Jurnal
Teknologi

Full Paper

IMPACT ENERGY AND DUCTILITY INDEX OF KEVLAR REINFORCEMENT WITH KENAF POLYESTER COMPOSITE

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Article history
Received
15 February 2015
Received in revised form
5 April 2015
Accepted
31 May 2015

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Graphical abstract

Abstract

This research focuses on the reinforcement of Kevlar in treated kenaf composite, specifically in the study of impact properties as well as the characteristics. The kenaf was treated with 6% Sodium Hydroxide (NaOH) solution at a specific period of time before being made into laminates. Impact test was conducted using an instrumented drop tower device at 36J level according to the standard ASTM D7136. Microstructures of the fractured specimens were also analyzed. The results of the study indicated that treated kenaf/Kevlar hybrid composite has better impact absorption energy than pure kenaf composite. Compared to the pure kenaf composite, the hybrid composite absorbs more impact energy and appears to have lower impact damage at the same impact energy level. This is because the Kevlar fibres play an important role to prevent and delay the destruction of composites.

Keywords: Kenaf, epoxy, polyester, impact, tensile, treatment

1.0 INTRODUCTION

Ecological problem is one of the major concerns in the industrial world nowadays. From the process of obtaining the raw material to the manufacturing and production stage then till the end use of a product, the effect on the environment and ecology is an issue to be taken into account. In any manufacturing industry, the process of transforming raw material into components and parts involves some process that can harm the environment, as well as the material degradability at the end of the day later on. Researches had been done recently with regards to those problems by trying to use naturally degradable composites such as natural fibres to substitute the widely used metal base material, but the huge wall to climb is the nature of these natural fibres have limited strength in mechanical properties [1].

The main challenge in this study is to come out with a new material, which is hybrid composite with appropriate mechanical properties which can be used in place of metal based material in the car door panel of automotive industry or other industries involving moderate impact and tensile performance.
Hybrid composite is the combination of two or more different type of fibres in the same matrix [2]. The aim is to obtain variety in mechanical properties in a single composite. Theoretically, it is accomplished by the combination of the properties of the build-up fibres. Hybrid composite provides options to obtain composite with good properties at minimum cost by reinforcing synthetic fibre with natural fibre [3]. Reinforcement will usually improve the properties of single fibre composite, whereas the selection of natural fibre is to minimize the dependence on synthetic fibre which has high cost [4]. Hybrid composite is the optimization of mechanical properties of composite at relevant cost.

Due to the low mechanical impact properties of the natural fibres likes kenaf, they are impossible to be used as the primary material in automotive component manufacturing and other industries that involve high impact and tensile performance [5].
Kenaf fibre's resistance to impact loading is very low and therefore reinforcing it with other material such as high impact Kevlar is encouraged. An appropriate volume fraction of both materials is needed to get the best impact behaviour of hybrid material.

2.0 EXPERIMENTAL

2.1 Materials

Kenaf fibres were supplied by Pultration Sdn. Bhd. Woven Kevlar was supplied by MyCond Sdn. Bhd. Woven Kevlar was used as the reinforcement to the kenaf fibre. Unsaturated polyester resin with hardener Methly ethyl kethone peroxide (MEKP) was obtained from local sources Monstrong (M) Sdn. Bhd.

2.2 Treatment of Kenaf Fibre

Kenaf fibres were treated with 6% concentration of sodium hydroxide solution (NaOH) and soaked for 12 hours. The treated fibres were then be cleaned up by using distilled water. After washing, the fibres were kept under the sun for 2 days.

2.3 Samples Fabrication

Fig.1 shows the manufacturing process of hybrid composite. Long Kenaf fibres were arranged at 0° direction by using hand lay-up technique in uniform orientation in the mold. They were coated with the matrix resin. The matrix resin was made by mixing the general purpose polyester resin and MEKP hardener mixture at weight ratio of 46.5:1 as given by manufacturer. After the pouring process done, the mold was closed using top plate that made by cast iron to prevent the dust or dirt from entering into composites during the curing time. After that the mold was cold pressed at approximately 10kN load and hold for 20 mins for polyester at room temperature. Finally, the successful specimens were cured for two days at room temperature. All the specimens were divided into 3 groups; kenaf composite (100% treated kenaf fibre), Kevlar composite (100% Kevlar) and kenaf/Kevlar hybrid composite (50% kenaf fibre/50% Kevlar).

2.4 Hardness Test

Hardness test was completed by using Instron Series 600 Rockwell Model A654R accordance to the standard ASTM D2240. To ensure the persistence of the result, an average of 5 readings was taken at different points on a sample.

