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Numerical study on Mechanical behavior of honeycomb sandwich with Random Fiber Reinforcement

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Abstract. Honeycomb sandwich structures have been promoting deal with mechanical performance extensively investigated. Modification in improving such mechanical properties is an innovation required of honeycomb sandwich with adding a random fibers reinforcement inside a thin panel plate. The study developed random fiber reinforcement using the commercial software code of MATLAB. It was investigated for its bending and impact behaviour by using finite-element model implemented in Ansys Workbench/Dynamic code. In this studies, a series of numerical simulations of three-point bending and impactor were carried out for the fiber reinforcement sandwich and conventional aluminum honeycomb sandwich. As a result, it was confirmed that the fiber reinforcement enhances the stiffness of the structure, which contributes a lot to the promotion of the bending resistance capacity and energy absorption. In addition, the fiber reinforcement sandwich with reinforced honeycomb core also shows better mechanical behaviour in the simulation.

1. INTRODUCTION

Honeycomb structures are natural or man-made structures with the geometry of a honeycomb to allow for the reduction of the amount of material required to achieve reduced weight and expense. Honeycomb structures come in a variety of shapes and sizes, but they all have an array of hollow cells built between thin vertical walls. Because of their excellent energy-absorbing ability and high strength-to-mass ratio, thin-walled aluminium honeycomb structures are commonly used in engineering fields. Deformable barriers, which are used in some crash tests to determine the crashworthiness of cars needed by regulations, are an example of a typical application [1-3].

Structural materials made from honeycomb are generally produced by laying a honeycomb material between two thin layers that provide tension resistance. This forms a platform-like mount. Wave materials are commonly used where flat or slightly curved surfaces are necessary and their high specific strength is important. For these reasons, they are commonly used in the aerospace industry and since the 1950s, honeycomb materials in aluminum, fiberglass and state-of-the-art composites have been present in avian and rockets. In several areas, from packaging materials in the shape of a paper carton to sports equipment such as skis and snowboards [4] some developed with varied tailored hierarchical honeycomb cores [5].

Honeycomb in sandwich system improving energy absorber such shown by the previous researcher [6], combination within Al/PTFE skeleton was increasing dynamic compressive strength at range of 1.5-3.1 times compared to traditional ingredient by varied arm length of honeycomb. Aluminium honeycomb skeleton had obvious

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strength effect the linear elastic stage. Plastic composite is one alternative honeycomb sandwich promise increasing energy absorption. Aluminum honeycomb-filled Carbon Fiber Reinforced Plastic (CFRP) was proposed to increase the dynamic impact of honeycomb by different configurations of laminate fibers [7]. The results have shown that the energy absorption and specific energy absorption of filled composite tubes can significantly increase by 104.3% and 26.8% respectively compared with those of CFRP hollow beams. Similar performance has reported by stacking angle (0 and 90^o) performance on hexagonal honeycomb which energy absorption properties highest in the 90°-layered honeycombs [8]. Due to high energy absorption, honeycomb was implemented in motorcycle helmet for head protector during road traffic accidents involving motorcyclists [9]. Helmet standard for the head responses in a range of A_{max} = 215.1 g, Head Injury Criterion (HIC) = 1985, intracranial pressure (ICP) = 228.8 kPa and σv = 33.6 kPa in conventional helmet design. The results design by using honeycomb achieved the protective performance of the optimum at $Amax$ = 137 g, HIC = 918, ICP = 146.9 kPa and σv = 18.1 kPa.

The numerical simulation technology has been used widely in engineering, especially the Finite Element Method has powerful to design and initial predicting in various engineering fields, which it has proofed and regarded as a reliable and effective to analyze honeycomb-like sandwiches [10]. The absorption of honeycomb design required to improve the performance and it needs careful predicting by using the finite element. In order to study the mechanical behaviors and energy absorption mechanism, a three-dimensional elastoplastic finite element model under three-point bending (TPB) and impacts are analyzed by adding fiber reinforcement, in which the real thin panel is reinforced using fiber generated technique is proposed in this project.

