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INVESTIGATION ON ENERGY ABSORPTION OF ALUMINIUM FOAM-CFRP SANDWICH PANEL SUBJECTED TO IMPACT LOADING

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Graphical abstract

Abstract

Sandwich panels are widely used in the fabrication of high strength low-weight structure that can withstand impact and blast loading especially for aerospace and automotive structures. Currently, aluminium foam is one of the lightweight materials used as a core in sandwich panels. The combination properties of core and face-sheet material are important to produce high strength and lightweight sandwich panel. This research is aimed to develop a carbon fibre reinforced polymer (CFRP) composite sandwich panel with aluminium foam as a core and study the impact properties of the structure. The preparations of the sandwich panel involved closed-cell aluminum foam as a core material and CFRP composite as the face-sheets. The impact tests were conducted using an Instron Dynatup 9250HV impact tester machine according to ASTM standard D3763 under constant impact velocity of 6.7m/s. The results of the impact tests showed that CFRP composite sandwich panel has better impact properties when compared to the other systems where it has higher specific energy absorption and longer impact time.

Keywords: Impact strength, energy absorption, carbon fibre reinforced polymer composite, aluminium foam

1.0 INTRODUCTION

In recent years, the investigation on lightweight materials is growing rapidly. One of the attractive materials to be investigated is metallic foams due to their lightweight and high energy absorption capacity properties. Metallic foams, such as aluminium foam, exhibit low density which have high volume of porosity, up to 95%. Aluminum foam is designed to withstand the impact and blast loading. The demand on using this material for energy absorbing applications keep increasing due to their good properties which are high in energy absorption, specific stiffness and strength [1]. For instant, aluminum foam acts as impact energy absorber in order to limit the acceleration of vehicle during crash situations [2]. The concept of energy absorbing components and devices is that, the more impact energy can be absorbed, the lesser risk of damage to be incurred especially to human life. Aluminium foam has been used in automotive and aerospace industries as engine mount brackets, floor panel and protection devices [3-4]. CFRP composites are recognized as high performance materials which commercially used in the fabrication of aircraft structures [5]. CFRP composites consist of epoxy resin polymer matrix with carbon fibre reinforcement. The reinforcement of fibre makes the cured polymer higher in strength and rigidity that are determined by maximum stress and elastic modulus respectively However, CFRP exhibits brittle behavior which results in poor fracture toughness, poor resistance to crack propagation and low impact strength [5]. Although carbon fibre is more brittle than glass fibre [6], carbon fibre is frequently selected to be used in high end applications due to its low density and high strength.

Sandwich panel, which is made of fibre reinforced plastic (FRP) face-sheets and metal foam core, is a new material and technology that becomes increasingly popular in many engineering fields due to the very favorable flexural properties to weight ratio [7]. Sandwich panel consists of two thin, stiff and strong face sheets, which withstand most of the bending load, and a thick low-density foam core, which provides stiffness and resistance to shear and delamination of the structure [7-9]. Previous researches showed that combination of metal-based alloy face-sheets and plastic-based core produced good properties such as high stiffness and strength, good plastic energy absorbing capabilities, good corrosion resistance and recyclable making it suitable for lightweight applications. [1]. However, this kind of sandwich panel exhibits low shear and adhesion strength at facesheet-core interfaces. This contributes to premature failure of the structure.

In this research, a new energy absorbing material was introduced and developed using CFRP composite laminates as face-sheet material and closed-cell aluminium foam as a core. The objectives of this research were to develop and characterize the impact properties of CFRP composite sandwich panel. In addition, aluminium foam, CFRP composite laminate and aluminium sheet sandwich panel were also tested in order to compare with CFRP composite sandwich panel. All samples were tested using impact tester machine and observed under optical microscope to obtain better understanding on impact damage mechanisms.

