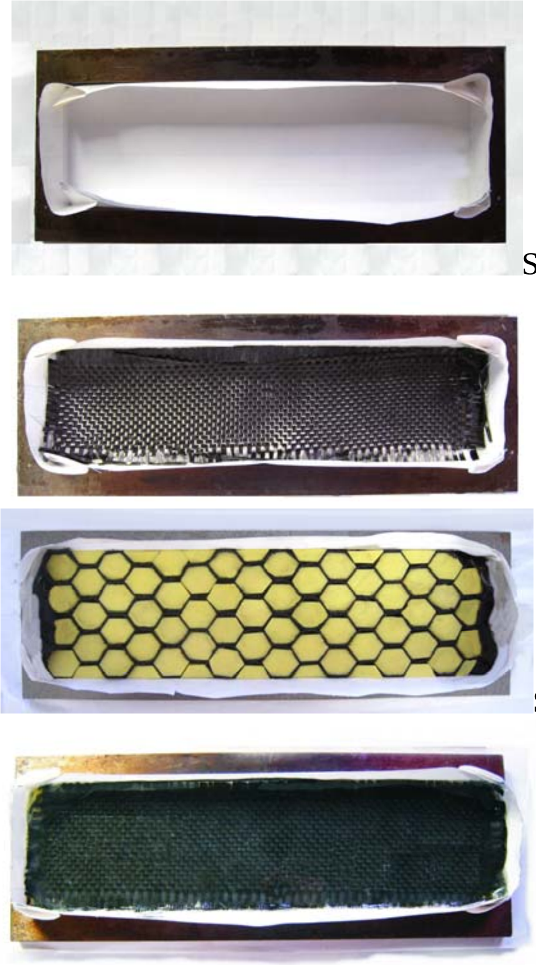


Figure 2 Weaving patterns of honeycomb preform

Figure 3 Acrylic fiber honeycomb preform

Figure 4 Carbon and glass honeycomb preforms



Step 1

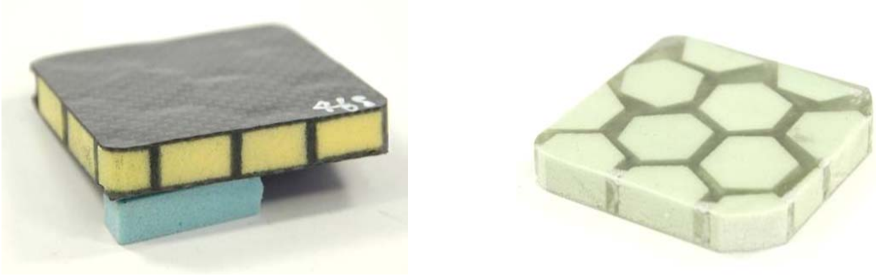
Step 2

Step 3

Step 4

Figure 5 Manufacturing procedures of sandwich composites.

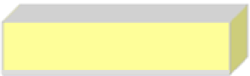
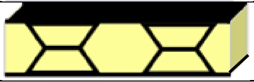
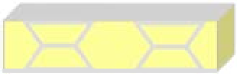
(a) C-PU (b) G-PU



(c) C-H (d) G-H

Figure 6 Sandwich Composites

Table 1 Details of the test samples structures

Nomenclature	Core Materials	Face Sheet Materials	Schematic of Samples	Density (kg/m^3)
C-PU	PU foam	Carbon plain fabric		0.56
G-PU	PU foam	Glass plain fabric		0.61
C-H	Honeycomb preform	Carbon plain fabric		0.64
G-H	Honeycomb preform	Glass plain fabric		0.73