2.5 Impact Testing

Impact test was conducted by using an instrumented drop weight test system (DYNATUP 9250). The samples were made in size 100 mm x 100 mm x 5 mm according to the standard ASTM D7136. The impact energy given was 36J.

The impact strength of the specimen can be determined by using formula ductility index (DI) [6]. The ductility index was determined from Equation (1),

$$\text{Ductilty index (DI)} = \frac{\text{Total Energy} - \text{Energy to maximum load}}{\text{Energy to maximum load}} \quad \textbf{(1)}$$

2.6 Microsturucture Observation

The fracture surfaces of the samples were analyzed via a Stereo-zoom Microscope. The microscope was using IMAP software to enlarge the image of the specimen in order to investigate the fibre dispersion and fibre-matrix characteristic on the fracture surface.

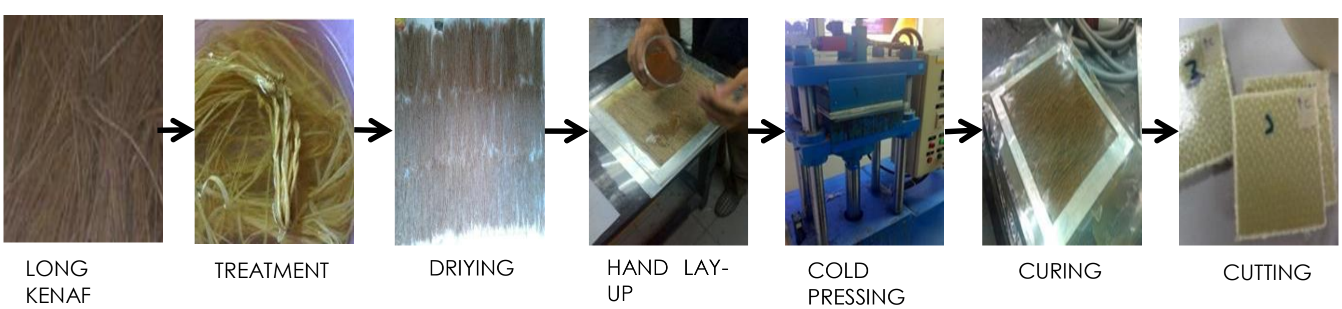

Figure 1 Process for the hybrid composites fabrication.

3.0 RESULTS AND DISCUSSION

Fig. 2 shows the graph of hardness value of kenaf composite, Kevlar composite and kenaf/Kevlar hybrid composite. Based on the bar graph, the value of hardness increased when the Kevlar was reinforced in kenaf composite. In comparison with the previous study [7], the Kevlar has higher hardness compared to natural fibre. Kevlar fibre is five times stronger than the steel in air [8]. Therefore, hybridization of kenaf and Kevlar presented better hardness than using kenaf fibres only. It seems that reducing 50% Kevlar fibre in the hybrid composites only slightly reduced about 10% hardness of pure Kevlar composites.

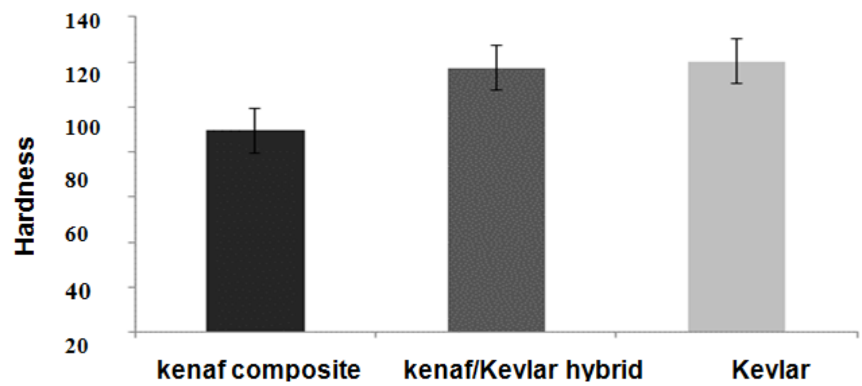

Figure 2 Hardness results

Table 1 Ductility Index for composites

COMPOSITION	PEAK LOAD (kN)	TOTAL ENERGY (J)	ENERGY TO MAX LOAD (J)	DUCTILITY INDEX (DI)	COST (USD/kg)
kenaf composite	1.10	5.09	2.38	1.14	5-15
kenaf/Kevlar hybrid	4.88	29.78	9.77	2.05	30-40
Kevlar composite	4.96	31.71	10.53	2.01	50-60

