Energy absorption performance of conical natural fiber reinforced composites

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Abstract

Natural fiber-reinforced composites have attracted increasing interest because of the advantages of fibers, such as low density, relatively high toughness, high strength and stiffness, good thermal properties and biodegradability. This present work used coconut coir as reinforcing tool in plastic composite. Different cone parameter and fiber volume fractions are produced and tested. The cone is compressed quasi-statically and force-displacement diagram is recorded for each case, then specific energy absorption performance is calculated and compared. It is shown that fiber volume fractions and cone parameter such vertex-angle, upper and lower diameter have controlled the cone performance. Most of the conical composites collapsed progressively under axial compressive loading.

Keywords: energy absorption, natural fiber, coconut coir, collapse mechanisms.

1.0 Introduction

The use of natural fiber such as oil-palm empty fruit bunch fiber, jute fiber or bamboo fiber as filler materials instead of glass and carbon fiber in reinforced composite can reduce the material cost significantly and at the same time yield high strength-to-weight ratio [1]. Car manufacturers have shown special interest in these materials for the replacement of glass fiber reinforced panels. The advantages of natural fibers over their traditional counterparts include, relatively low cost, low weight, less damage to processing equipment, improved surface finish of molded part, good relative mechanical properties. Another important advantage of natural fiber is that they are relatively abundant in nature and therefore can be obtained from renewable resources. The can also be recycled [2]. A comprehensive experimental investigation of the quasi-static axial crushing of hybrid and non-hybrid natural fiber/polyester composite solid cones between flat flattens has been carried out [3]. The composite solid cones were fabricated from two types of natural fiber namely oil palm fiber and coir fiber and different vortex angles carried from 0^0 to 60^0. In their study found that reinforcement type greatly affects the crashworthiness parameters for the natural fiber solid composites and an increase in cone vertex angles results in non-flatter load-deformation curves.

Basically, unidirectional fibers can support the compressive load which is applied in the longitudinal direction of the fibers. Crushing element under compressive load, therefore require unidirectional fibers. Usually, however, cracks within the fiber bundles occur easily in this material system. Hull [4] suggested the importance of the ratio of axial fibers to hoop fibers because crack in the unidirectional fibers are prevented by hoop fibers which can apply a radial compressive stress. The specific energy absorption (SEA) value is calculated from the mean crushing load, P the area of cross section, A and the density of the material, ρ as follows;

$$E_s = \frac{P}{A\rho} \qquad (1)$$

The units of E_s which express the crushing performance, therefore in kJ/kg. E_s values for various materials, including metallic materials are summarized in Table 1.

Table 1 SEA values of various materials [5]

Reinforcement	Matrix	E_s
Glass fiber	Epoxy	53.7
Aramid fiber	Epoxy	57.9
Carbon fiber	Epoxy	82.1
Steel		33.7
Aluminum		66.9

In this present work, coconut coir is used to reinforce the polyester resin. Quasi-static axial compressive tests are conducted on the conical composite with different vertex angles and fiber volume fractions. The compressive energy absorbed is discussed in relation with conical parameters and filler densities and collapsible mechanisms are also observed.

2.0 Experimental programs

Coconut coir fibers are obtained locally with random orientation and the length of fiber in average about 102mm with maximum diameter less than 0.5mm. Steel mould prepared with different vortex angles from 0^0 to 60^0. A 20mm space between two mould surfaces is prepared to fill the coir fiber. 20, 30 and 40% of volume fraction of fiber occupied into this space prior to pour polyester resin. Careful consideration emphasized in this stage in order to avoid any pore formation, to do this transparent outer mold is used to monitor the progressive filling polyester into the mold. The inside surfaces of both mould are covered by a layer of wax in order to make it easier to extract the cone from the moulds. The fabrication process is conducted in controlled environments; 25^0C, 50% relative humidity and after 24 hours the hardened composite is removed from the mould, this is because the composite would have enough time to shrink and fully hardened. Table 2 summarized the parameter involved in fabricating the conical specimens.

