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Experimental study of energy absorption capability of metallic-palm fiber-metallic hybrid composite plate.

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Abstract. An experimental campaign on metallic-palm fiber-metallic hybrid subjected to impact loading using spherical projectile has been carried out. High initial energy impact with projectile mass of 24 kg and speed of 1, 3 and 5 mm/s, has been set enabling to determine the energy absorption capability of hybrid composite panel. The influence of stacking sequences metallic-palm-fiber-metallic and metallic-palm fiber-metallic-palm fiber-metallic with different thickness of metallic and palm fiber, to the energy absorption were investigated. The effect of different striker radius; 10, 13 and 20 mm were carried out as well. The mechanism of failure and energy absorbed by the hybrid composite panel and its components; metallic alone and palm fiber alone, were carried out to understand the advantage of having hybrid structure. The optimum configuration of hybrid panel in term of stacking sequence to absorb the energy of impact is proposed. The methodology of this study can be used for designing the armor to absorb the energy of projectile using palm fiber composite panel.

Introduction

A tendency to a more environmental friendly design in industries leads to the introduction of using natural fibers in the composite application and technology. One of the natural fibers that have been available in abundance in the region of south and south East Asia is namely fiber made from coconut fruit [ref 1-8]. The recent application of this type of fiber is for armor application where the impact energy from bullet is absorbed completely by the fiber. In practice, a significant thickness of palm fiber needs to be employed to absorb the bullet energy and a high deformation of the panel after the impact has been observed. A skin need to be added to able to shape the palm fiber panel and also to localize and reduced the deformation of palm-fiber panel. In this work, an Aluminum skin will be employed since its mechanical behavior is well known which in return it makes easier to understand the influence of skin to the capability of hybrid panel in absorbing the energy of impact. An experimental study are carried out using different energy of impact, different radius of spherical striker, different stacking sequence of aluminum-palm fiber in order to understand the mechanism of failure and its influence to the capability in absorbing the energy.

Specimens and Experimental set up

Experiment campaign will be carried out on hybrid metallic-palm fiber composite panel using different thickness of aluminum plate; 0.2, 1 and 1.5 mm and two different thicknesses of palm fiber; 1 layer (7.5 mm) and 2 layers (15 mm). The specimens are named with specimen A, B and C as shown in Table 1. To understand the effect of stacking sequence in absorbing the impact energy, two different type of hybrid panel are fabricated; one with 2 aluminum plates as skins with 1.5 mm of thickness (specimen C) and the other one with three aluminum plates with thickness of 1 mm (specimen D) where the third plate is inserted in the middle of palm fiber (figure 1). The 2 specimens represent different configuration of hybrid panel while maintaining the same weight. Therefore, it is interesting to observe the different energy absorbed by the two specimens in order to determine the best configuration of hybrid panel in absorbing the energy. The palm fiber is bonded to the aluminum plate using specific glue and compressed uniformly at constant force of 8.7 kN which relates to the beginning of densification of 300 mm* 300m palm fiber plate (Figure 1). The pressure is maintained to be constant for all specimens in order to obtain a standard process of fabrication. The impact

loading uses constant masse of 24 kg, different speed of 1, 3 and 5 mm/s and different diameter of spherical striker; 10, 13 and 20 mm. The impact machine records the contact force during penetration of striker through the specimen and initial speed just before the contact between striker and specimen. With this information, the speed of striker during penetration can be calculated and energy absorbed by specimen can be determined. A clamp boundary condition with diameter of 40 mm is applied to all specimens.

Table 1 Hybrid composite specimens.

Specimen	Layer 1	Layer2	Layer 3	Layer 4	Layer 5
A	0.2 mm of Al	Palm fiber	Palm fiber	0.2 mm of Al	
B	1 mm of Al	Palm fiber	Palm fiber	1 mm of Al	
C	1.5 mm of Al	Palm fiber	Palm fiber	1.5 mm of Al	
D	1 mm of Al	Palm fiber	1 mm of Al	Palm fiber	1 mm of Al

