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Sandwich Structure Composites: Effect of Kenaf on Mechanical Properties

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***Abstract*—**Sandwich structure composites produced by epoxy core and aluminium skin were developed as potential building materials. Interface bonding between core and skin was controlled by varying kenaf content. Five different weight percentage of kenaf loading ranging from 10 wt% to 50 wt% were employed in the core manufacturing in order to study the mechanical properties of the sandwich composite. Properties of skin aluminium with epoxy were found to be affected by drying time of the adhesive. Mechanical behavior of manufactured sandwich composites in relation with properties of constituent materials was studied. It was found that 30 wt% of kenaf loading contributed to increase the flexural strength and flexural modulus up to 102 MPa and 32 GPa, respectively. Analysis were done on the flatwise and edgewise compression test. For flatwise test, it was found that 30 wt% of fiber loading could withstand maximum force until 250 kN, with compressive strength results at 96.94 MPa. However, at edgewise compression test, the sandwich composite with same fiber loading only can withstand 31 kN of the maximum load with 62 MPa of compressive strength results.

***Keywords*—**Aluminium, kenaf fiber epoxy, sandwich structure composite.

I. Introduction

THE Sandwich panels have been widely used for structural applications in the marine, aerospace and performance automotive industries for several decades. The use of composite sandwich structures is increasing in the aerospace and marine industry, as well as in other areas where a lightweight material with elevated flexural stiffness is required [5]. Increasing use of lightweight materials in automobile manufacture will mean lighter cars and resultant fuel economy [6]. Typically, aluminium plate is commonly used for the facing layer and the skins are thin, stiff and very strong [4]. Aluminium has good resistance to corrosion [5].

The properties of this aluminium include good stiffness and strength to weight ratios, impact energy absorption, thermal insulation and non-combustibility. Many of these characteristics are particularly attractive for skins in sandwich structure [5]. According [1], epoxy has high chemical and corrosion resistance, good chemical and thermal properties and ability to be processed under variety of conditions.

Epoxy resin is categorized in thermosetting polymer which has high tensile strength and modulus, excellent chemical and corrosion resistant ad good dimensional stability. Hence there are widely use in structural adhesives, surface coating, engineering composites and electrical laminate [6].

In this study, five different weight percentage of kenaf loading ranging from 10 wt% to 50 wt% were employed. Then, the effect of kenaf fiber was studied on sandwich structure composites made of epoxy core and aluminium skin and their mechanical performances were investigated.

II. Materials and Methods

Kenaf Short Fiber Preparations-Kenaf (which is known as *Hibiscus cannabinus*) fibers were supplied by Innovative Pultrusion Sdn. Bhd. Naturally is in short fiber. From the supplier, it is known that the length of short fiber used is less than 8mm and the diameter in average of 45 µm.

Kenaf fibers were sieved and placed in the oven under 105°C for 24 hours before fabrication. Resin Preparation - The resin used as core matrix is Epoxy Grade DER 331 and Zeepoxy TB Epoxy curing agent (hardener) supplied by Skytech Sdn. Bhd.

The ratio of this resin to hardener is 1:2 (epoxy: hardener). Epoxy and hardener will be used as adhesive to stick the faces and core. This mixture of epoxy has properties with tensile strength of 800 ± 50 kg/cm^3 and flexural strength of 375 ± 50 kg/cm^3. Fabrication of Sandwich Structure-The fabrication was done by hand lay-up and then by compression; using universal testing machine.

Dimension of the fabricated composite sandwich structure should be 305mm x 305 mm x 10 mm. Pressure applied during fabrication is 8.5 kN in room temperature to ensure adequate contact of epoxy to kenaf fiber and aluminium sheet for 24 hours to ensure complete curing of epoxy.

Flexural 3-Point Bending Test-Flexural three point bending test require different specimen geometry and a different configuration for applying the load. Test was performed according to ASTM 393/ C393 M (10kN). In this test, the load was applied at the mid-span of a simply supported beam.

Five samples were cut for dimension of 25 mm x150 mm x10 mm. Speed rate used was 2mm/min with the span length of 100mm The flexural strength and flexural modulus of these sandwich panels were identified. Flatwise Compression Test-This test was performed to determine the compressive strength and modulus [3].

The test was carried out on a Shimadzu Universal Testing

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Machine and performed according to ASTM C 365 / C365-M. 5 samples was cut for dimension 50.8 mm x 50.8 mm with thickness of 10 mm. Speed rate used was 1.3mm/min.

