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Experimental Analysis of Kenaf Filament Wound Tubes under Axial Compression Load

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ABSTRACT. The objective of this study was to determine the strength of kenaf filament wound tubes under axial compression load. Kenaf is natural reinforcement fibre in which need to explore its capability to replace and compare with other common commercial reinforcement materials. Axial compression test was performed as an early indication to identify the performance of kenaf filament wound composite tubes. Comparisons have been done towards basalt, e-glass and carbon tubes using polyester as a resin. Axial compression test of kenaf/polyester and kenaf/epoxy tubes were conducted with different winding angles involved which are 45^0, 55^0, 65^0 and 75^0. The result showed the 45^0 kenaf/epoxy tubes generated the higher compressive strength followed by other winding angle in the ascending order. The layer strength identification have been conducted in 55^0 winding angle sample in which indicate the increment layer of winding is uniform between one, two and three layers in ascending orders. Comparison between the different reinforcement materials show carbon tubes produced the higher compressive strength followed by e-glass, basalt and kenaf. Kenaf/epoxy recorded 38.7% lower the e-glass tubes. Kenaf/epoxy tubes were observed to identify the improvement from kenaf/polyester tubes and results showed at least 22% increment have been generated. It can be concluded that kenaf presence as a reinforcement material was successfully combine as composite system under axial compressive load as well as lead to the promising indication to be introduced in low load bearing application.

INTRODUCTION

The unique advantages which is high strength to weight ratio of composite materials have been supported by the excellent characteristics of the synthetic fibres. The domination of carbon, and e-glass fibres are commonly majoring materials in the aeronautic, automotive and industrial sectors. However, serious drawbacks are reported for these fibres include: nonrecyclable, high energy required for manufacturing process, health risks when inhaled and being nonbiodegradable [1]. In recent decades, any materials that are being considered ‘‘green’’ are very important to many researchers and engineers. Utilizing natural fibres in engineering can be considered as a ‘‘green solution’’ to hazards associated with using carbon and glass fibres. Acceptable specific strength, low cost, renewability and biodegradability made these natural fibres an excellent choice to use in engineering application. Several natural fibres have been used and excellent results have been recorded for various non-load bearing applications. A comparison is shown in Table 1 was highlighted the advantages of using natural fibres instead the synthetic fibre such as glass fibres. Kenaf with scientific name (Hibiscus cannabinus L) as an example of natural fibre shows a lot of promises as a reinforcement material and used to live among a variety of weather conditions [2,3]. Recently, it is gain a lot interest among researchers to develop a product by using kenaf as a reinforcement material. Alkbir et al. analyzed the effect of geometry on crashworthiness parameters of natural kenaf fibre [4]. Kenaf fibre mat form was used with hexagonal tubes by using hand lay-up process. They concluded that kenaf hexagonal tubes produces a variation results and indicated that the angle of kenaf tubes reinforced composite hexagonal tubes affected the crashworthiness parameters. The influence of kenaf was clearly shown in their experimental study. Aji et al.

conducted an experimental study on the dynamic mechanical property of hybridized Kenaf/PALF-reinforced HDPE composites [5].They mentioned that the presence of the kenaf fibre helps reduce the loss modulus in the dynamic mechanical properties. Yousif et al. investigated the effect of untreated and alkali treated kenaf fibre on flexural properties of epoxy composites [6]. They were revealed that reinforcement of epoxy with treated kenaf fibres increased the flexural strength of the composite by about 36%, while, untreated fibres introduced 20% improvement. They also stated that the increamental results are mainly due to the high improvement of the chemical treatment (NaOH) on the interfacial adhesion of the fibres and the porosity of the composites which prevented the debonding, detachments or pull out of fibres. Mokhtar et al. investigated the performance of UHMWPE/HDPE-reinforced kenaf, basalt and hybrid kenaf/basalt composites [7]. They highlighted that the presence of kenaf, basalt and hybrid kenaf/ basalt as reinforcement material produced a good performance to increase the original properties of UHMWPE/HDPE blends. The performance of the UHMWPE/HDPE blends reinforced with kenaf and basalt fibre produced approximately 61.2%, higher from its original properties due to the good adhesion between fibre-matrix interfaces. These studies directly proved that kenaf has a lot of potential to modify any polymer properties to get require properties. In this study, kenaf filament wound composite tubes is characterize in term of compressive strength to determine the performance under axial loads.