Ductitlity index (DI) for all samples from Equation (1) were indicated in Table 1. Low ductility index is an indication of the brittle material composite. Kenaf composite has the lowest hardness and ductility index, this means that kenaf composite is brittle than others. Kenaf composite also has much lesser load energy to failure and ductility. The low DI value for kenaf composite is resulted by low energy absorbed capability of kenaf fibres. Therefore the brittleness of the composite will lead to reduction in impact energy [9]. The total energy of hybrid composite is about 29.78J. The value is higher compared to pure kenaf composite without Kevlar. The addition of 50 % Kevlar into 50% kenaf fibre contributed higher impact energy of the specimen. The load of this hybrid composite mainly attributes to the kenaf fibre pull out and creation of the fibre-matrix new interface. This means that Kevlar can withstand with higher load and absorb more the sudden impact load thus enhanced the impact strength.

Combining materials in composites manufacturing can optimize the overall performance of the final product. The most interesting aspect about kenaf/Kevlar hybrid composite is their lower cost, which is reduced almost 30% of the cost from pure Kevlar composite. The advantage of using hybrid composite is the product performance can be improved although the quantity of Kevlar usage is minimized.

Fig.3 shows the kenaf composite creates a clearer damage formation when it is subjected to 36J of impact energy. A round deep shape crack occurs at the point of impact location. This cracks revealed that the composites consisting 100% treated kenaf fiber has less strength and less ability to absorb energy. The polyester matrix tents to break first before the reinforcement (kenaf fiber). The total energy of 36J allowed total full penetration to kenaf composite samples. When comparing between those Kevlar composite in Fig. 4 and kenaf/Kevlar hybrid composite in Fig. 5, the figures show that no significance differences in energy absorbed and penetration profile. This microstructure analysis of both composites proved that the hybrid composite has higher strength in perpendicular or normal direction compared to kenaf composite [10]. It is also observed that the impact energy absorption is improved when Kevlar is added. In this hybrid composite, Kevlar fibers act as the strength contributor, while the matrix acts as the binder that binds or holds fibers together This fibres-matrix combination contributes higher impact strength than kenaf fibre alone. Wide hole penetration damage in Fig. 3 shows that the kenaf composite structures reaching limit load or fail load path, making this very rare combination for impact test events. Meanwhile, for the case defects in Kevlar composite and kenaf/Kevlar hybrid composite (Fig. 4 and 5), small penetration is occurred with matrix cracking and fibre fracture. It was observed that sample in fig. 3, 4 and 5 reveals different damage pattern as the amount of Kevlar fibre loading increased, the size geometries of the crack decreased. It can be seen that there is a large increment in the energy impact absorption in the hybrid composite compared with the kenaf composite (Table 1). This proved that the addition of Kevlar fibre into kenaf composite can improve energy absorption capability because Kevlar resists the high impact energy and protected the kenaf fibre from breakage.

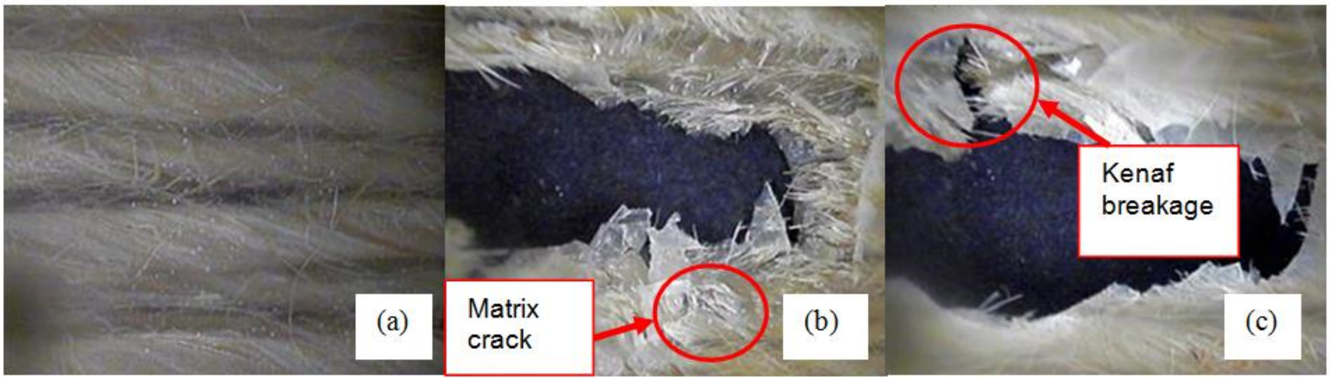

Figure 3 Damage pattern in kenaf composite (a) before impact test, (b) front impacted surface and (c) back impacted surface