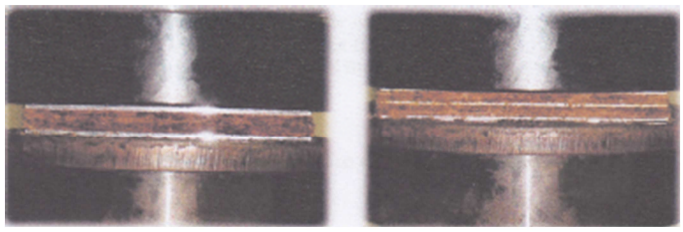

Figure 1 Two and three aluminum plate specimen

Experimental results

-Different thickness of skin (specimen A, B and C)

The energy absorption for the three specimens which relates to different thickness of skins is shown in figure 2 for different diameter of striker. It seems that the energy absorption increases linearly with the thickness of skin. The energy absorption increases as well with the diameter of striker which can be explained by bigger contact area between striker and specimen for bigger striker diameter. From the graph of specific energy in figure 2, it shows that the specific energy absorption varies constantly with the thickness of skin. One can then predicts the capability of energy absorption of the panel for any thickness of aluminum skin.

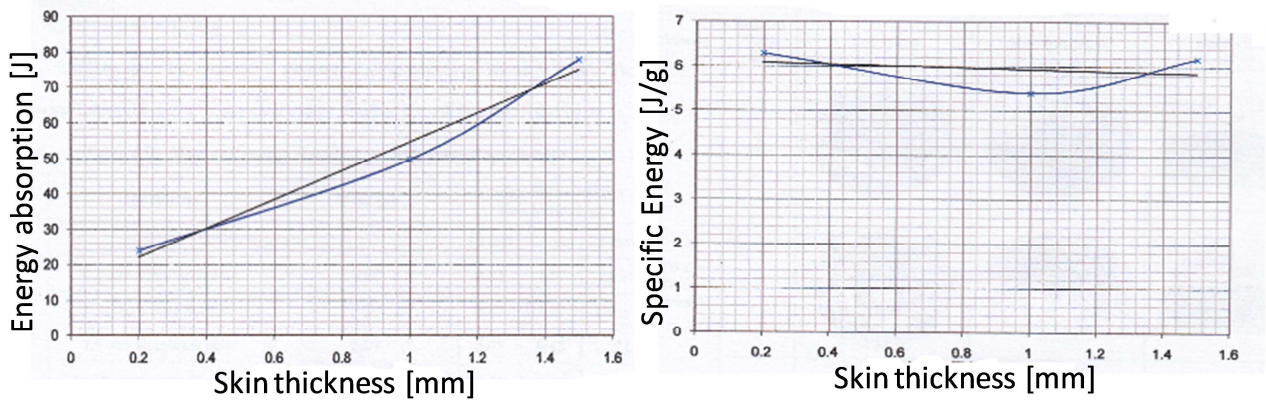

Figure 2 Energy absorption and specific energy absorption vs aluminum thickness.

From the failure mechanism after impact (figure 3), it shows that for thin aluminum plate the failure is happened locally in the contact area while for the thicker one, bending deformation outside the contact area is observed. For Palm fiber only, the failure is happened by fiber fracture locally in the contact area. The hybrid composite deformation seems to be controlled by the aluminum skin with smaller area of damage compared to deformation of skin only. The energy absorption of hybrid composite plate compared to additional of energy absorption of skin and palm fiber individually as

listed in table 2 shows that the hybrid composite gain between 5 to 23.1 % of energy absorption compared to additional skins and palm fiber individually. The difference is due to different boundary conditions from circular fixed support with diameter of 40 mm for aluminum only and palm fiber only to foundation support due to palm fiber layer for hybrid composite panel. The difference boundary condition explains the difference damage area between aluminum plate only and hybrid composite as shown in figure 3 previously. It can be observed that the effect of foundation boundary condition is significant for thin skin.