2. NUMERICAL MODEL

The numerical simulation is divided into two stages which the first stage covers the fiber development by using MATLAB software and the second stage focus on Finite Element analysis. The detailed process is explained below:

2.1 Fiber Development

To develop fiber randomly inside a thin panel plate, the thin plate is designed based on the size needed then developed domain size which fiber distributed inside. To develop fiber randomly inside the thin plate panel, the thin plate is designed based on the size needed, then the developed domain size that fiber distributes inside. The thin panel plate dimension is designed with 76 mm × 221 mm × 1 mm based on the three-point bending (TPB) standard of ASTM C-393. This bending test size covers the impact test dimension because the size is adequate by the following ratio conditions: width/thickness > 2, Length/width > (1.5+50mm) and t_{panel}/t_{core} < 0.1. The random fiber is designed in a straight line shape with a radius of 0.1 mm and the step is described in Figure 1. The points are launched inside the domain randomly and avoid the repeated point selected by the program. Once the points are selected and save on the storage as x, y and z-axis which connected to another side axis point. In the final step, fiber is created by connecting each point side along the x-axis. The fibers number observed by 2 different quantities: 50 and 100 fibers number.

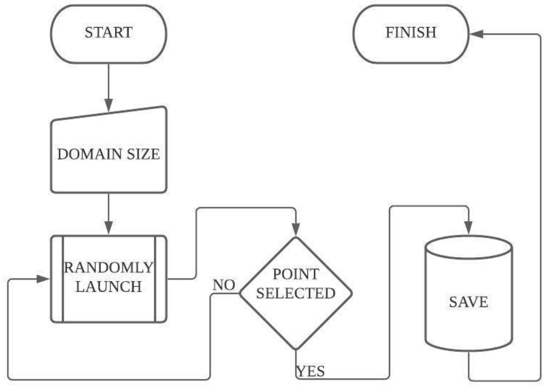


FIGURE 1. Flow-chart fiber development using MATLAB software.

2.2 Finite Element Model

To investigate the dynamic mechanical behavior of sandwich panels with honeycomb core, a three-dimensional nonlinear elastoplastic finite element model of Three-Point Bending (TPB) and Impact testing is established by using the commercial software Ansys Workbench Dynamic. The honeycomb sandwich panel considered here is constituted by the top and bottom thin plate panel as well as regular hexagon aluminium honeycomb core as shown in Figure 2. The thin panel plate polyethylene and aluminium honeycomb core are bonded as sandwich while the steel fibers are imported from MATLAB software by introducing the coordinate points using a text document file. In this simulation, the sandwich model's geometrical parameters are defined as follows: The thicknesses of the face sheets and aluminium honeycomb core are defined as 22 mm. The wall length and thickness of honeycomb cells are 7.0 mm and 0.2 mm, respectively. The dimension of the square sandwich panel is 76 mm × 221 mm with 20 mm of thickness. The side length value of the regular hexagon honeycomb core is chosen as 7 mm. The hard mass hammer and three-point bending load are chosen as hemisphere impactor with the diameter are 16 mm and 30 mm, respectively. The mechanical properties of steel, thin-panel plate and aluminium were summarized in Table 1. Regarding boundary condition, three-point bending is supported by 2 steel semi bars to accommodate the sample to receipt the load, while the impact is clamped to the left and right side along the testing process as shown in Figure 3.