Table 2 The parameter involved in fabricating the conical specimens.

Degree, α	h(mm)	D_i (mm)		t(mm)
5	110	96	118	12
10	110	92	135	12
20	110	93	174	12

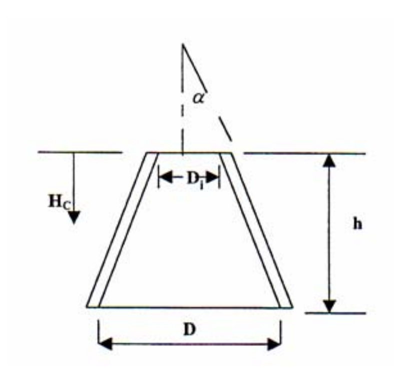

Figure 1 Geometry of the specimen

Quasi-static tests conducted on these conical composite with 1.5mm/min cross-head speed. The specimen is place between the two flat platens and the bottom surface is fixed in all degree of orientation. The specimens are aligned centrally so that the compressive load distributed uniformly. During the test, the collapsible mechanisms are captured in order to analyze the behavior of deformation. Composite cone are axially crushed between two parallel steel flat platens. The bottom platen is fitted with a load cell from which the load signal is taken directly to the computer. For each test, the crush load is plotted on the Y-axis and the crosshead displacement on the X-axis.

3.0 Results and discussion

Force-displacement curves obtained automatically from the universal testing machine. Fig. 2 – 4 show the force-displacement curves of different parameters of conical composites. Two primary regimens are observed in this work. First regime is an elastic deformation or a straight line curve and curve gradually changed indicating that the axial compressive loading increased due to conical wall moved inward of the cone and creating superb mass at the end of experiments. For cone with vertex angle 5^0, no significant difference detected between 30 and 40% fiber loading in term of force-displacement curves. At the same time when vertex angle increased, cone with vertex angle 10 and 40^0 experienced higher material stiffness compared with 5^0. Figure 5 pictured the sequence of conical composite deformations and it is progressively collapsed during compression. Referring to Fig. 2 – 4, conical composites behaved likely as ductile materials. For ductile fiber-reinforced composite materials and certain brittle fiber-reinforced composite materials, the material in the region of the crushing initiator plastically deforms and the tube crushes in a local buckling mode. While Fig. 5 – 6 shows initial damage is visible as a folding of the structure. Small cracking occurred around the folding sharp ends. The loads increased linearly with stroke until the initial damage. Then, the load increased sharply

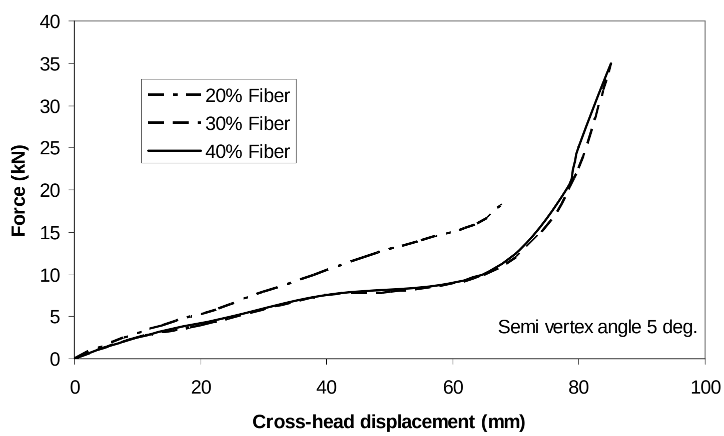

Figure 2 Force-displacement curves of conical composite with semi-vertex angle 5^0 with different fiber volume fractions.