Edgewise Compression Test-This test was performed to determine the edgewise compressive strength. The test was carried out on a Shimadzu Universal Testing Machine and performed according to ASTM C 364 / C 364-M. 5 samples were cut for dimension 80 mm x 50.8 mm x 10 mm. Speed rate used was 1.3mm/min [2].

III. Results and Discussions

A. Flexural Strength and Flexural Modulus of Sandwich Structure

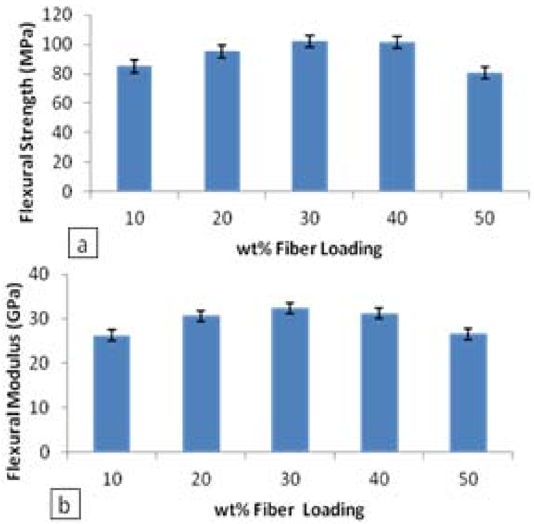

Fig. 1 (a) Flexural Strength and (b) flexural modulus acting of sandwich structures during flexural test with varying percentage of fiber loadings

The flexural strength and flexural modulus of sandwich structure are presented in Figs. 1 (a) and (b). The flexural strength and flexural modulus of 30% kenaf fibre sandwich structure are 102.16 MPa and 32.42 GPa, respectively. This result is highest compared to other fibre loading.

It means sandwich panel with 30 wt% has high stiffness and resistance to deform when it is placed under a load. During load applied, the stress will transfer from the matrix to the incorporated kenaf fiber in the core of sandwich structure.

Furthermore, after the flexural test, the skin pulled out from core. This caused the sandwich panel undergoes the delamination failure. Delamination or layer interface cracks constitute a common failure phenomenon in laminated composites and they are most easily introduced from impact loads and may deteriorate the performance of the structure under compressive loading. In this case, the failure occurs because of non-uniform distribution of epoxy resin on aluminium sheet surface since hand lay-up method was used.

B. Maximum Force and Flatwise Compressive Strength of Sandwich Structure

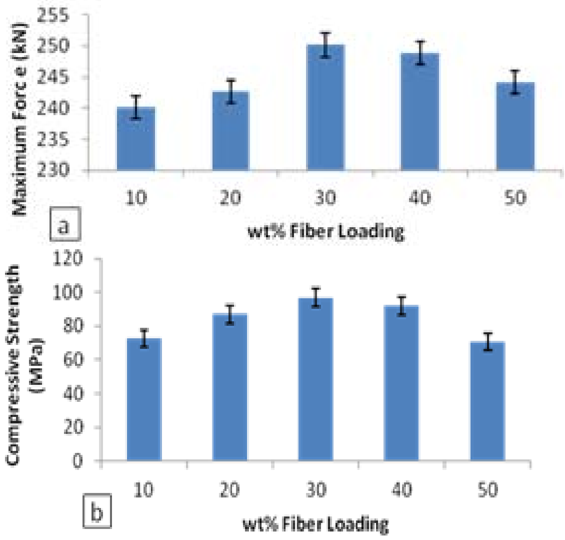

Fig. 2 (a) Maximum Force and (b) flatwise compressive strength for sandwich structures during flatwise compression test with varying percentage of fiber loadings

As shown in Figs. 2 (a) and (b), 30 wt% kenaf fiber loading can withstand the highest maximum force applied compared with the other percentages of fiber loading.

The highest load universal testing machine was used for this compression test is approximately 250kN and this sandwich structure is failed around that.

As shown in Fig. 2, 30 wt% kenaf fibre loading has highest compressive strength which is 96.94 MPa compared to other percentage of fiber loading. The fibers inside the core will give the strength to the core to withstand such load. This improvement is significant and the 30wt% loading will be proceeded to be used in sandwich structure.

Besides, based on research, lower content of fiber loading will lead to lower strain when the stress is applied. Higher strain is preferable for high performance applications. High strain rate loading is one of the possibilities in many of such applications [6].

C. Maximum Force and Edgewise Compressive Strength of Sandwich Structure

TABLE I
Maximum Force and Edgewise Compressive Strength of Sandwich Structures

Weight of Fiber Loading	Maximum Force (kN)	Compressive Strength (MPa)
10	240.14	72.53
20	242.64	86.93
30	250.16	96.94
40	248.87	91.95
50	244.21	70.57

In this edgewise compression test, the skin firstly started to separate from the core after given the applied load. Usually the skin will be the first one to fail under this test as it will be separated from the core and bend as the force given. Then, all the applied force will be handled by the core and until certain load, the core could not resist anymore, cracks will propagate and failure of the core occurs.