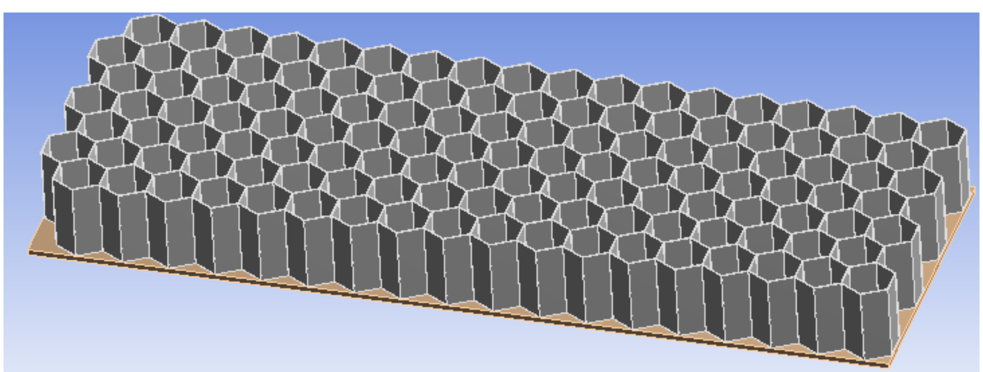
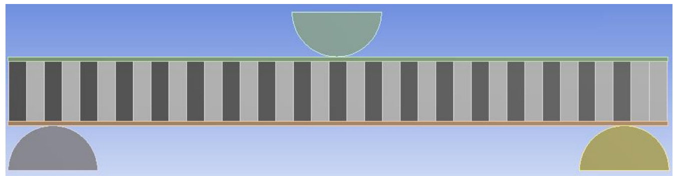


FIGURE 2. Ansys Workbench model of honeycomb sandwich panel.



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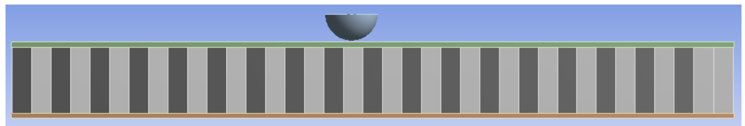


(b)

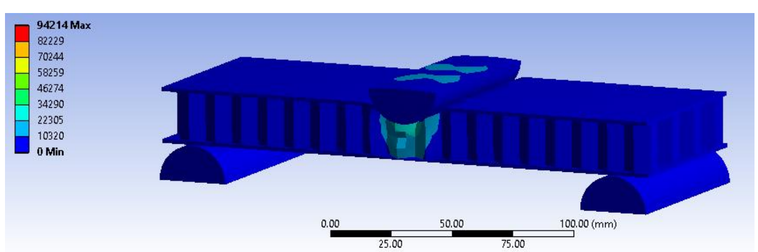
FIGURE 3. Mechanical testing : (a) Three-Point Bending and (b) Impact using Ansys Workbench.

TABLE 1. The material mechanical properties.

Properties/Material	Aluminium	Steel	Polyethylene
Density, (kg/m^3)	2770	7850	950
Young Modulus, (GPa)	71	200	1.1
Poisson Ratio	0.33	0.3	0.42

3. RESULTS AND DISCUSSIONS

In the numerical dynamic calculation process, the total time of the analysis step range is 1.14×10^{-5} to 2×10^{-5}s. To investigate the details of the bending resistance ability of the honeycomb sandwich, its deformation mode in the bending process is depicted in Figure 4. This figure shows the equivalent stress simulation results in which of three conditions of fiber content: 0, 50 and 100 fibers in each thin-plate, respectively. Obviously, clear the stress occurred at the sample higher by increasing fibers number to the thin panel plate, due to the strong shear tensile in bending loading. As shown in Figure 5, the numerical load given was higher by increasing the number of the fibers due to fiber reinforcement increasing resistance to the load. Based on the graph, the trends are increasing by fiber reinforcement number.



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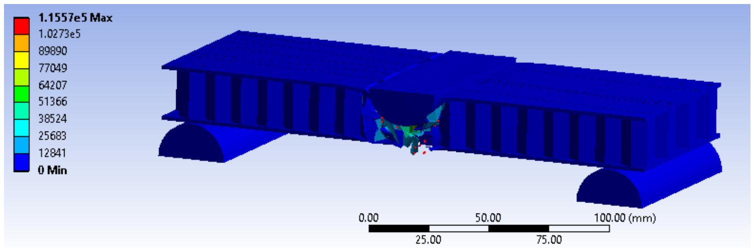