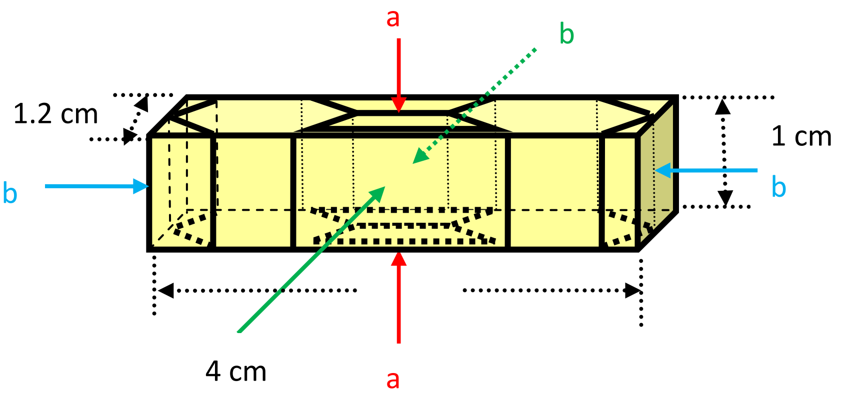
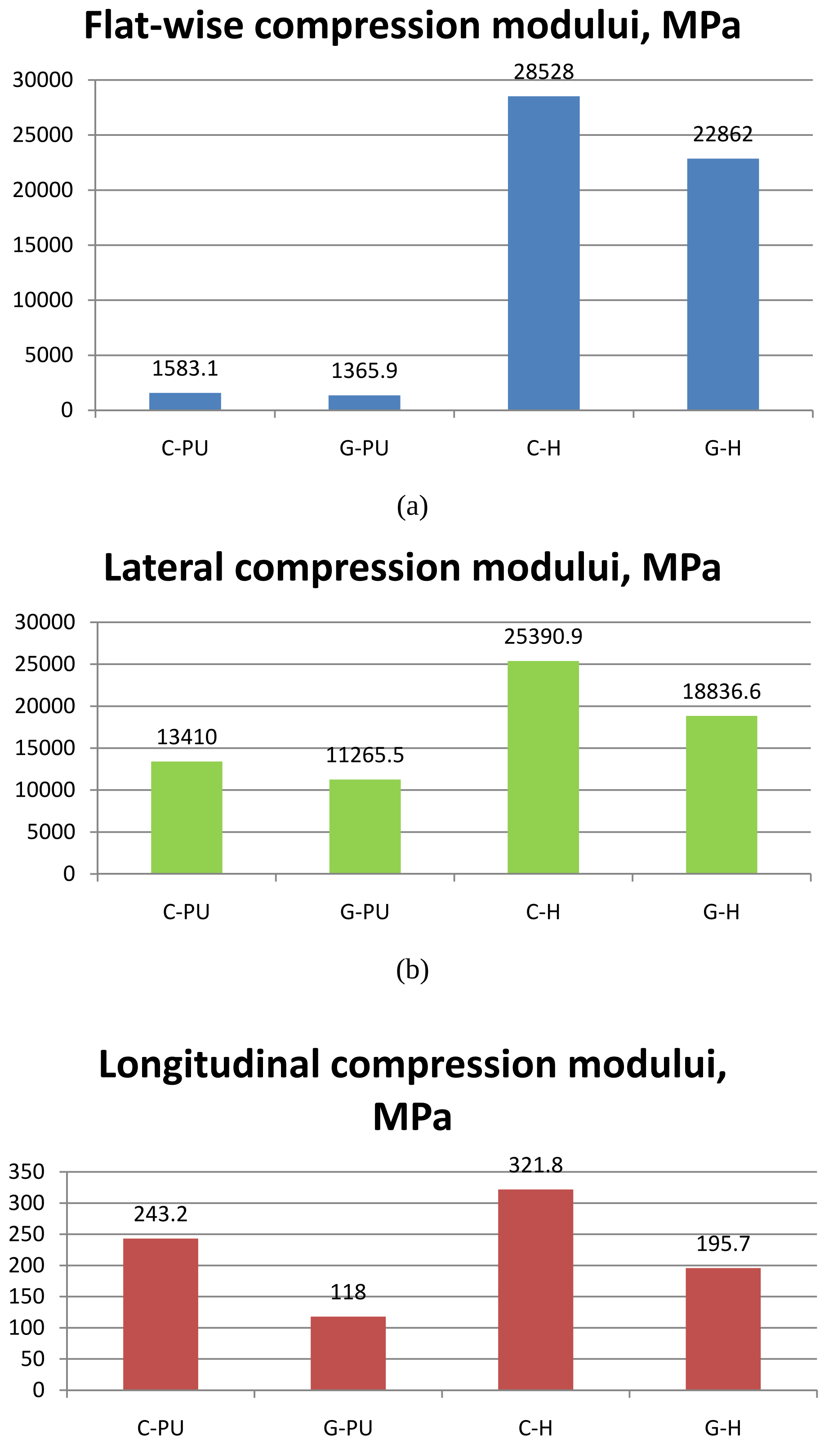


Figure 7 Loading directions of compressive test for sandwich composite specimen.



