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Residual tensile stress of kenaf polyester and kenaf hybrid under post impact and open hole tensile

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Abstract

Natural fibres have emerged as the potential reinforcement material for composites and have thus gained an attraction by many researchers. This is mainly due to their applicable benefits as they are light weight and offer low cost compared to synthetic fibre composites. Kenaf fibres recently have been a substitute material in many weight-critical applications in areas such as aerospace, automotive and other high demanding industrial sectors. In this study, natural fibre kenaf composites and kenaf/fibreglass hybrid composites were fabricated by a combination of hand lay-up and cold-press methods. The post impact tensile and open hole tensile of long kenaf fibre composites with and without the addition of fibreglass were further studied. The fracture behaviour verified qualitatively via scanning electron microscopy. A significant improvement in tensile strength and modulus were indicated by the introduction of long kenaf/woven fibreglass hybrid composite. Investigation on the tensile and low velocity impact of kenaf composites and kenaf/fibreglass reinforced polyester resin composites revealed that the composites were seriously impaired when a low energy impact was applied. The tensile strength of open hole long kenaf composites was more notch sensitive than long kenaf/woven glass hybrid composite. Although the hybrid composite was stronger than pure kenaf composites, the damage progression mechanisms in the two materials were very similar. In the above case the polymer matrix failed initially. It is followed by fibre matrix debonding and finally ending in fibre ruptures or pull-outs.

Keywords: Kenaf composite; kenaf hybrid composite; residual tensile stress

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1. Introduction

Natural fibre composites have been popular interest in composite applications over the past few decades. This kind of composites give many advantages compared to synthetic fibres, such as low density, cheaper cost, availability, and biodegradability [1] and low tool wear [2]. This natural fibre composite also have a higher specific strength than glass fibre and a similar specific modulus [3]. With all this advantages and cheaper sources, these natural fibres tentatively offer wanted specific strengths and modulus, at a lower cost. Bast fibres such as sisal, kenaf, flax, jute, and hemp are the most common natural plants used in applications. Natural fibre cannot stand alone to suit in the heavy application, thus it is suggested to hybrid with other synthetic fibre such as fibreglass to strenghten the material. Many researchers also reported that the natural composite material only can sustained at low loading ranging between 20 -30% from its strength before failure. The composite will start induce widespread surface delamination damage and consequently reduce the material strength and lead serious damages such as matrix crack, delamination and fibre breakage [4-7]. Unexpected impact can really happen during fabrication such as dropped tool or flying debris which will damage to the composites since natural fibre is too sensitive due to impact. Thus, it is important to know how the post impact will affect the strength and performance of the structure. The drilling induced damage will direct affect the in service performance of the composite products with drilled holes. Therefore, the open hole tensile properties of composite is important to be studied. The effect of the presence of the hole can lead to the poor strength if compared with an composite without hole making.

The fibreglass is incorporated into kenaf composite in this study to improve the impact and strength of final product. Based on the optimum post impact tensile strength and open hole tensile, the effect of fibreglass reinforcement will be recommended for further development of kenaf hybrid composites.

2. Sample Preparation

Kenaf polyester and kenaf hybrid polyester were fabricated by combination of hand lay-up and cold press method as reported in ref [8]. Fibres compositions are set to be 20% volume fraction of kenaf and 7 % volume fraction of fibreglass. A mechanical extensometer with gauge length of 25mm was used to measure the strain in the samples during all the tests. The extensometer was attached at the middle of the sample. The test was then conducted with the cross head moving at the rate of 1mm/min. Tensile test specimens were followed the test procedure according to BS EN ISO 527 (1997). For post impact tensile specimen, an impactor with a hemispherical nose of diameter 12.7mm was used as the drop weight. The samples were subjected to a low energy impact of 1J – 4J for long kenaf composites whereas 1J – 16J for long kenaf/woven fibreglass composite. To prepare an open hole tensile specimen, the hole was made using a vertical hole drill machine with diameter sizes (D) 1mm, 4mm, 6mm, 8mm, 12mm and 16mm for both long kenaf composites and long kenaf/woven glass composites. The standard dimensions of the samples used in tensile and post impact tensile were similar. Both types of specimens having dimension of 200 mm x 250 mm, as following the standard BS EN ISO 527 (1997). The surface fracture of kenaf composite and kenaf hybrid composite were then observed using a SUPRA 40 VP (Carl Zeiss) Field Emission Scanning Electron Microscope (FESEM).

3. Results and Discussion

The effect of low impact on the residual tensile strength of the kenaf composite is shown in Table 1. Each value represents the average data taken from of five samples for each testing. The SD values are standard deviations. The results showed that the residual tensile stress was reduced by the impact energy. The composites were shown to have lost almost 57% of their tensile strength after impact at 4J. The effect of low energy impact on tensile modulus of the kenaf composite is also tabulated in Table 1. The tensile modulus declines gradually as the impact energy on the specimen is increased. Composites lost almost 45% of their tensile modulus after experienced the impact energy of 4J. Following an impact at 4J energy, kenaf fibre composites lost almost 70% of their intrinsic strength and stiffness. As a comparison, the kenaf hybrid composites residual tensile strength and modulus are shown in Table. 2. The residual tensile strength and modulus decreased gradually as impact energy levels increases.