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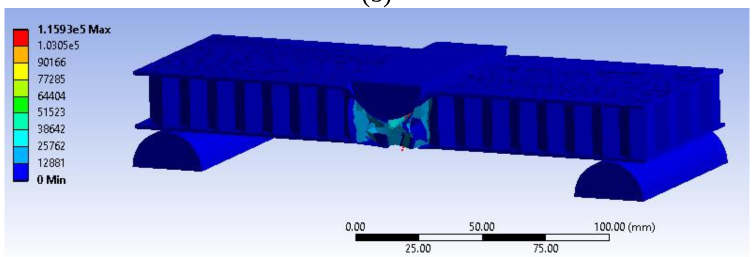

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FIGURE 4. Equivalent stress of : (a) 0 Fiber and (b) 50 Fibers and (c) 100 fibers number.

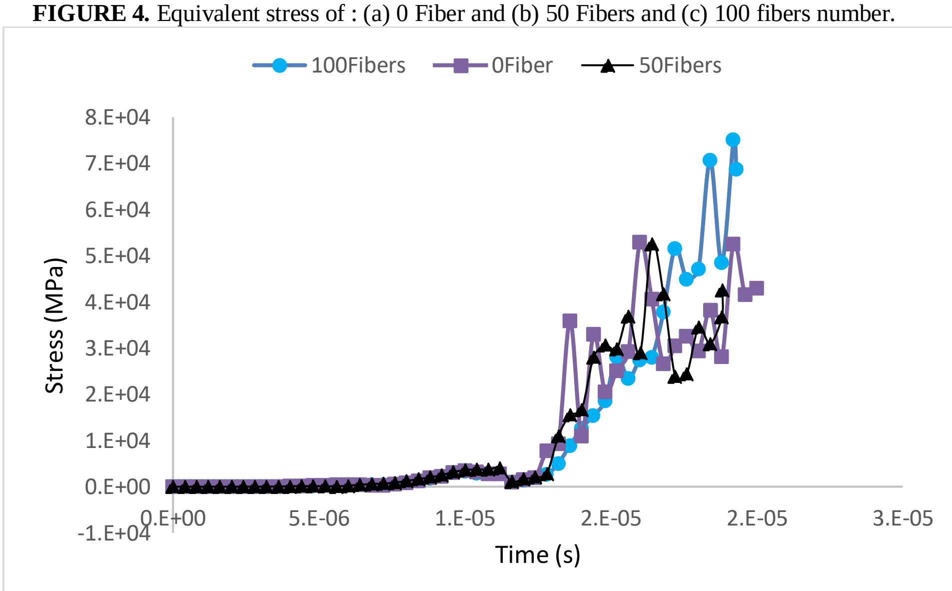
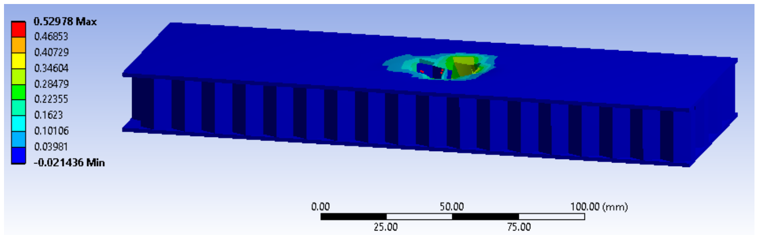


FIGURE 5. True Stress comparison.

The interaction contact relationship between the impactor and sandwich panel is shown in Figure 6. The debonding phenomenon between face sheets and honeycomb core did not appear during our impact tests due to using high velocity until sample destructive. Based on the impact finite element model, the figure illustrates that the energy absorption capability was increasing by showing increasing the strain of the model sample in increasing fibers number. They coincide well with stress absorption showing in Figure 7 which increasing by fibers number.