(a)

(b)

(c)

Figure 8 Compression Modului of Sandwich Composites

Table 2 Compression Peak Stresses of Sandwich Composites (Unit: MPa)

Samples	Flat-wise	Lateral	Longitudinal
C-PU	11.9	68.6	4.2
G-PU	12.8	51.2	8.3
C-H	903.1	903.2	4.6
G-H	871.1	580.3	9.3

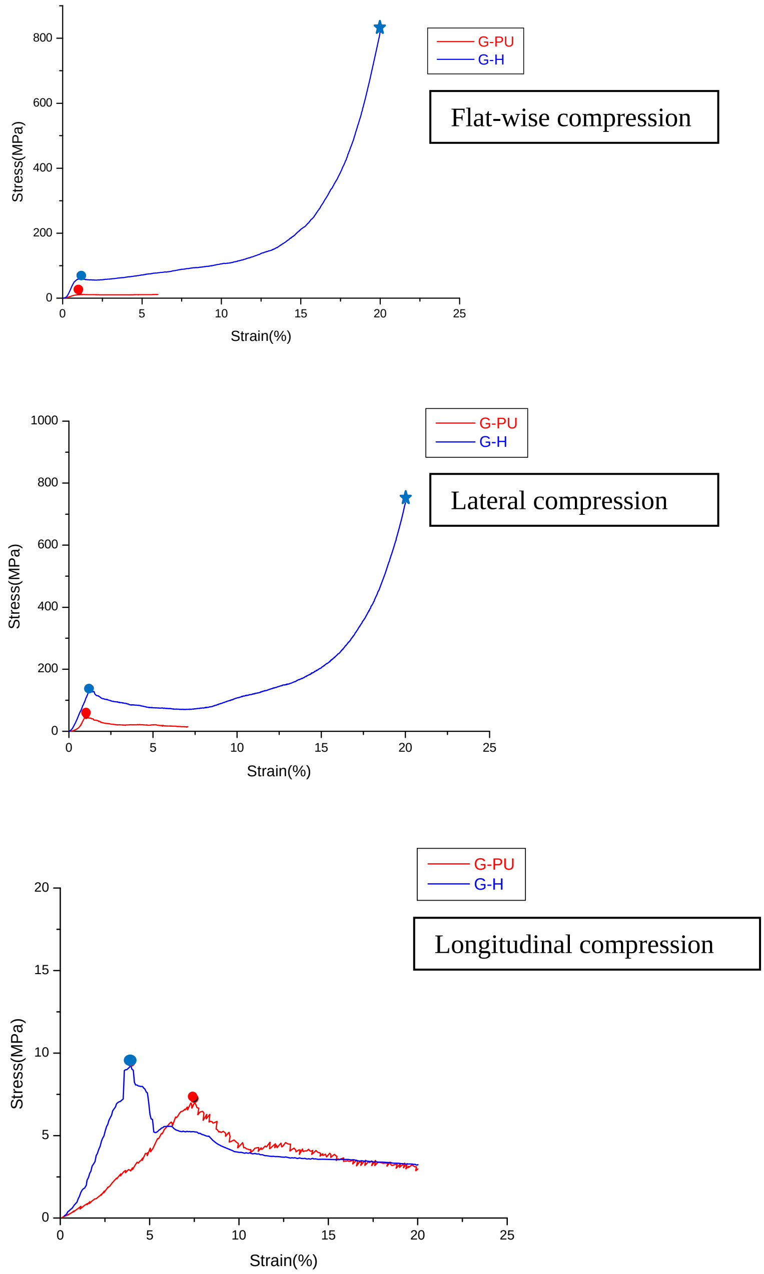


Figure 9 Typical compression stress-strain relations of sandwich composites

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