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Effect of fibre orientations on the mechanical properties of kenaf–aramid hybrid composites for spall-liner application

R. YAHAYA [a,b], S.M. SAPUAN [a,c,d,*], M. JAWAID [c,e], Z. LEMAN [a], E.S. ZAINUDIN [a,c]

[a] *Department of Mechanical and Manufacturing Engineering, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia*
[b] *Science and Technology Research Institute for Defence (STRIDE), 43000 Kajang, Selangor, Malaysia*
[c] *Laboratory of Biocomposite Technology, Institute of Tropical Forestry and Forest Products (INTROP), Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia*
[d] *Aerospace Manufacturing Research Centre (AMRC), Faculty of Engineering, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia*
[e] *Department of Chemical Engineering, College of Engineering, King Saud University, Riyadh, Saudi Arabia*

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Abstract

This paper presents the effect of kenaf fibre orientation on the mechanical properties of kenaf–aramid hybrid composites for military vehicle's spall liner application. It was observed that the tensile strength of woven kenaf hybrid composite is almost 20.78% and 43.55% higher than that of UD and mat samples respectively. Charpy impact strength of woven kenaf composites is 19.78% and 52.07% higher than that of UD and mat kenaf hybrid composites respectively. Morphological examinations were carried out using scanning electron microscopy. The results of this study indicate that using kenaf in the form of woven structure could produce a hybrid composite material with high tensile strength and impact resistance properties.

Keywords: Hybrid composites; Spall-liner; Aramid fibre; Porosity; Mechanical testing

1. Introduction

The search for alternative fibres as a replacement for man-made fibres has had continued. The well-known advantages of natural fibres are low density, low cost, its availability, renewability, ease of production, low process energy, non-abrasive, good acoustic property, acceptable specific strength and modulus, low cost, easily available, and easy recyclability [1–5]. However, there are some limitations which required further improvement such as its moisture absorption due to hydrophobicity, dimensional stability and poor wettability, low thermal stability during processing and its poor adhesion with synthetic fibres [5,6]. The combination of two or more natural and synthetic fibres into a single matrix has led to the development of hybrid composites [7]. Natural–synthetic fibre hybrid composites are increasingly used in a wide range of applications [8]. The advantages of hybridisation are fully utilised to reduce the use of synthetic fibres which are generally non-environmentally friendly. Hybrid composites can be made from artificial fibres, natural fibres and with a combination of both artificial and natural fibres [9].

Kenaf fibres (*Hibiscus cannabinus L.*) have a potential as an alternative for partial replacement of conventional materials or synthetic fibres as reinforcement in composites [10]. It is reported in the literature that kenaf are already being used in hybrid form with synthetic materials such as glass [8,11–13], carbon [14], and polyethylene terephthalate (PET) [15]. Aramid is one of the synthetic fibres used in hybrid composites. Aramid fibres are a class of heat-resistant and strong synthetic fibres which are widely used in aerospace and military applications, for ballistic rated body armour fabric and ballistic composites. Para-aramid fibre (Kevlar) is one of the commercially available aramid fibres and provides a unique combination of toughness, extra high tenacity and modulus, and thermal stability [16]. Kenaf–Kevlar hybridisation for defence application was reported in Refs. [17,18].

There are factors that influence the properties of kenaf hybrid composites. One of the factors is the hybrid types

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* Corresponding author. Tel.: +603 89466318.
E-mail address: sapuan@upm.edu.my (S.M. SAPUAN).

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(inner-laminar and interlaminar) [19]. Pearce et al. [20] relates the architecture and permeability of the fabrics and mechanical properties of woven carbon-fibre fabrics reinforced epoxy composites. Khan et al. [21] studied the influence of woven structure and direction on the mechanical properties, i.e. tensile, flexural and impact properties. It was reported that the mechanical properties of untreated woven jute composite (in warp direction) were improved compared with the non-woven. Azrin Hani et al. [22] studied the mechanical analysis of woven coir and kenaf natural fibres. They found that the structure used as a composite reinforcement in turn produced better mechanical properties. Pothan et al. [23] studied composites of woven sisal and polyester using three different weave architectures (plain, twill and matt) with special reference to resin viscosity, applied pressure, weave architecture, and fibre surface modification. This study provided detailed information on the effect of weaving, architecture and fibre content on the mechanical properties of the hybrid composites. Karahan et al. [24] observed the decrease in the mechanical properties of carbon–epoxy composites as a result of weaving structure. Karahan et al. [25] determined the effect of weaving structure and hybridisation on the low velocity impact properties of carbon–epoxy composites. It was reported that the best result obtained from twill woven composite with the energy absorption capacity was increased by around 9–10% with hybridisation. Alavudeen et al. [26] studied the effect of weaving patterns and random orientation on the mechanical properties of banana, kenaf, and banana/kenaf fibre-reinforced hybrid polyester composites. They found that the plain type showed improved tensile properties compared to the twill type in all the fabricated composites.

