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Hybrid Composites: Study on Un-Treated Kenaf/Glass Fibre Properties

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ABSTRACT

A hybrid composite consisting of untreated kenaf fibre and glass fibre was investigated by varying the fibre glass weight ratios and using interply fabrication method. The expected results were to have better composite performance in terms of its toughness and impact strength as a comparison between the hybrid (kenaf/E-glass fibre composites) and E-GF composites alone. For the purpose of this study, all the samples were prepared using typical sample preparation. Results show that the incorporation of E–glass fibre resulted in brittle failure and a higher amount of E-Glass fibre with low percentage of kenaf fibre causing high strength, low ductile, and low toughness behaviours.

Keywords: Kenaf fibre, E- glass fibre, weight ratio, fibre reinforced composites

INTRODUCTION

This investigation was done to verify the mechanical properties of the un-treated kenaf fibre/E–glass fibre composites. The preparation of the composites samples was carried out utilizing the vacuum bagging process in order to minimize the percentage of water ingression inside the composites samples. The idea of hybrid fabrication is due the understanding of low mechanical properties of cellulose fibre in comparison to syntactic fibres, such as E–glass fibre. As such, this investigation should provide evidence of low mechanical properties or the behaviour of kenaf fibre (as a single fibre or as hybrid) and an increase in the toughness of the kenaf/E- glass fibre composite samples as compared to the E–glass fibre composites alone.

MATERIALS

In this study, the kenaf fibres were obtained from Malaysian Agricultural Research and Development Institute (MARDI), Malaysia. The estimated properties of the kenaf fibres used in this study possessed a density of 1.4 g/cm^{-1} (Zampaloni *et al.*, 2007), with the tensile strength 930 MPa, the Young's modulus of 53 GPa and elongation at break of 1.6% (Mohanty *et al.*, 2005). Meanwhile, the glass fibre used was of the fabric type non-prepreg E-glass fibre (120-38 STD E-Glass). The estimated tensile strength for the E-glass fibre ranged from 2400 to 3400 MPa, with a tensile modulus of 69 to 73 GPa and a density of 2.5 to 2.55 g/cm^{-1} (Mohanty *et al.*, 2005). In this work, the resins

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used were the Alpha Epoxy resins (Parts A and B). The density of epoxy resin used was 1.15 g/ml. The fabrication of the composite samples in this study utilized the ideal wet lay up mixing ratio of 60:40 (fibre:resin). This investigation used an epoxy system that cures at room temperature, and it thus requires post-curing stage prior to a complete fabrication of the composite samples**.** The post-curing stage is required for this composites system for the purpose of increasing the mechanical and toughness properties of the sample. With regards to post-curing, the fabricated samples were post-cured inside an oven at 100ºC for 2 hours.

METHODOLOGY

Preparation of the Composites

The hybrid samples of the kenaf fibre and E-glass fibre produced for this study utilized the bi-directional orientation concept, where one fibre layer runs in the weft direction and the second fibre layer runs in the warp direction. Hybrids are most commonly found in 0°/90° woven fabrics, which are also known as multi-axial fabrics. The main concern involved in the production of bidirectional samples is to have better mechanical properties as there are more orientations of fibre per number of layers of fabric which will result in a better stress distribution.

Lay up Process

Kenaf fibre were chosen randomly, cleaned and cut based on the length of the mould (i.e. 30 cm x 30 cm). The matrix ratio used in this study was 2:1, where Epoxy resin and hardener were mixed well to achieve a proper mixing by using an air pressure mixing tool. Meanwhile, the wet lay up method was used to fabricate the samples by laying down each fibre in sequence and with the centre kenaf fibre core. To provide compression pressure to the composites preparations, an air pressure vacuum fixed at 21 ± 3 Hg pressure was used by means of vacuum bagging. *Figs. 1* and *2* show an example of a complete sample preparation used in this study.