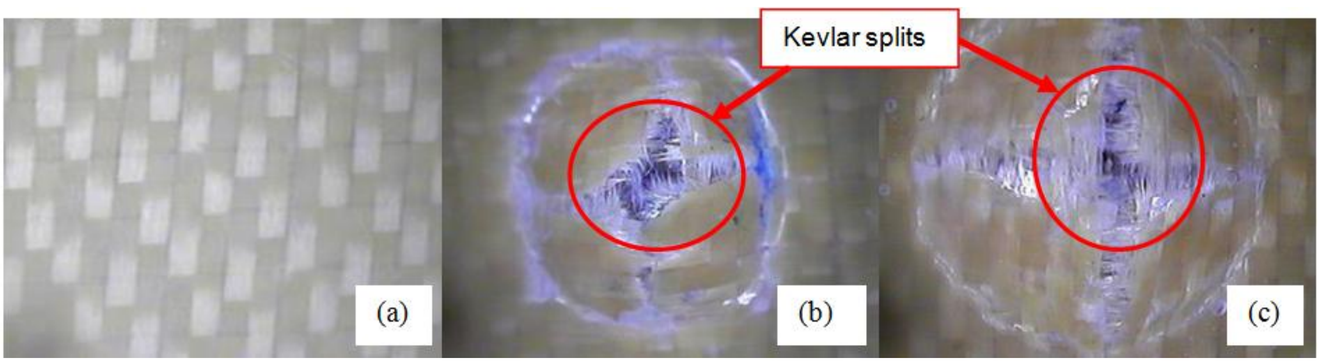

Figure 4 Damage pattern in Kevlar composite (a) before impact test, (b) front impacted surface and (c) back impacted surface

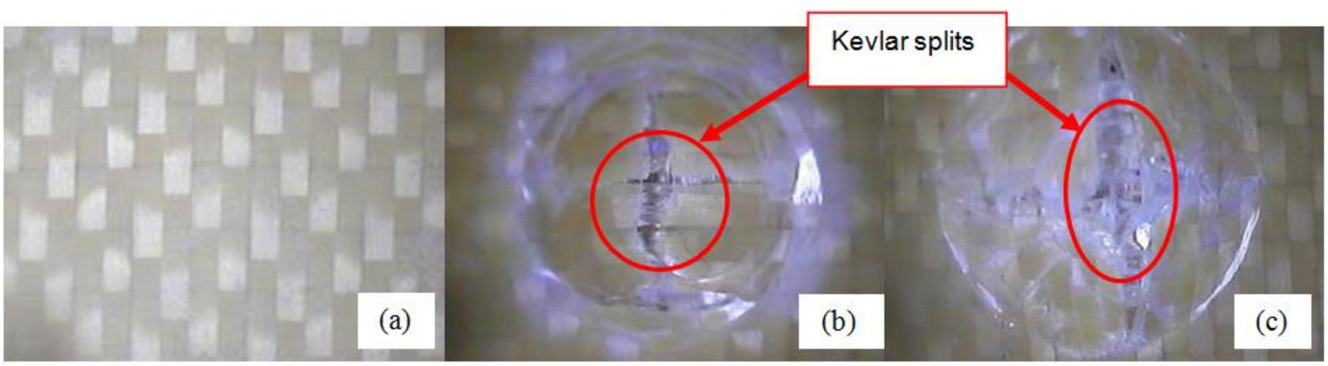

Figure 5 Damage pattern in kenaf/Kevlar hybrid composite (a) before impact test, (b) front impacted surface and (c) back impacted surface.

4.0 CONCLUSION

The Kenaf/Kevlar hybrid composite showed better impact energy absorption and higher ductility index than kenaf composite. From the microstructure observed, kenaf composite showed that the matrix tends to break first before the kenaf fibre was penetrated. The total energy with the addition of Kevlar contributed to the higher impact energy compared to the composite without Kevlar. It was proven that by hybridization of Kevlar into the kenaf composite, improved significantly the impact properties and ductility. Hence, the hybrid composite was recommended as the most economical and effective combination.

Acknowledgement

The authors would like to thank Research Management Institute (RMI) UiTM and Ministry of Higher Education Malaysia for financial supports. The research is conducted at Faculty of Mechanical Engineering,Universiti Teknologi MARA (UiTM), Malaysia under support Grant 600-RMI/ERGS 5/3 (24/2013). Noor Haznida Bakar would like to acknowledge the Department of Polytechnic Education (DPE) and Ministry of Education (MOE) for funding her PhD scholarship.

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