Based on the literature studies, it was found that mechanical properties of kenaf–aramid hybrid composites were not reported. The present study aimed to evaluate the mechanical performance of kenaf–aramid hybrid composites for spall-liner application. Since the properties of a composite are often determined by the properties of the components and the fraction of inclusions [27], there is a requirement to study the effect of fibre properties in hybrid composite. In this study, the effects of kenaf fibre orientation on the physical and mechanical properties of kenaf–Kevlar hybrid laminate composites were studied. The kenaf fibres and Kevlar were arranged in similar sequences to prepare the hybrid laminated composites. The kenaf tested are in the form of woven and non-woven structures. The effects of the fibre content and its morphology were also analysed.

2. Materials and methods

2.1. Materials

Aramid fabric used in this study is the plain weaved structure Kevlar 129. Three types of kenaf fibres were used in this study: woven, unidirectional and mat. The woven kenaf was produced by the interlacement of warp and weft yarns by using table loom. The yarns were obtained from local suppliers, Innovative Pultrusion Sdn Bhd. The unidirectional samples consist of kenaf yarn (800 tex) cross plied at 0°/90°. No chemical treatment was conducted on the kenaf fibres prior to this study. The resin used in this study is DER 331 liquid epoxy with a density of 1.08 g/m^3. The resin was cured using joint mine type (905-3S), cycloaliphatic amines.

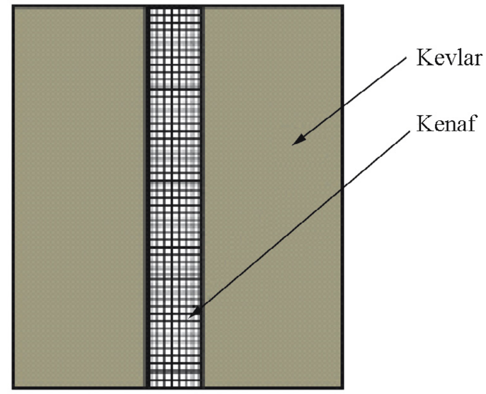

Fig. 1. Illustration of kenaf–Kevlar hybrid composites.

2.2. Fabrication of composite laminates

Hand lay-up method was adopted to fabricate laminates of Kevlar 129 and kenaf in epoxy resin. The specimen consists of six layers of Kevlar with the kenaf fibres in the middle as shown in Fig. 1. Kenaf and Kevlar fabric were hand lay-up with the epoxy matrix by mixing epoxy resin (DER 331) and amine hardener in the ratio of 2:1. Two thick mild steel plates are used as a mould (20 × 20 cm) in the fabrication process. All the mould surfaces were sprayed with a mould release agent to prevent adhesion of composites to the mould after curing and also to ensure smooth sample surface. Composites were cured by applying compression pressure using dead weights on the top of the mould and cured at room temperature for 24 hours. The specimens were also post-cured at 70 °C for 2 hours after removing from the mould. The composition of hybrid composites is shown in Table 1.

2.3. Density and void contents

The density of the hybrid laminates was measured according to the ASTM D792 standards. Rectangular samples with size of 10 mm × 10 mm were used. Distilled water at room temperature was used as the immersion fluid and the mass was measured using a digital balance with a 10^{-3} g resolution. Five specimens were tested and an average was taken. To analyse the void percentage in the composite laminates, the ASTM D2734 standard was used. The void content was determined from the

Table 1
Hybrid composite formulation.

Designation	Composition
Woven (W)	One layer of woven kenaf (10.46 vol %) + woven Kevlar (21.2 vol %) + Epoxy
Unidirectional (UD)	One layer of 0°/90° kenaf yarn (16.51 vol %) + woven Kevlar (16.78 vol %) + Epoxy
Mat (M)	One layer of non-woven kenaf mat (9.57 vol %) + woven Kevlar (21.39 vol %) + Epoxy