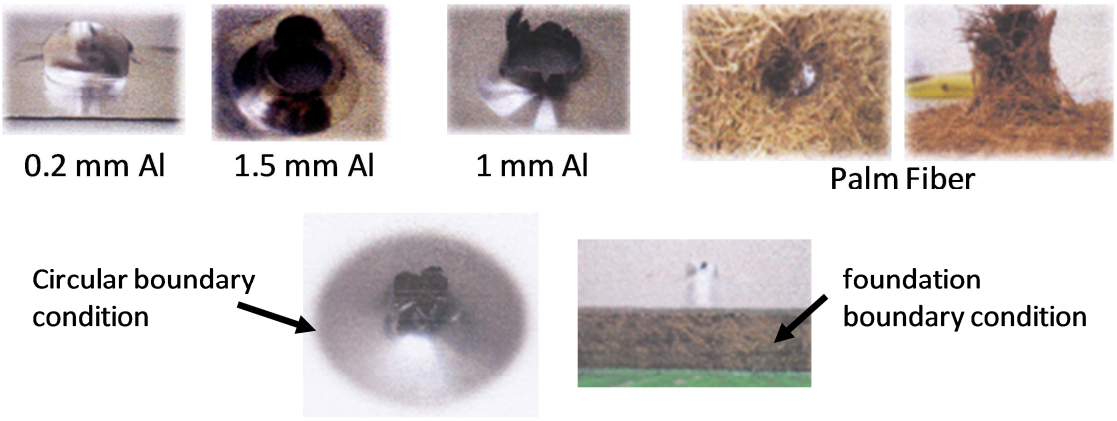

Figure 3. The failure mechanism for aluminum plate only, Palm fiber only and hybrid composite.

Table 2. Difference energy absorption of hybrid panel and additional energy of its components.

Specimen	Addition of energy absorption [J]	Energy absorbed by hybrid panel [J]	Energy gain [%]	Specific energy gain [J/g]
A	2*(0.42) + 18.63 = 19.47	23.97	23.1	1.18
B	2*(11.77) + 18.63 = 42.17	49.83	18.2	0.83
C	2*(27.83) + 18.63 = 74.29	78	5	0.29

-Different stacking sequence with the same total weight (specimen C and D)

The 2 specimens represent different stacking of hybrid composite (figure 1) while maintaining the same total weight. Specimen C consists of 2 aluminum skin plates with thickness of 1.5 mm and palm fiber layer with thickness 15 mm while Specimen D consists of 3 aluminum plates with thickness of 1 mm each where the third plate is inserted in the middle of palm fiber. For specimen D, the palm fiber has a total thickness of 15 mm to maintain the same weight with Specimen C. The comparison of energy absorption between Specimen C and D as listed in table 3 indicates that specimen C absorbs more energy compared to specimen D. It seems that having less but thicker skin benefits energy absorption compared with having more plates with thinner thickness. The phenomena can be explained by the fact that the thicker skin which at the beginning in contact with the projectile absorbs more energy compared to the thinner one. The remaining energy which is taken by the next layer, palm fiber layer, will be less for thicker skin compared to the thinner one which explains the higher capability of specimen C in absorbing the energy.

Table 3. Comparison of energy absorption between Specimen C and D.

Specimen	Average energy absorption [J]	Specific Energy [J]
C	78	6.18
D	58.3	4.62

The experimental results show similar tendency for all test using different speed and different diameter of striker. For different speed, the energy absorbed by the specimen is almost the same since the projectile was going through the specimen for all striker speeds. Different striker diameter results in higher energy absorption since the contact area becomes bigger for bigger striker diameter.

Conclusion

An experimental study on hybrid aluminum-Palm fiber-Aluminum hybrid composite plate subjected to energy impact has been carried out. The energy absorption of the hybrid composite plate increases linearly with the thickness of aluminum plate while maintain the thickness of palm fiber layer. It is interesting to observe that the specific energy increases constantly with the thickness of skins which one can predict the energy absorption of hybrid composite plate using certain thickness of skin. The damage area of hybrid composite differs with the aluminum and palm fiber alone since the boundary condition is changed from circular fixed support for aluminum and palm fiber only to foundation support due to palm fiber layer for hybrid specimen. The difference boundary conditions lead to the increasing of energy absorption of hybrid composite specimen compared to additional aluminum and palm fiber specimen individually.

The hybrid composite panel with 2 aluminum plates as skin will absorb more energy compared to the hybrid specimen having more plates but thinner skin with the same total of weight. It can be explained by the fact that thicker aluminum plate at the beginning of contact with the striker will absorb more energy compared to the thinner one. The remaining energy will be taken by the fiber as the second layer of panel where it will be smaller for the panel having thicker skin compared to thinner one.

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