The hybrid composites exhibits the same trend but better properties compared to the kenaf composite. They were able to endure an impact of 16J energy for 70% reduction in their intrinsic strength and stiffness. The superior tensile properties of kenaf hybrid composite were expected to result in better impact resistance of composites having fibreglass as a skin and kenaf as a core. The similar finding was reported on flax-glass fibre hybrid composites when impacted on the glass side [9].

Table 1. Tensile strength and tensile modulus of kenaf composite after post impact tensile testing.

Kenaf composite	Tensile Strength (MPa)		Tensile Modolus (GPa)	
	Average	SD	Average	SD
0J	74.3	3.63	7.31	0.53
1J	72.21	6.49	6.14	0.70
2J	52.63	6.31	4.62	0.82
3J	39.53	5.47	3.97	0.69
4J	37.42	5.53	3.54	0.65

Table 2. Tensile strength and tensile modulus of kenaf/fibreglass hybrid composite post impact tensile.

Hybrid composite	Tensile Strength (MPa)		Tensile Modolus (GPa)	
	Average	SD	Average	SD
0J	130.72	4.63	8.36	0.48
1J	118.54	6.10	7.64	0.94
2J	115.05	3.03	7.52	0.60
3J	112.77	2.14	7.49	0.68
4J	108.48	6.27	7.39	0.33
5J	102.11	6.40	7.29	0.36
6J	86.74	6.74	6.78	0.74
8J	70.81	6.07	6.21	0.56
10J	67.53	6.09	5.04	0.40
12J	46.46	3.61	4.26	0.20
14J	48.27	5.04	3.36	0.41
16J	48.79	6.14	3.15	0.44

Theoretically, by increasing the impact energy levels, the modulus and residual tensile strength shoud be reduced. The kenaf composite tested for low-energy impact in this research showed lower impact damage tolerance as compared to a hybrid [10]. The composite fracture was contributed mostly by the fibre strength rather than the matrix strength. This means fibreglass helps in improving the reinforcing effect to matrix. The work carried out therefore showed kenaf hybrid composites displayed similar properties to metallic materials with fewer effects on impact compared to its kenaf composite counterpart.

Fig. 1 illustrates improved residual strength sensitivity of the kenaf hybrid composites as compared to kenaf composites. The strength sensitivity is indicated by the slope of normalised residual tensile strength. The long kenaf composites are almost 73% more sensitive than the hybrid composite.

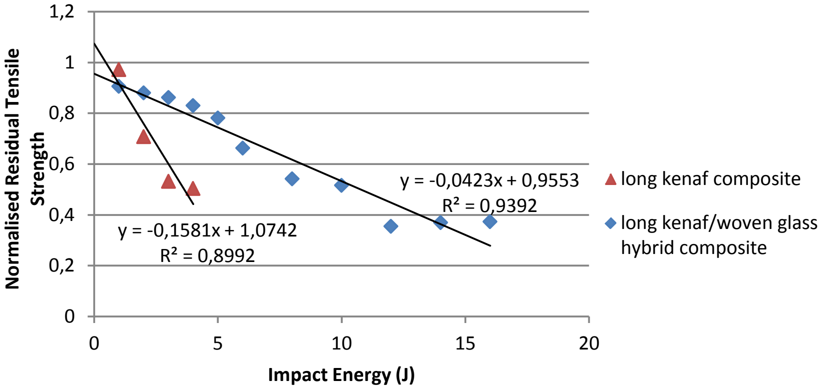

Fig. 1. Comparison of normalised residual tensile strength of long kenaf composite and long kenaf/woven hybrid composite after post impact tensile.

Mechanical properties of open hole kenaf composites and kenaf hybrid composite are shown in Tables 3 and Table 4 respectively. The results showed a decrease in tensile strength when the size of hole increased. The composites lost about sixty percent (60%) of their tensile strength when the hole diameter is greater than 8 mm. The notch sensitivity of composite laminates have been studied [11-12]. For small hole diameter, the stress can be distributed to larger sections of the cross-section. For larger holes the damage zone extend to a greater portion of the ligament hence less remaining region to support the stress [13]

The damage mechanism of the open hole tensile can be postulated as follows. As the load is increased, damage initiates near the hole due to stress concentration, it then propagates and is confined within a certain region near the hole site as the strain or stress reaches a certain value.

Table 3. Tensile strength and tensile modulus of kenaf composite open hole tensile.

	Tensile Strength (MPa)		Tensile Modulus (GPa)	
Kenaf composite	Average	SD	Average	SD
Unnotched	74.30	1.63	7.31	0.53
H 1mm	72.87	3.31	5.73	0.27
H 4mm	45.17	0.57	3.69	0.13
H 6mm	43.62	2.35	3.72	0.46
H 8mm	30.45	2.04	2.75	0.20
H 12mm	29.36	1.59	1.96	0.40
H 16mm	18.01	1.07	1.64	0.40

Table 4. Tensile strength and tensile modulus of kenaf hybrid composite after open hole tensile.