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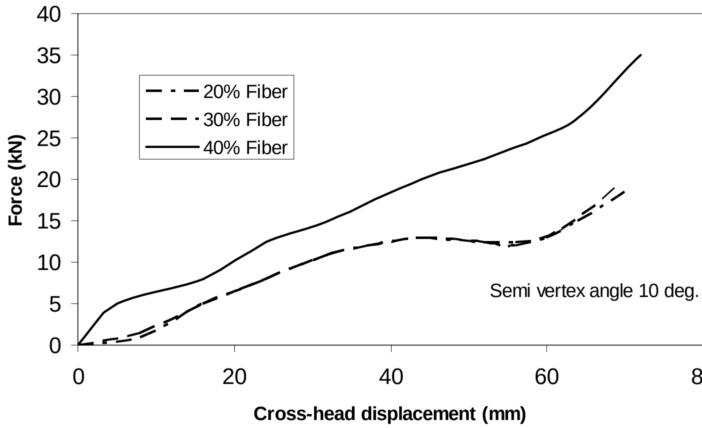

Figure 3 Force-displacement curves of conical composite with semi-vertex angle 10^0 with different fiber volume fractions.

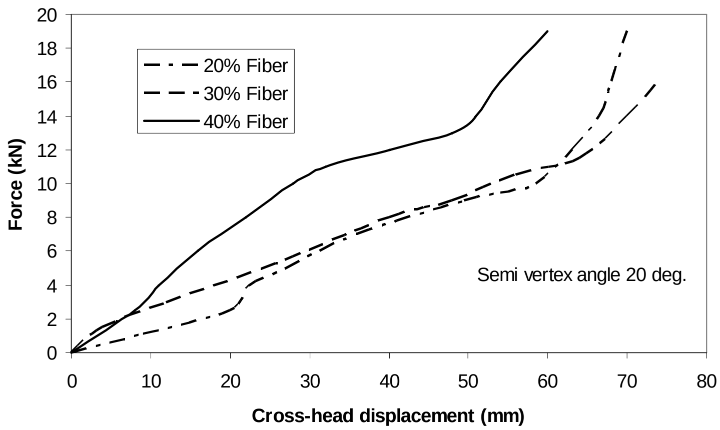

Figure 4 Force-displacement curves of conical composite with semi-vertex angle 20^0 with different fiber volume fractions.

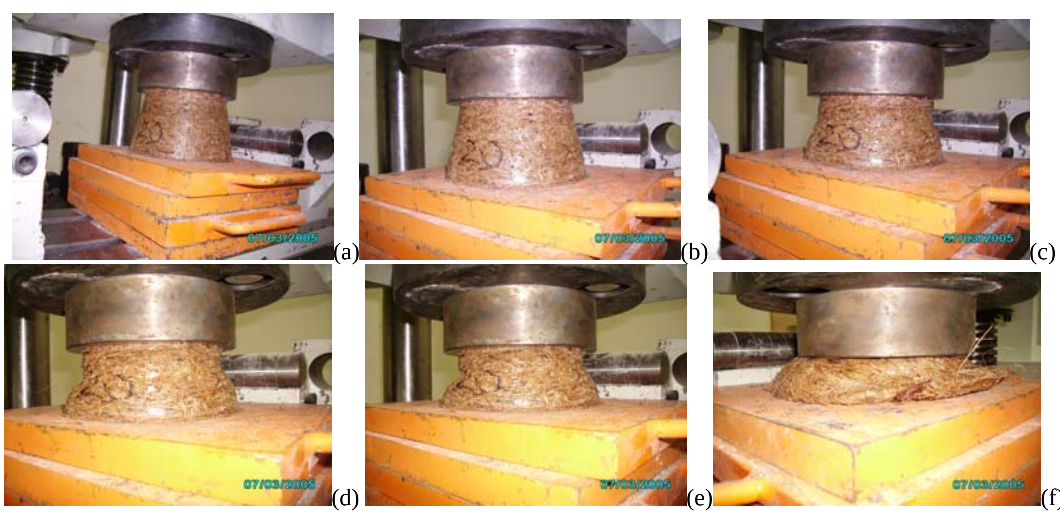

Figure 5 The sequence of cone deformations under axial compressive loading (vertex angle 5^0 and 20% fiber volume fraction).