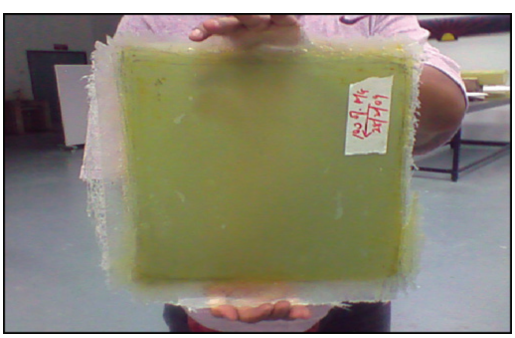

Fig. 1: 100% wt E- glass fibre composites (Control)

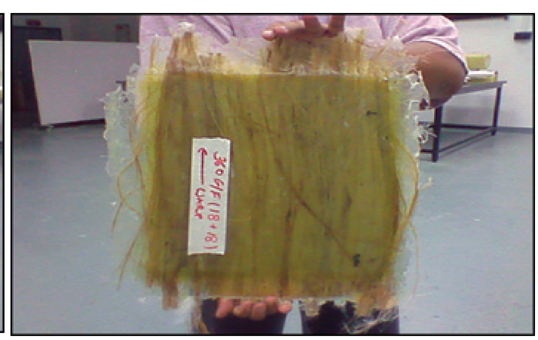

Fig. 2: 10% wt kenaf (Un-treated)

Preparation of the Test Specimen

The determination of the tensile properties was as per ASTM D 3039. The tensile test was carried out using Lloyd 30 kN machine. A gauge length of 50 mm, with a cross head speed of 0.02 inch/min, was employed. The average width and the length of the specimen were 25.4 mm and 172 mm, respectively. The impact properties using Charpy impact test for un-treated kenaf / E- glass fibre composites were determined under specific conditions of humidity, i.e. of 50% at the temperature of 73°F. The width of all the impact specimens was set at 12.7 mm and the length was standardized at 127.0 mm. The breaking energy for all the specimens was estimated using 11.0 Joule pendulum. All the procedures for the impact resistance determination are in accordance with ASTM D 256. Meanwhile, the determination of the flexural properties is in accordance with ASTM D 790-98 and 92 for the standard test methods for the flexural properties of un-reinforced and reinforced plastics and electrical insulating materials using Instron machine for the 3–point bending system.

RESULTS AND DISCUSSION

Tensile Properties

The tensile behaviour of 100% wt kenaf composites in *Fig. 3* shows a unique curve of brittle-ductile failure and ductile failure. It is assumed that the brittle failure is due to the matrixes system and ductile behaviour is produced mainly by the higher percentage of kenaf fibre % wt. Observation on overall tensile result showing a similar pattern of brittle failure. Observation on each hybrid composites samples surfaces after tensile testing shows that most of the samples were de-bonding in between the interphase layers of kenaf -E-glass fibre composites samples due to un-treated surfaces that resulted in the interphase failure of the specimens. The observation during the tensile test also showed that failure occurred mainly at the E-glass fibre section which is the outer skin, whereas the sudden failure at the kenaf section indicated that majority of the tensile strength was actually provided by the E-glass fibre, not the kenaf fibres. As such, the behaviour of brittle failure is considered acceptable as the total strength is provided by the E-glass fibre in comparison to kenaf fibres.