2.0 EXPERIMENTAL

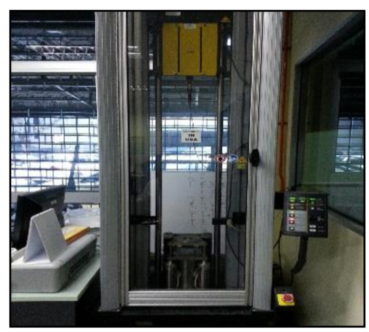
2.1 Specimen Preparation

In this study, 2x2 twill weave carbon fibre prepreg was used to fabricate CFRP composite laminate. The laminate was used as the face-sheet of the sandwich panel. Based on the manufacturer datasheet, the resin content of this carbon fibre prepreg was around 33% to 39%. The carbon fibre prepreg was cut into 200x200mm and stacked ply by ply on the steel plate until the thickness of 1mm was achieved. Then, carbon fibre prepreg was cured in a vacuum oven at 154°C with the soaking time of 1 hour. The CFRP composite laminate was removed from the vacuum oven after the temperature was cooled down to less than 66°C. The CFRP composite laminate and closed-cell aluminium foam were cut into 50x50mm regarding on impact machine requirement. Araldite was used as the adhesion material to create bonding between the core and the face-sheet materials. Figure 1 shows the sample of closed-cell aluminium foam and CFRP composite sandwich panel.

Figure1 Closed-cell aluminium foam with CFRP composite sandwich panel

2.2 Impact Test

An Instron Dynatup 9250HV impact tester machine was used to conduct the impact test on the samples according to ASTM standard D3763. Figure 2(a) shows the impact tester machine used in this experiment. The puncture of the impact test machine was hemisphere tip with diameter of 12.7mm and the impact velocity used to strike the samples was constant at 6.7m/s. The data of force, energy and time were captured by the data logger during the impact event. The damage samples after impact test, example as shown in Figure 2(b), were observed under an optical microscope to identify the types of failure existed.



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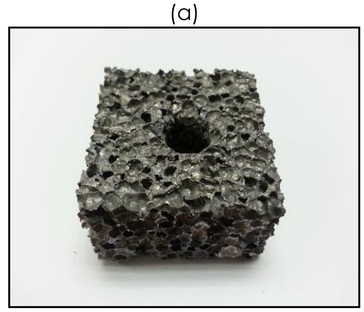

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Figure 2 (a) Instron Dynatup 9250HV impact tester machine, and (b) Example of damage specimen

3.0 RESULTS AND DISCUSSION

Figure 3 shows the example of load and energy versus time curve of different samples that have been tested.

From the graph, the value of the absorbed energy, deflection at peak load and total time of the impact event were analysed. These data are discussed in details in the following subsection.