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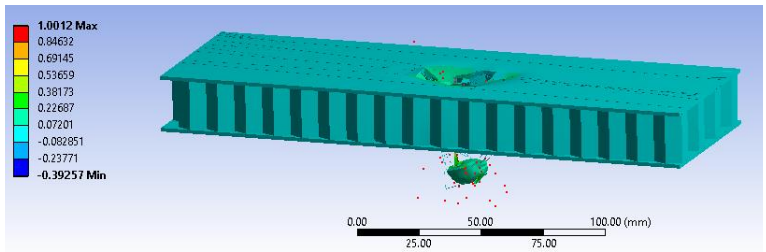

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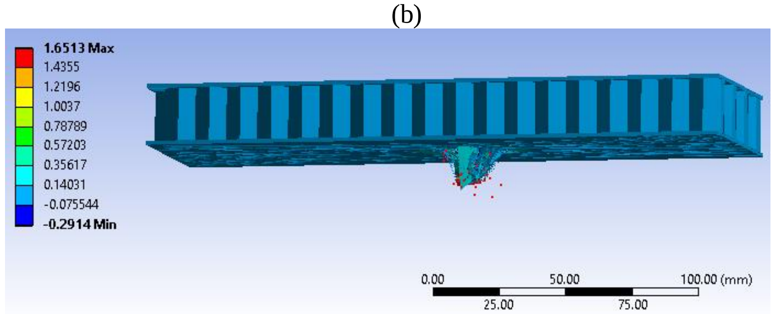

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FIGURE 6. Equivalent strain of : (a) 0 Fiber and (b) 50 Fibers and (c) 100 fibers number.

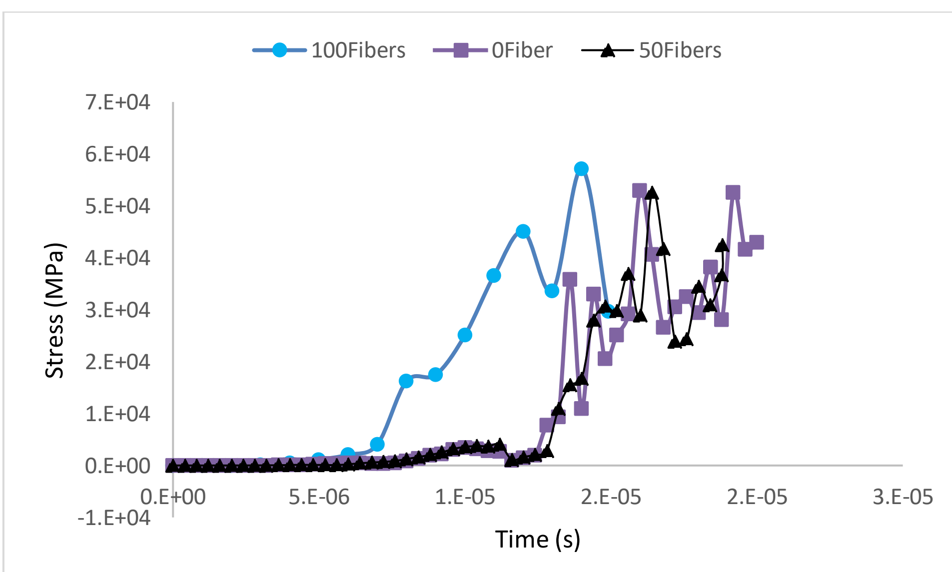

FIGURE 7. True Stress comparison.

4. CONCLUSION

Numerical simulations were carried out for the aluminum honeycomb sandwich and fibers reinforcement was successful to develop reinforcement distribution technique by coding software of MATLAB. Based on the above-mentioned results and discussions, some significant conclusions can be drawn as follows:

a. The reinforcement clearly brings an increase in strength and stiffness for the whole sandwich. In this way, the bending resistance capacity of reinforcement sandwiches gets substantial promotion accordingly comparing with the basic ones. This fact embodied in the load-deflection curves and different deformation patterns.
b. The numerically calculated results of the impact dynamic mechanical behaviors of sandwiches show an increase of the energy absorption can be effectively modulated by the reinforcement fibers.

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