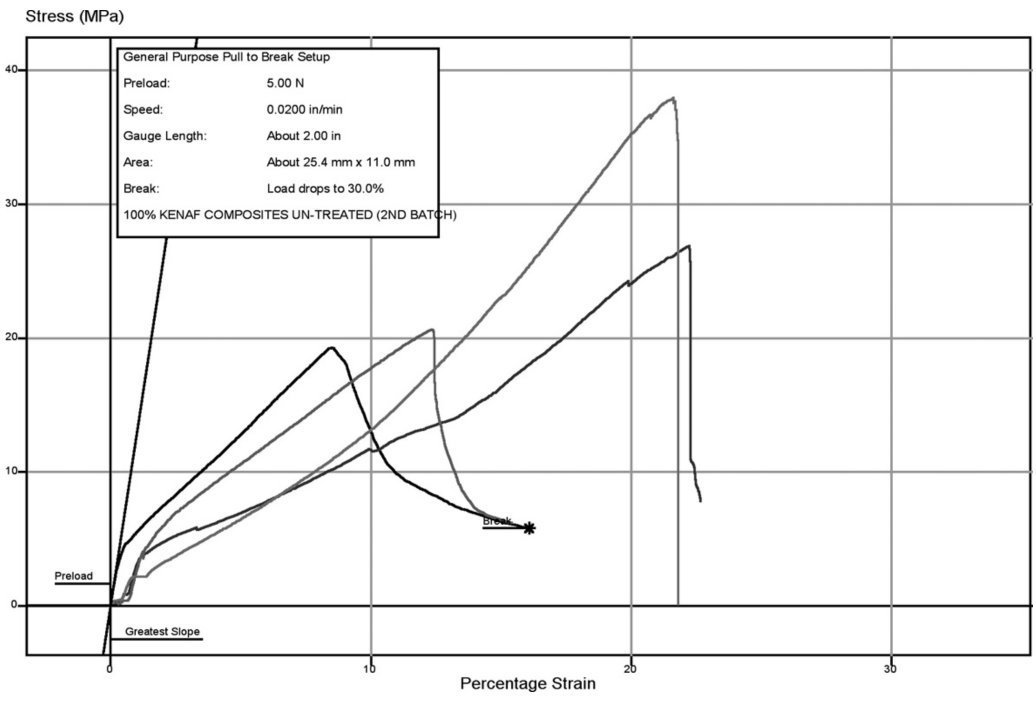

Fig. 3: Tensile properties of 100% wt kenaf composites

The overall results for the hybrid (untreated kenaf - 10% wt, 20% wt, 30% wt, 40% wt, 50% wt, 60% wt, 70% wt, 80% wt, and 90% wt kenaf fibres) and 100% wt E – Glass fibre composites showed a similar pattern of brittle failure, as illustrated in *Figs. 4, 5,* and *6* below.