When the first stage of the skin is failed or bent, all the stress will be acting on the core and maximum compressive strength will be gained when the core is started to fail. As shown in Table I, in this edgewise compression test, it seems the maximum force which is around 30 kN acting on the sandwich structure and it is lower compared to flatwise compression test.

It is shown that 30 wt% kenaf fiber loading can withstand up to 31.84 kN maximum force. Plus, it shows 30% kenaf fibre loading has highest compressive strength which is 96.94 MPa compared to other percentage of fiber loading. Lower fiber contents in fiber will lead the sandwich structure to fail in lower applied load as less stress is transferred to fibers.

The composition of matrix and reinforcement must be ideal to get the best results of mechanical properties. Lower fiber contents will lead to lower mechanical strength and if too many fiber contents also will lead to weak bonding to the skin thus reducing mechanical strength.

Basically, 30 wt% kenaf fibers is the best composition as it shows high performance in mechanical strength. This high compressive strength and maximum force it can withstand can make the sandwich structure can be used in many high applications.

D.SEM Analysis

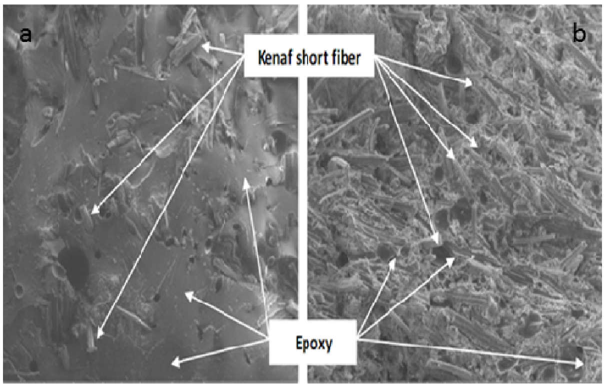

Fig. 3 Mixture between kenaf fiber and epoxy of (a) 10 wt% kenaf fiber loading and (b) 30 wt% kenaf fibers loading

As shown in Fig. 3, it can be seen that the mixture of kenaf fiber and epoxy in the core part for 10 wt% fiber loading, the epoxy part is more than in 30 wt% fibers loading. As for 30 wt% fibers loading, the fiber part is more than in 10 wt% fibers loading.

Based on the result of mechanical test, this higher fiber content gives better mechanical properties than lower one. Fibers will hold the strength of the core as all the load or any force given to core will be transferred to the fibers. In short, more fiber loading in the core, the better mechanical properties of composite sandwich structure it would be. However, if too many percentages of fibers inside the core, this will lead more moisture uptake and make the weight of the composite sandwich to be higher.

Also, it will lead to decreasing of mechanical properties as shown in the previous results where 40 wt% and 50 wt% has lower mechanical properties compared to 30 wt% fiber loading. This is clearly 30 wt% is the best composition to be used.

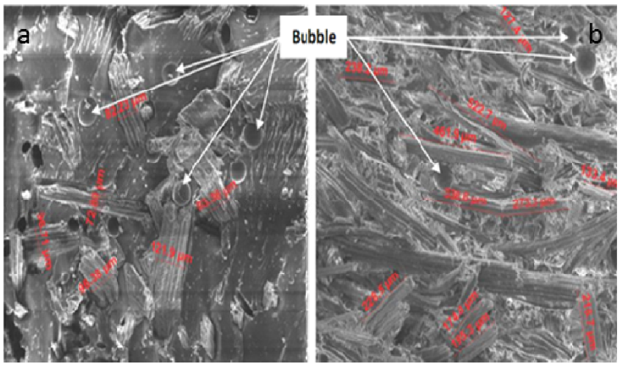

Fig. 4 Bubbles trapped in the core for (a) 20 wt% fiber loading sandwich structure and (b) 30 wt% fibers loading

As shown in Fig. 4, bubbles trapped in the core in 20 wt% kenaf fiber sandwich structure are more than in 30 wt%. These bubbles will lead to decreasing mechanical properties of sandwich structure.

The higher content of fibers in the core will increase the performance of sandwich structure as the fibers will fill out the voids presence in the epoxy. Any load applied to the sandwich structure will be transferred from the matrix (epoxy) to the reinforcement (fibers).