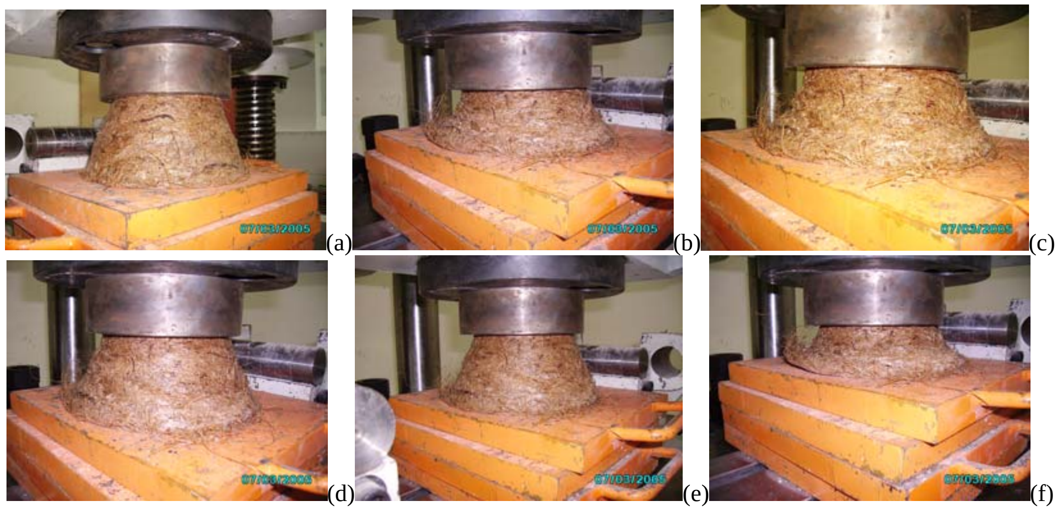

Figure 6 The sequence of cone deformations under axial compressive loading (vertex angle 20^0 and 40% fiber volume fraction).

Figure 7 summarized the effect of vertex angle and fiber volume fractions on specific energy absorption capabilities. Cones with semi-vertex angle 5 and 20^0 unable to sustain higher crushing energy than 10^0. For 40% fiber loading attained maximum energy absorption especially conical composite fabricated with 10 and 20^0 vertex angel and specific crushing energy increased gradually as fiber loading increased but it is not for cone with vertex angle 5^0.

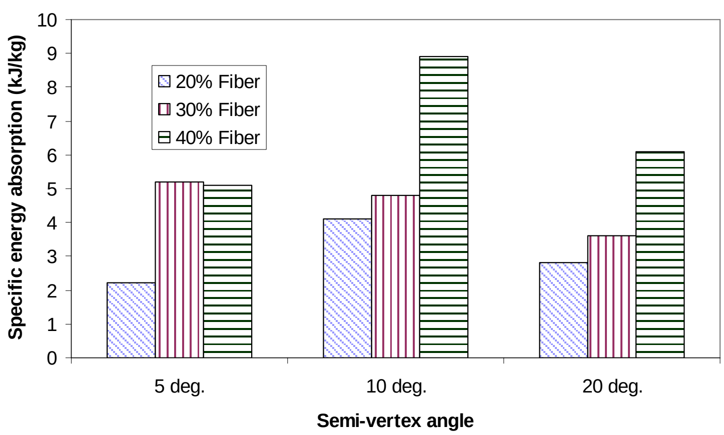

Figure 7 Specific energy absorption of conical composites.

4.0 Conclusion

Several conclusions can be drawn from this work;

a) Most of conical composites have collapsed in stable progressive manners.
b) Cones contained 40% fiber loading capable to absorb more quasi-static energy compared with others cones.
c) 10^0 vertex angle and 40% fiber loading cone absorbed maximum energy.
d) Averagely, increasing fiber loading increased capability to absorb more energy and vertex angles do not contributed absorbing more energy.

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