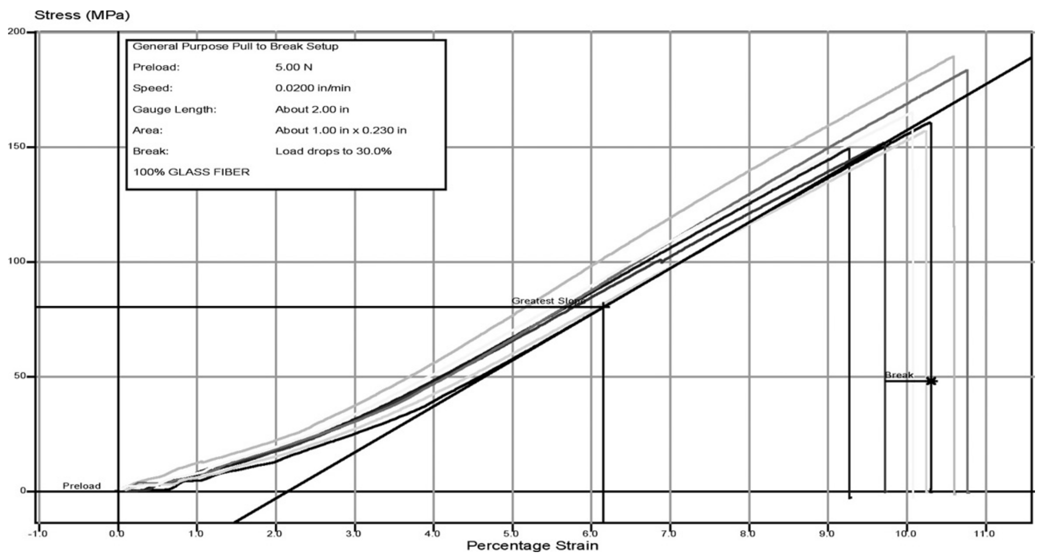

Fig. 4: Tensile properties of 100% wt E – glass fibre composites

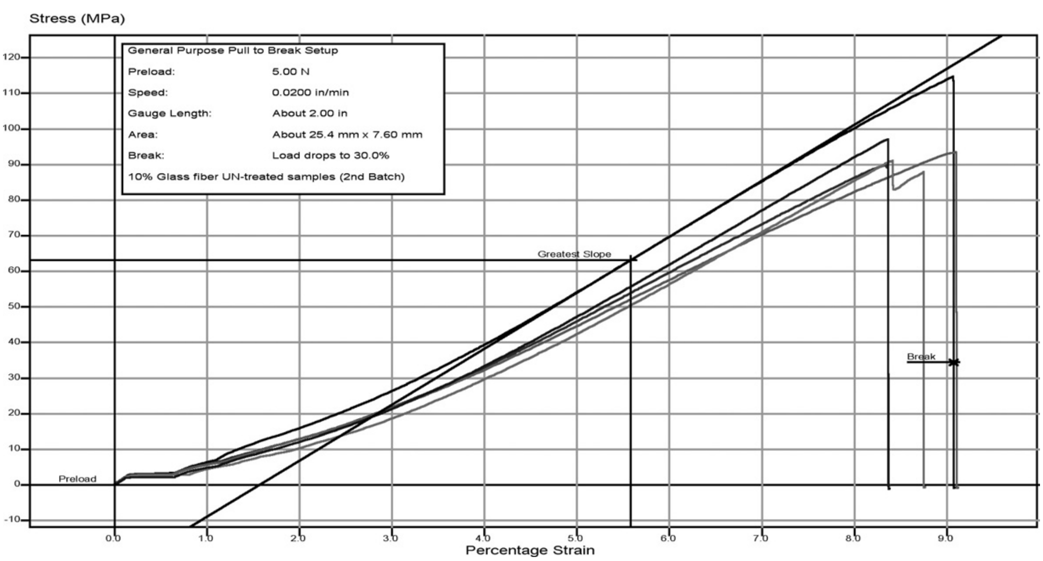

Fig. 5: Tensile properties of 10% wt E – glass fibre composites

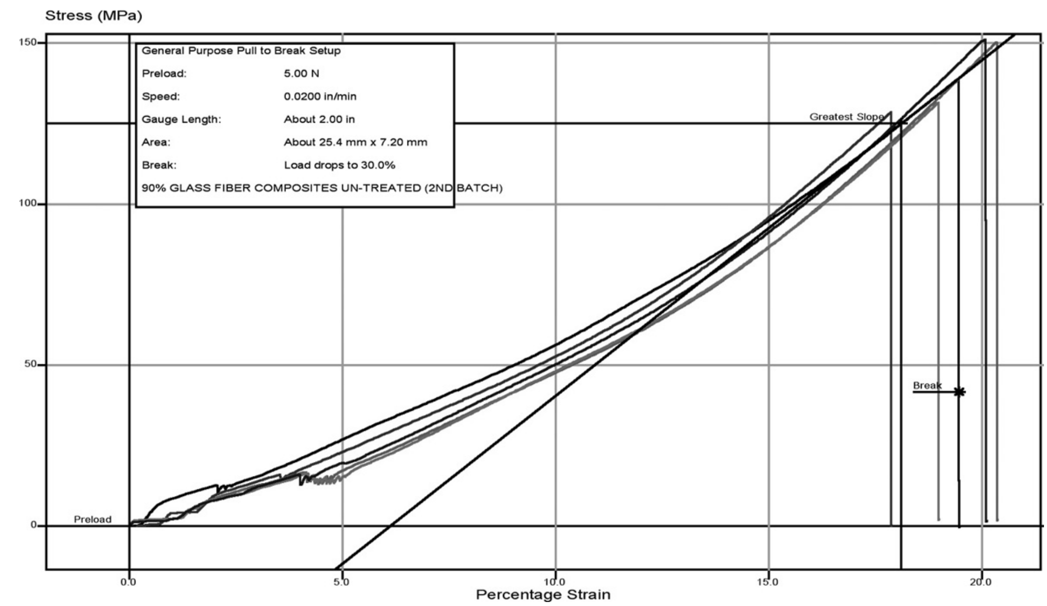

Fig. 6: Tensile properties of 90% wt E – glass fibre composites

Flexural Properties

The flexural results show an increase in amount by the weight of E-glass fibre resulted in a brittle behaviour of all the composite samples. Meanwhile, a fibre combination of the kenaf/E-glass fibre resulted in a brittle-ductile or ductile-brittle transition behaviour. *Fig. 7* shows that at 100% wt kenaf fibre, the flexural properties became uncertain; for instance, the curve shows ductile behaviours and multiple ductile behaviours in certain locations. The SEM observation carried out on the fractured surfaces for 100% wt kenaf fibre, after the flexural testing, showed poor adhesion and poor resins contributed to uncertain results. On the contrary, the flexural result (*Fig. 8*) for 100% wt E- glass fibre composites showed a brittle behaviour for all the composite specimens.

