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Technical Report

Effect of geometry on crashworthiness parameters of natural kenaf fibre reinforced composite hexagonal tubes

M.F.M. Alkbir [a], S.M. Sapuan [b,*], A.A. Nuraini [a], M.R. Ishak [c]

[a] Department of Mechanical and Manufacturing Engineering, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia
[b] Laboratory of Biocomposites Technology, Institute of Tropical Forestry and Forest Product (INTROP), Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia
[c] Department of Aerospace Engineering, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia

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ABSTRACT

The effect of geometry on energy absorption capability and load-carrying capacity of natural kenaf fibre reinforced composite hexagonal tubes had been investigated experimentally. A series of experiments were carried out for composite hexagonal tubes with different angles from a range of 40–60° in 5° steps. This range is suitable for obtaining a regular hexagonal shape. Kenaf fibre mat form was used in this work due to several advantages such as low cost, no health risk, light weight and availability. The kenaf density was usage 0.17 g/cm^3 with thickness of 4 mm. Results demonstrated that structures failed in few distinct failure modes. Precisely in progressive failure mode and fragmentation failure associated with longitudinal cracks. The composite tube with $\beta = 60°$ exhibited local buckling failure mode and displayed the highest specific energy absorption capability equal to 9.2 J/g. On the other hand, new crashworthiness parameter has been introduced as catastrophic failure mode indicator (CFMI). Furthermore, typical load–deformation histories were presented and discussed.

1. Introduction

Safety is one of most pressing problems among values demand in vehicles such as cars, helicopter and trains. As a result of protective passengers from associate degree accidental collision is daily need. The automotive body, for instance, should possess high performance in protecting passengers, i.e. a high energy-absorption capability. Generally, two varieties of energy absorbers are used in automobiles; first, elements such as bumpers to absorb tiny impacts. Second, element such as facet beams to absorb large impacts in event of crash or collision, and the main purpose of crash absorber is to absorb the impact energy in a very controlled manner like that the passenger cell brought to rest without much damage [1,2]. Many studies have been carried out to determine the effects of various variables on energy absorption capability of composite material especially composite tubes such as geometry shape [3,4], fibre orientation stacking sequence [5,6], hybrid material [7,8], boundary conditions [9], and fibre reinforcement type [5,10],on the crashworthiness parameters.

Elgalai et al. [11], studied the effect of fibre type and corrugation angle on their crashworthiness performance. The results showed that the crushing behaviour of composite corrugated tube is found to be sensitive to the change in corrugation angle and fibre type. Alkateb et al. [12] examined experimentally the behaviour of composite elliptical thin walled cones subjected to quasi-static axial crushing. They concluded that the crushing behaviour of the elliptical cones is very sensitive to the change in the vertex angle. Natural fibres such as kenaf, bagasse, jute, ramie, oil palm and hemp have been a growing interest within last few years due to their advantage compared with synthetic fibres, such as renewable, low density, biodegradability, biodegradability, low cost. Also natural fibre composites have the potential to widely apply in energy absorption structure [13–17].

Recently few studies crash worthiness parameters in composite material tubes using natural fibres have been carried out. Eshkoor et al. [18] concluded that different trigger configurations can cause significant differences in the crashworthiness parameters and failure patterns of silk epoxy composite tubes. Ataollalhi et al. [19] studied the influence of the wall lengths on the compressive response and failure mode of natural silk/epoxy composite square tubes. They found that decrease in the length of tubes lead to increase the specific energy. Mahdi et al. [20] investigated experimentally the crushing behaviour of hybrid and non-hybrid natural fibre/polyester composite solid cones. Two types of natural fibre used (oil palm and coir fibre to fabricate sold cones with vertex angles varied from 0° to 60°. They pointed that sold cones greatly affects the crashworthiness for the natural fibre sold composite.

* Corresponding author. Tel.: +60 3 89466318; fax: +60 3 86567122.
E-mail addresses: alkbir74@yahoo.com (M.F.M. Alkbir), sapuan@upm.edu.my (S.M. Sapuan), nuraini@upm.edu.my (A.A. Nuraini), mohdridzwan@upm.edu.my (M.R. Ishak).

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Nomenclature

A	cross-sectional are of hexagonal tube (m^2)	CFMI	catastrophic failure mode indictor (%)
A, b, c, t	dimension of hexagonal tube (mm)	β	hexagonal angle (°)
CFE	Crush Force Efficiency (–)	P_{cr}	critical crushing load (kN)
E_S	specific energy absorption (J/g)	P_i	initial crushing load (kN)
IFI	initial failure indicator (–)	P_m	mean-crushing load (kN)
m	weight of the specimens (kg)		

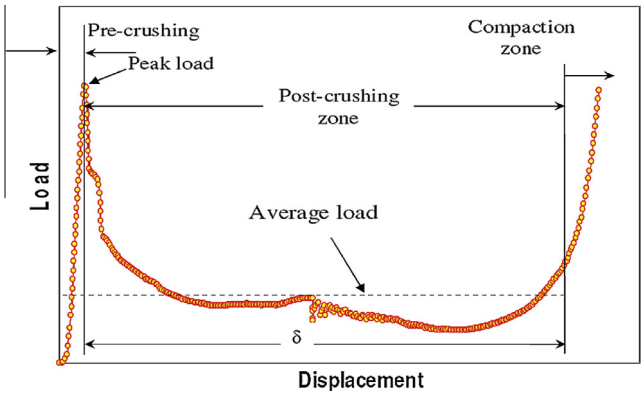

Fig. 1. Typical load displacement curve [19].

Fig. 2. Non-woven (mat) natural kenaf fibre.

In this paper, inclusive experimental work was implemented to study the response of non-woven kenaf fibre/epoxy composite hexagonal tubes to quasi-static axial compressive load.

2. Crashworthiness parameters in composite shell

The ability to absorb impact energy and be survivable for the occupant is called the "crashworthiness" of the structure. Crashworthiness is concerned with the absorption of energy through controlled failure mechanisms and modes that enable the maintenance of a gradual decay in the load profile during absorption.

The crashworthiness parameter can be evaluated by knowing the following:

2.1. Initial peak load (P_i)

The initial crushing load can be obtained directly from the load–displacement response:

2.2. Mean-crushing load(P_m)

The average crushing load can be obtained by averaging the crushing load values over the crush displacement through the post-rush region.

2.3. Crush Force Efficiency (CFE)

It is the ratio between mean crush load and initial crush load. It is calculated as:

$$\mathrm{CFE} = \frac{P_i}{P_m} \tag{1}$$

Fig. 3. Fabrication steps.