As the fibers fill out those voids, the stress in the core can be distributed well and enhancing its performance of mechanical strength. This bubbles problem is usually occur during fabrication process. The manufacturing of composites involves several operations depending on available technology, facilities and personnel skills [6].

Some of the failure during fabrication might be due to personnel skills as using hand lay-up, the results of the fabrication would be based on the personnel skills as if the skill is not good enough then the results would be not good. This flaw can be prevented by using vacuum bag during fabrication.

Occurrence of fiber pull out failure causes the low toughness and weak interfacial toughness in sandwich panels [7]. This problem occurs in low fiber loading in the core. Thus, the energy absorption also reduced. These affect the mechanical properties of sandwich panels.

It occurs due to weak interface bonding between the kenaf fiber (reinforcement) and the epoxy (matrix) in the core. Once the load is applied, the fibers are simply pulled out and the matrix could not support the load given.

So, the sandwich structures will fail at lower applied load compared to the one that has no fibers pulled out failure like in 30 wt% kenaf fiber loading composite sandwich structure.

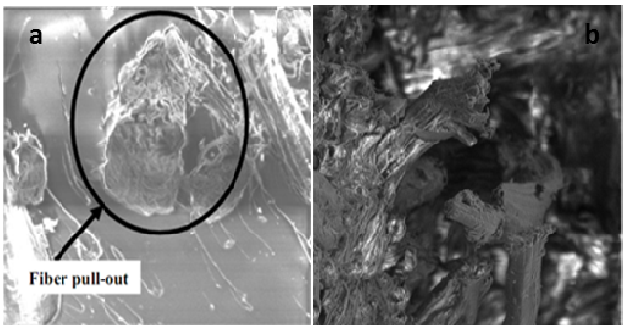

Fig. 5 Types of failure of kenaf fiber after the test; (a) 10 wt% and (b) 30 wt%

As the load given will be transferred from matrix to the reinforcement, if the reinforcement (kenaf fiber) is pulled out, then the matrix alone will withstand the load [8]. And since it cannot withstand too high load, then it will fail at lower load applied. Thus, increasing fiber loading in sandwich structure up to 30wt % was found out provided better result in mechanical properties.

IV. Conclusions

In this study, mechanical properties particularly for compression and flexural properties of five different kenaf weight loading of composites materials are studied. On the basis of the experimental evidence, the conclusions are as follows:

1. The flexural strength, flexural modulus and compressive strength of 30 wt% kenaf fiber loading are the highest compared to the others fiber loadings.
2. Under SEM analysis, it is shown that the presence of higher fiber loading in the core will lead to improvement of mechanical properties of sandwich structure.
3. It is proved that lower contents of fibers in core will lead reduce mechanical strength compared to higher one.
4. However, too many fiber loading e.g 50 wt%, will increase the weight of sandwich composite, moisture intake problem and also weak interfacial bonding in the core.
5. The result of the study showed that 30 wt% kenaf fibers loading is the best potential percentage to be used to produce epoxy kenaf composite sandwich structure.

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References

[1] A. H. Abdullah, S.K Alias, N. Jenal, "Fatigue Behavior of Kenaf Fibre Reinforced Epoxy Composites," *Engineering Journal,* Vol 16, no. 5, 2012, pp. 33-34.
[2] American Society for Testing, ASTM C 364/C 364M – 07 Standard Test Method for Edgewise Compressive Strength of Sandwich Constructions, West Conshohocken, 2002.
[3] American Society for Testing, ASTM C 365/C 365M – 11a Standard Test Method for Flatwise Compressive Properties of Sandwich Cores, West Conshohocken, 2002.
[4] Hexcel Composites, "Mechanical Testing of Sandwich Panels", Publication LTU035b., March 2007.
[5] I.S..Aji, S.M Sapuan, "Kenaf Fibres As Reinforcement For Polymeric Composites: A Review", *International Journal of Mechanical and Material Engineering (IJMME)*, vol. 4, no. 3, 2009, pp. 239-248.
[6] M. K. Khan, "Compressive and lamination strength of honeycomb sandwich panels with strain energy calculation from ASTM standards", Proc. IMechE Part G: J. *Aerospace Engineering*, vol. 220, 2006, pp. 375-386.
[7] T. Nishino, k. Hirao & M. Kotera, "X-ray diffraction studies on stress transfer of kenaf reinforced poly (l-lactic acid) composite," *Composites Part A*, vol 37, no. 12, 2006, pp. 2269–2273.
[8] Y. Lei, Q. Wu, F. Yao & Y. Xu, 'Preparation and properties of recycled HDPE/natural fiber composites," *Composites Part A,* vol. 38, no. 7, 2007, pp. 1664–1674.