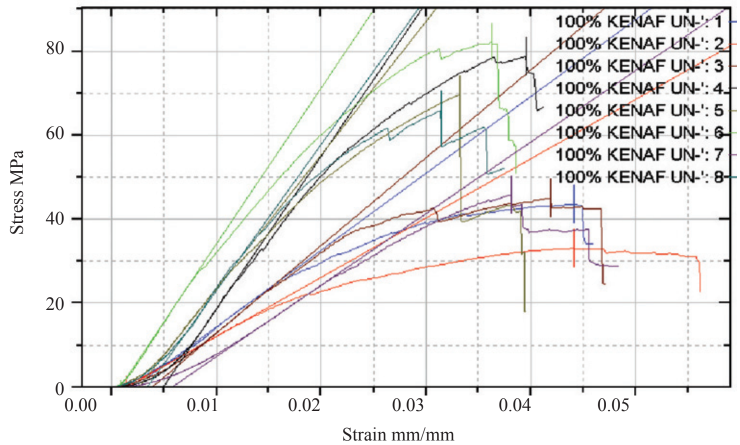

Fig. 7: Untreated 100% wt kenaf fibres

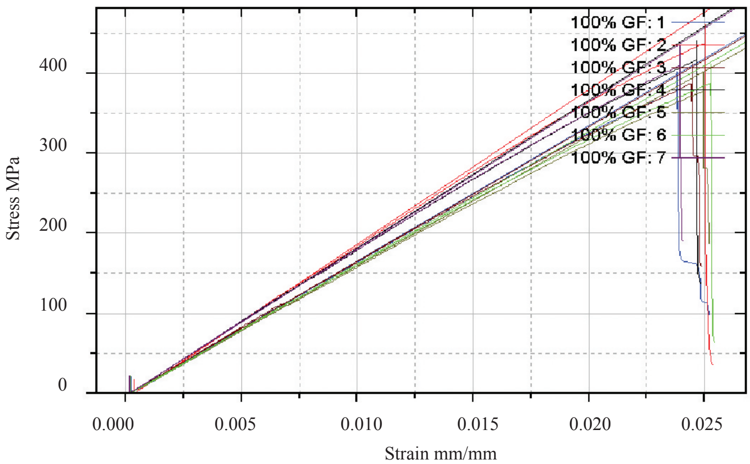

Fig. 8: 100% wt E-glass fibre composites

The fibre combination of kenaf /E-glass fibre resulted in a brittle-ductile or ductile-brittle transition behaviour. In more specific, brittle-ductile transitions are shown in untreated 10% wt, 20% wt, 30% wt and 40% wt kenaf fibre samples, whereby the amount by weight for the E-glass fibre is dominant. *Fig. 9* shows the brittle-ductile or ductile-brittle transition behaviour for 10% wt untreated kenaf composites.