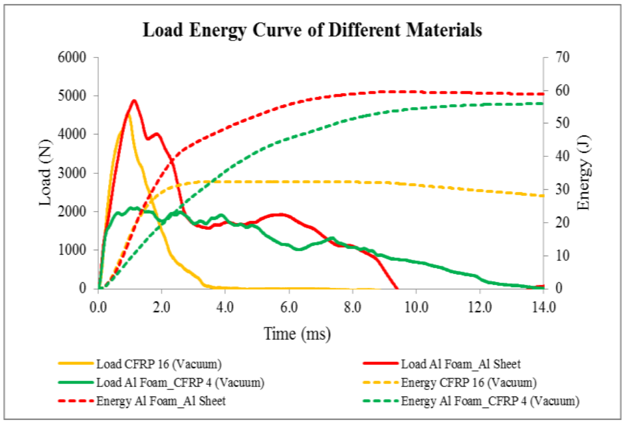


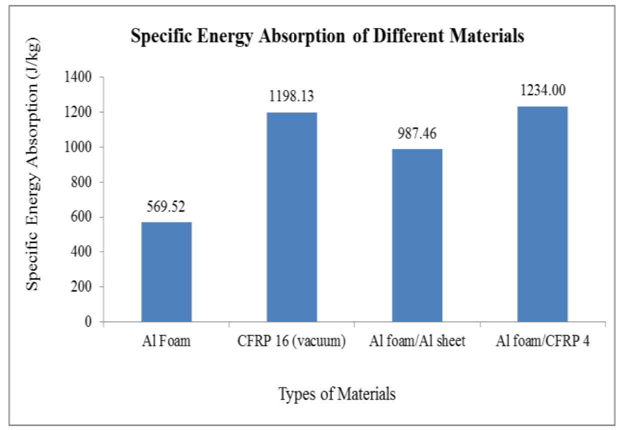
Figure 3 Typical load and energy vs time curves during impact of the three different specimens

3.1 Impact Resistance

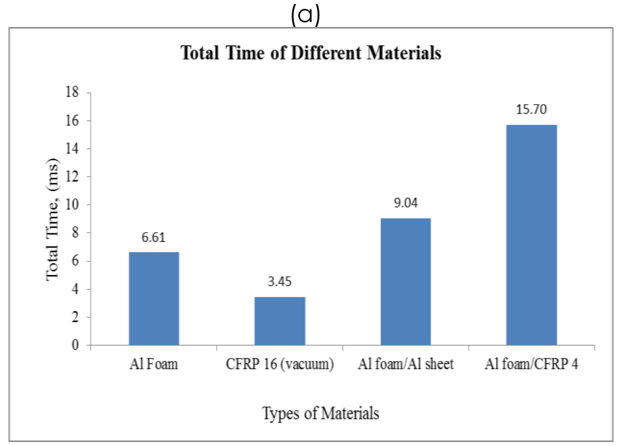
Four types of samples were tested in this study which is closed-cell aluminium foam, CFRP composite laminate, CFRP composite sandwich panel and aluminium sheet sandwich panel. Specific energy absorption was calculated by dividing value of absorbed energy and mass of the sample. Figure 4(a) shows the specific energy absorption value of four different samples. CFRP composite sandwich panel exhibited the highest specific energy absorption compared to others. The value of specific energy absorption of aluminum sheet sandwich panel is 20% lower than CFRP composite sandwich panel. This is because the density of the CFRP composite sandwich panel is lower than aluminium sheet sandwich panel. This value is important to evaluate the performance of energy absorbing materials.

Neat CFRP composite laminate showed a lower specific energy absorption value, about 3%, when compared to CFRP composite sandwich panel. The CFRP composite sandwich panel used 1mm thick CFRP composite face-sheet, while the neat CFRP composite laminate has 4mm thickness. Although the neat CFRP composite laminate has higher thickness, the presence of aluminium foam in the CFRP composite sandwich panel contributes to a higher specific energy absorption value during impact load. The value of total time during the impact event for all samples was shown in Figure 4(b). The figure shows that CFRP composite laminate samples consumed 3.45ms of total impact time. This means that CFRP composite laminate sample consumed the shortest duration to make it fully damage when compared to other samples. Meanwhile, aluminum foam, CFRP composite sandwich panel and aluminum sheet sandwich panel consumed 6.61ms, 9.04ms and 15.70ms, respectively, to complete the impact damage.

As can be seen, CFRP composite sandwich panel exhibited the longest impact time among others. This proved that CFRP composite sandwich panel has optimum strength to prevent damage with specified impact velocity applied on it. This also clarifies the highest specific energy absorption properties of CFRP composite sandwich panel as shown in Figure 4(a).



