Flexural Properties of hybrid oil palm empty fruit bunch and kenaf reinforced epoxy composite laminates at various ply stacking sequence

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ABSTRACT – In this paper, the effect of ply stacking sequence of novel hybrid oil palm empty fruit bunch (OPEFB) and kenaf fibers reinforced epoxy composite laminates is investigated based on four various ply stacking sequences. Three types of fibers were used in the composites fabrication, namely short fiber (sf) OPEFB, short fiber (sf) kenaf and woven kenaf mat. Epoxy was selected as the composites thermoset matrix ranging from 58.1 wt% until 68.6 wt%. The hybrid composite laminates were fabricated by using hot compression moulding process (at 25 psi and room temperature). All samples were prepared based on steel mould with fixed length x width x height of 200 mm x 200 mm x 3 mm. Flexural tests were later conducted based on ASTM D790 standard. Results from the tests revealed that kenaf_sf/OPEFB_sf/kenaf_sf ply stacking produced the highest flexural modulus (3.92 MPa) while the lowest flexural modulus was obtained for OPEFB_sf/kenaf_sf/OPEFB_sf ply stacking (3.16 GPa). Furthermore, kenaf_mat/OPEFB_sf/kenaf_mat ply stacking produced the highest flexural strength (77.91 MPa) while the lowest flexural strength was obtained for OPEFB_sf/kenaf_mat/OPEFB_sf (55.45 MPa). The obtained results showed that hybrid composite laminates with higher kenaf fiber loading were able to yield higher flexural properties. In addition, hybrid composite laminates ply stacking sequence with higher kenaf mat was able to provide higher flexural strength, while highest flexural modulus was influenced with the use of higher kenaf sf.

1. INTRODUCTION

Among the many advantages of polymer composites is the ability to tailor the materials architecture in order to obtain the desired final mechanical properties [1]. For natural fiber composites, the materials architecture can easily be manipulated for similar intention by many ways such as varying the fiber loadings, fiber aspect ratio, fiber type (short, long), fiber orientation (random, unidirectional, woven), number of ply, and ply stacking sequence [2].

Based on available literature review, there are several studies which reported on the effect of ply stacking sequence to the mechanical properties of hybrid natural fiber composite laminates such as for kenaf/Kevlar reinforced epoxy composites [3] and oil palm empty fruit bunch (OPEFB)/jute reinforced epoxy composites [4]. In addition, study by Mansor et al. [5] also reported that the final hybrid composites product quality was also influenced by the ply stacking sequence due to the interaction between the combined fibers and matrix.

In this paper, a novel hybrid natural fiber reinforced thermoset epoxy composites was developed by using the combination of OPEFB and kenaf fibers. The objective of the project was to investigate the effect of varying ply stacking sequence to the final hybrid OPEFB/kenaf reinforced epoxy composite laminates flexural properties. Four different ply stacking configurations were formulated by using compression moulding process during sample preparation. All samples were subjected to flexural tests based on ASTM D790 standard to determine the final composites flexural strength and flexural modulus.

2. RESEARCH METHODOLOGY

2.1 Raw Materials

Kenaf bast fiber was obtained from Lembaga Kenaf dan Tembakau Negara (LKTN) Malaysia, while the OPEFB fiber was supplied by Kilang Kelapa Sawit Kempas, Melaka. Neat epoxy resin (CP360 Part A) and amine hardener (CP360 Part B) with resin to hardener ratio of 2:1 was used as matrix for the hybrid composites.

2.2 Sample Preparation

Four various fiber stacking sequences were applied to prepare the hybrid composites panels, at thermoset epoxy matrix between 58.1 wt% until 68.6 wt%, as shown in Table 2.1. Three types of fibers were used in the composites fabrication, which were short fiber (sf) OPEFB, short fiber (sf) kenaf and woven kenaf mat (at 0/90 orientation). All short fibers were randomly orientated within the ply, with fiber length between 1 mm to 3 mm. Laminates were subjected to compression moulding at 25 psi and room temperature.

All laminates were fabricated based on steel mould with fixed length x width x height of 200 mm x 200 mm x 3 mm. The compressed panels were left to cure at room temperature for 24 hours.

Table 2.1 Compositions of hybrid OPEFB/kenaf reinforced epoxy composite laminate at various ply stacking sequence

Stacking Sequence	Composition (wt%)		
	OPEFB	Kenaf	Epoxy
OPEFB_sf/kenaf_sf/ OPEFB_sf	28.9	13	58.1
OPEFB_sf/kenaf_mat/ OPEFB_sf	34.5	4	61.5
Kenaf_sf/OPEFB_sf/ kenaf_sf	14.9	26	59.1
Kenaf_mat/OPEFB_sf/ kenaf_mat	21.6	9.8	68.6

2.3 Flexural test

The conducted flexural test was 3-point bending in accordance to ASTM D790 by using INSTRON machine. Samples were cut to 127 mm x 12.7 mm rectangular size by using circular saw. The tests were conducted at a crosshead displacement rate of 2.0 mm/minute. For each stacking sequence, five specimens were tested at room temperature and an average of five samples was taken as a final result. The flexural strength and flexural modulus of the samples were calculated using the following equations [6]:

$$\sigma = \frac{3PL}{2bd^2} \quad (1.1)$$

where P, L, b and d represent load, support span, width of sample and depth of samples respectively.

$$E = \frac{L^2 m}{4bd^2} \quad (1.2)$$

where m is the slope of load–displacement curves

3. RESULTS AND DISCUSSION

Table 3.1 shows the overall results on flexural strength and flexural modulus of the final composite laminates.

Table 3.1 Hybrid composites overall flexural properties

Stacking Sequence	Flexural Strength (MPa)	Flexural Modulus (GPa)
OPEFB_sf/kenaf_sf/O PEFB_ sf	55.78	3.16
OPEFB_sf/kenaf_mat/ OPEFB_ sf	54.55	3.26
kenaf_sf/OPEFB_sf/ke naf_sf	59.44	3.92
kenaf_mat/OPEFB_sf/ kenaf_mat	77.91	3.47

Results from the tests revealed that kenaf_sf/OPEFB_sf/kenaf_sf ply stacking produced the highest flexural modulus (3.92 MPa) while the lowest flexural modulus was obtained for OPEFB_sf/kenaf_sf/OPEFB_sf ply stacking (3.16 GPa). Furthermore, kenaf_mat/OPEFB_sf/kenaf_mat ply stacking produced the highest flexural strength (77.91 MPa) while the lowest flexural strength was obtained for OPEFB_sf/kenaf_mat/OPEFB_sf (55.45 MPa).

4. SUMMARY

Several conclusions from the study are listed as below: -

i) kenaf_sf/OPEFB_sf/kenaf_sf ply stacking produced the highest flexural modulus (3.92 MPa) while the lowest flexural modulus was obtained for OPEFB_sf/kenaf_sf/OPEFB_sf ply stacking (3.16 GPa)

ii) kenaf_mat/OPEFB_sf/kenaf_mat ply stacking produced the highest flexural strength (77.91 MPa) while the lowest flexural strength was obtained for OPEFB_sf/kenaf_mat/OPEFB_sf (55.45 MPa)

iii) hybrid composite laminates prepared at higher kenaf fiber loading were able to yield higher flexural properties

iv) hybrid composite laminates ply stacking sequence using higher kenaf mat was able to provide higher flexural strength, while highest flexural modulus was influenced with the use of higher kenaf_sf.

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