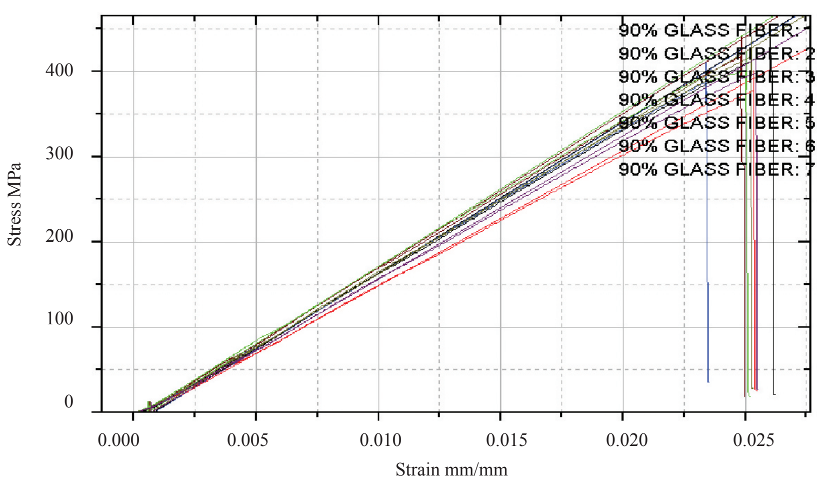

Fig. 9: Untreated 10% wt kenaf fibres

The ductile-brittle transitions are also shown at higher amount by weight of the kenaf fibres for the untreated 90% wt, 80% wt, 60% wt and 50% wt kenaf fibre samples. *Fig. 10* presents the ductile–brittle failure for 90% wt untreated kenaf composites.

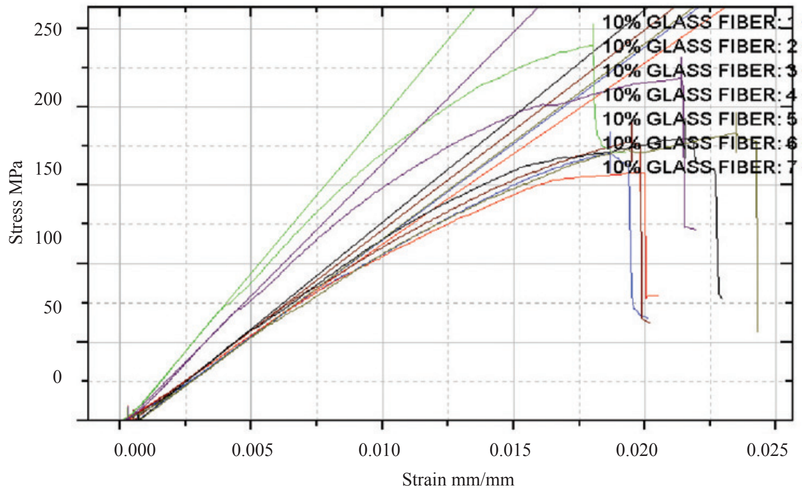

Fig. 10: Untreated 90% wt kenaf fibres

Impact Properties

As shown in *Fig. 11*, the impact value for 70% wt E- glass fibre up to 100% wt E- glass fibre is higher compared to those with higher percentages of kenaf fibre % wt. The results also show that E- glass fibre provides higher impact property values, suggesting that a combination of the hybrid at higher E – glass fibre increases the overall impact value.

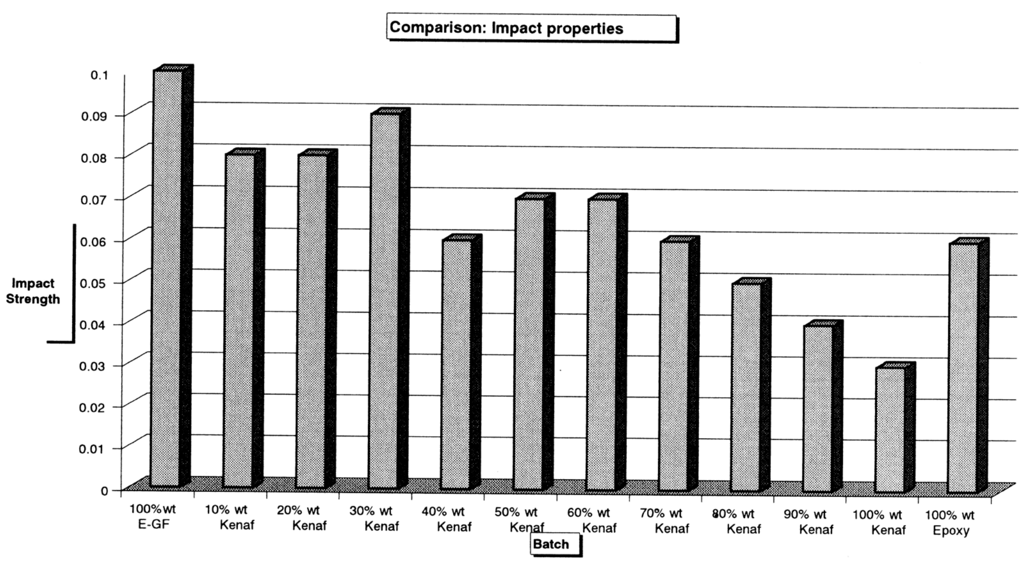

Fig. 11: Impact properties comparison between the hybrid composites

Morphology Properties

Fig. 12 shows untreated 100% wt kenaf composites with high impurities on the fibre surfaces. The observation carried out showed a poor resin –fibre surface adhesion and no wettability to the surfaces of kenaf fibre.