(a)



(b)

Figure 4 (a) Specific energy absorption of different samples, and (b) Total time of impact event

3.2 Damage Area

Figure 5 shows the images of the samples after impact test when observed under optical microscope from top and bottom views. The optical microscope images of bottom view as shown in Figure 5(b), all samples were fully penetrated when subjected to impact velocity of 6.7m/s except aluminium sheet sandwich panel. As can be seen in Figure 5(b)(i), complete tearing was observed on the aluminium foam while fibre breakage on the CFRP composite laminates (see Figure 5(b)(ii)). The bottom side of aluminium sheet sandwich panel deformed during impact with no penetration occurred (see Figure 5(b)(iii)). Aluminium sheet is a ductile material which has elastic-plastic behavior, therefore, it can deform plastically when impact load is applies. The CFRP composite sandwich panel exhibited complete penetration as shown in Figure 5(b) (iv), however, the hole due to the fibre breakage was smaller than that of the CFRP composite laminate as shown in Figure 5(b)(ii). This is because of the impact load applied on the sample was absorbed by the aluminium foam and imparted smaller damage to the CFRP at the bottom side. On top of that CFRP composite laminate is brittle, therefore the amount of impact energy absorbed is slow when compared to the sandwich panel.

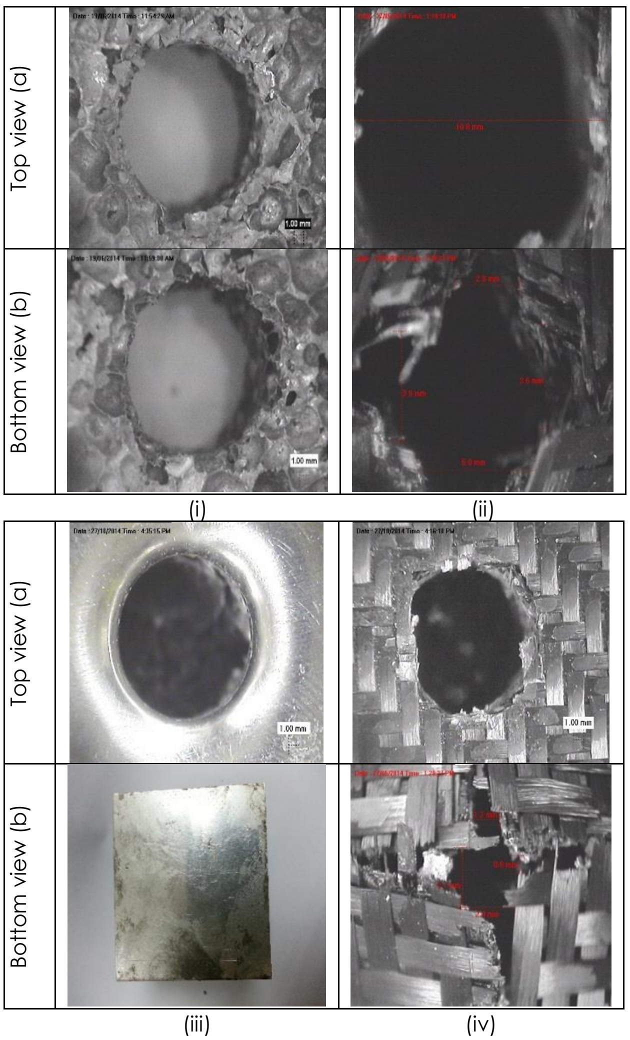


Figure 5 The damage specimens after impact.
(a) Aluminium foam (b) CFRP composite laminate
(c) Aluminium foam/aluminium sheet (d) Aluminium foam/CFRP composite.

4.0 CONCLUSION

Energy absorption of the sandwich panel has been investigated by performing low velocity impact test with a constant impact velocity of 6.7m/s. CFRP composite sandwich panel was developed by attaching the CFRP composite laminate to closed-cell aluminium foam as the core. The result of the energy absorption CFRP composite sandwich panel was compared to the other three material systems that were the aluminium sheet sandwich panel, CFRP composite laminate and closed-cell aluminium foam. The results showed that CFRP composite sandwich panel exhibited a similar high quality material system based on its properties i.e. high specific energy absorption value and longest total time taken to complete the impact damage. The combination of high strength of CFRP composite laminates and high energy absorption of aluminium foam offered higher strength and stiffness thus gave better specific energy absorption value compared to the other materials.

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