Table 1 Comparison between natural and glass fibres [8]

	Natural fibres	Glass fibres
Density	**Low**	**Twice than natural fibres**
Cost	**Low**	**Low but higher than NF**
Renewability	**Yes**	**No**
Recycability	**Yes**	**No**
Energy consumption	**Low**	**High**
Distribution	**Wide**	**Wide**
CO_2 neutral	**Yes**	**No**
Abrasion to machines	**No**	**Yes**
Health risk when inhale	**No**	**Yes**
Disposal	**Biodegradable**	**Not biodegradable**

EXPERIMENTAL

Material and Method

Raw kenaf fibres were supplied by Lembaga Kenaf dan Tembakau Negara (LTKN), Malaysia in roving form, and the basalt roving was purchased from Incotelogy GmbH Company located in Pulheim Germany while e-glass and carbon roving fibre were supplying from Universal Star Group Limited Company in Ningbo China. Polyester and epoxy resin are purchased from S&N Chemical Company located in Johor Malaysia. Dry filament winding process was used in this study for kenaf roving prior to subsequent process. Vacuum infusion technique was used to impregnating the fibres using two different resin types which are polyester and epoxy as well as to control the quality of all tube samples.

Mechanical Testing

Compression tests were performed using the universal testing machine which is 600DX model that was supplied by Instron Company, Singapore branch. A crosshead speed of 5mm/min was used and the test was performed at room temperature. The compressive strength, strain and failure extension were calculated from load-displacement graph. Results that were collected represent the values of the load resisting performance of the material. The results of the maximum load were divided with cross-sectional area to obtain the compressive strength (MPa) of each samples.

RESULT AND DISCUSSION

Compressive Strength

According to Fig. 1(a), kenaf/polyester tubes generated a significant increments of strength result based on winding angle. The 45^0 winding angle recorded highest compressive strength (39.6 MPa) in which 47% different than 75^0 winding angle. The decreasing strength performance of kenaf/polyester tubes are uniform due to the fibre direction against the applied loading. The performance of kenaf/polyester tubes were deeply evaluated in Fig. 1(b) which is improvement have been made by increasing number of layer subjected in constant 55^0 winding angle samples.

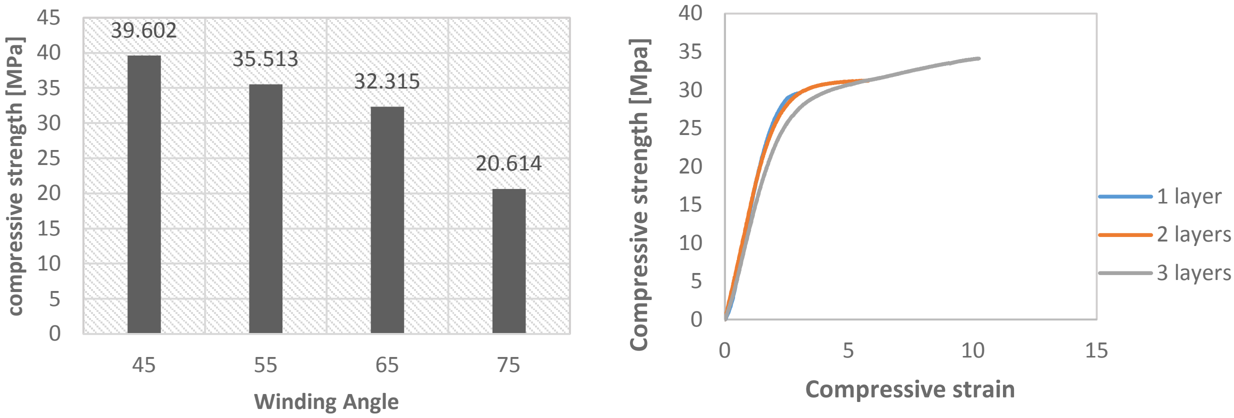

Fig. 1 Kenaf/polyester tubes (a) different winding angle (b) different winding layer

Kenaf Reinforced Epoxy Tubes

In the Fig. 1(a) and 1(b) shows the promising indication of kenaf roving fibre influences in composite tubes system due to the high cellulose content with high microfibrillar angle which is strengthens the internal tubes structure. In the meantime, the cooperation with epoxy as a resin system shows a lot of different which is can be clearly seen in Fig. 2. In overall performance, at least 22% improvement successfully was produced using epoxy as a resin in 45^0 winding angle. This improvement increased with increasing of winding angle. An epoxy resin have improved bonding condition with kenaf fibres and this results also shows the maximum reaction against the loading created the fibre failure faster but produced a better strength. For the higher winding angle, resin system plays more important roles which is can be clearly seen the obvious different of compressive strength between kenaf/epoxy and kenaf/polyester tubes were produced.