Kenaf hybrid composite	Tensile Strength (MPa)		Tensile Modolus (GPa)	
	Average	SD	Average	SD
Unnotched	130.72	4.63	8.36	0.48
H 1mm	110.29	5.66	7.24	0.41
H 4mm	68.33	2.30	5.79	0.42
H 6mm	67.07	5.80	5.18	0.32
H 8mm	60.48	5.03	4.40	0.79
H 12mm	39.29	5.22	2.44	0.33
H 16mm	28.30	4.24	1.69	0.30

Open hole tensile behaviour of both kenaf and kenaf hybrid composites can be illustrated using their normalized values. Fig. 2 shows the normalized strength versus hole size for both composites. It is obvious that the kenaf composites are more notch sensitivity than the hybrid composites by about 25%, although not that significant.

The modulus degradation and residual strength of the composite reduces as the holes increased. Failure initiates at the periphery of the holes perpendicular to the loading direction. In kenaf composites the tensile strength and modulus reduced by about 59% and 62% respectively. While, for kenaf hybrid composites the tensile strength and modulus reduced by about 54% and 47% respectively with a hole size greater than 8 mm for the both cases. The polymer matrix fails initially with a cracking sound followed by fibre–matrix debonding. Thereafter, the progressive shear damage takes place around the hole with increasing time steps.

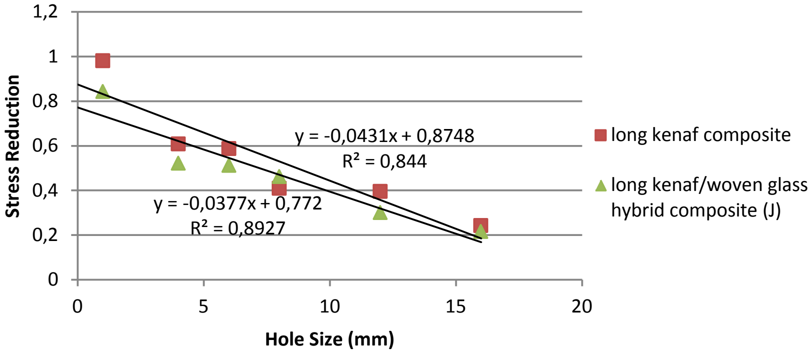

Fig. 2. Comparison of normalised residual tensile strength of kenaf composite and kenaf hybrid composite after open hole tensile.

The scanning electron micrograph of the fracture surface of kenaf composite is depicted in Fig.3. This figure illustrates the complex nature of the fracture mechanisms in the composite system. Failure of the composite consists of matrix fracture, fibre-matrix debonding, fibre pull-out and finally followed by fibre fracture. The same fracture mechanism occurs for long kenaf glass hybrid composites.

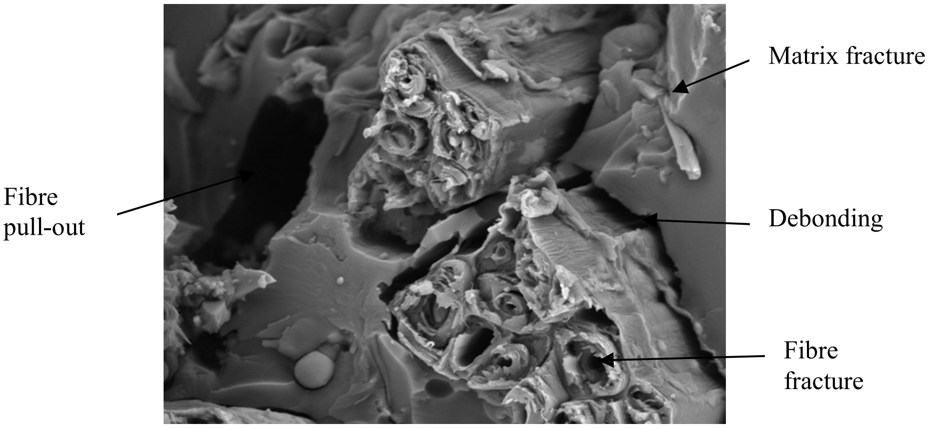

Fig. 3. SEM micrograph of fracture surface.

4. Conclusion

The impact damage tolerance of kenaf fibre composites was very low compared to kenaf glass hybrid composites. They lost almost half of their intrinsic strength and stiffness following an impact of 2J of energy. Considerable evidence of matrix fracture, interfacial debonding and fibre fracture was found in the fracture surface. However, hybridisation of kenaf with glass fibres even at low concentration increased their impact damage tolerance considerably and hence can be considered as a viable method for increasing the impact damage tolerance of kenaf fibre composites. In fact, kenaf composites had lower tensile strength than kenaf hybrid composites in post-impact tensile and open-hole tensile properties. Also, their tensile sensitivity was lower than kenaf hybrid composites, shown by their high steep normalised stress reduction curve than kenaf hybrid composites. Therefore, it is recommended that fibreglass can be added in the kenaf composities to enhance the reinforcing effect for better mechanical performance.

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