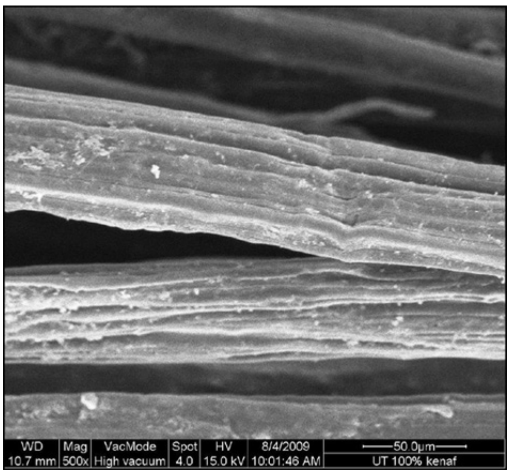

Fig. 12: SEM for 100% wt kenaf composites

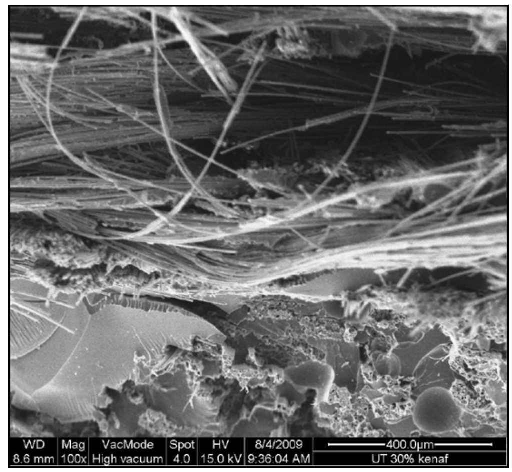

Fig. 13: SEM for 30% wt kenaf composites

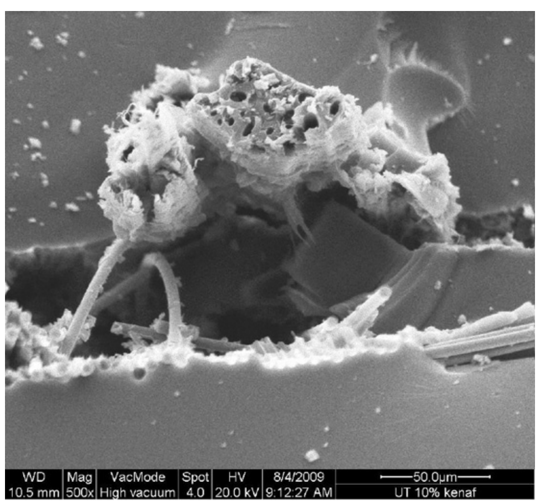

Fig. 14: SEM for 10% wt kenaf composites

Fig. 13 illustrates 30% wt untreated kenaf composites phase separation between the E-glass fibre and kenaf fibre, indicating poor fibre-matrix adhesion, high porosity, and inhomogenity at fractured surface areas.

Fig. 14 shows 10% wt untreated kenaf composites with high porosity; the presence of fibre aggregation and surface impurities, cellulose porous structure (lumen) due to the non-treated fibres and high void areas resulted in a low fibre-matrix adhesion.

CONCLUSIONS

Several conclusions made include:

1. The incorporation of E – glass fibre resulted in brittle failure.
2. Combining E-glass fibre at higher amount to cellulose fibre resulted in high strength, low ductile, and low toughness behaviour.
3. Ductile behaviour was observed in several composites at higher cellulose fibre % wt.
4. An increased amount of cellulose fibre % wt resulted in high ductility and high toughness behaviours.

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