Comparison of Different Reinforcement Materials

An identification has been made. Kenaf composite tubes generated promising compressive strength during experimental procedure with two different parameters. In 55^0 winding angle, a comparisons were made with other composite tubes to analyze the performance of kenaf composite tubes. Based on Fig. 3, carbon/ epoxy tubes generated the highest compressive strength (97.88MPa) followed by e-glass/epoxy tubes (75.81MPa). Kenaf/polyester tubes produced the lowest compressive strength (35.5MPa) while basalt/epoxy and kenaf/epoxy produces 68.77MPa and 46.46MPa respectively which is third and fourth higher values. A large different of performance indicates at the graph due to the fibre characteristics itself. Kenaf fibre is an untreated product which is more exposed in uneven fibre size distribution that can leads the smaller section will be fail first. Furthermore, several structure defects on the kenaf fibre cannot be identified during sample preparation process due to the untreated condition which is involving the micro scales analysis to verify the quality of overall fibre condition.

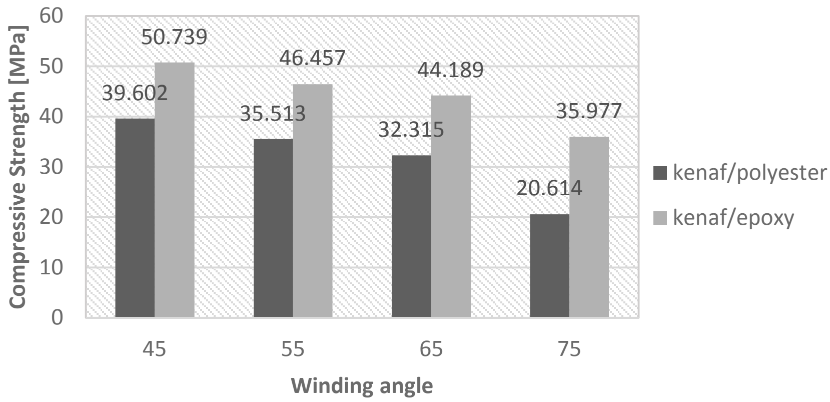

Fig. 2 Kenaf tubes with different resin system

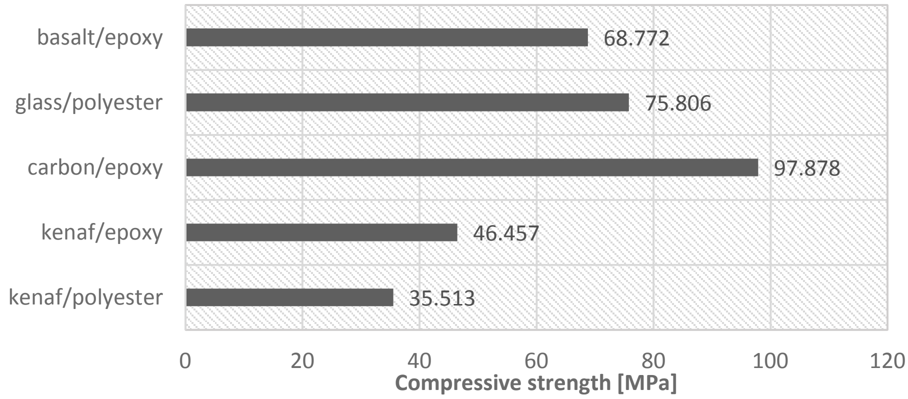

Fig. 3 Comparison of different composite tubes compressive strength

Specific Strength

For identifying the potential of kenaf filament wound tubes, strength to weight ratio (specific strength) is an easy indication to compare with other common composite tubes which is known have better ration. It is also highlighted the fibre behavior when cooperate with resin in manufacturing process. As well as expected, carbon filament wound composite tubes generated the highest ratio which is 2.97 that can be seen in Fig. 4. In the meantime, both kenaf composite tubes show a different indication where kenaf/polyester tubes show a better strength to weight ratio than kenaf/epoxy tubes. This is due to the higher density of epoxy resin that leads to the tubes to become heavy and less effective in the performance results. Kenaf fibre technically have higher absorption characteristics than other reinforcement materials which is lead the tubes to become heavier. The resin penetrated deeply inside the lignocellulosic structure and influence directly in strength performance and tubes density.

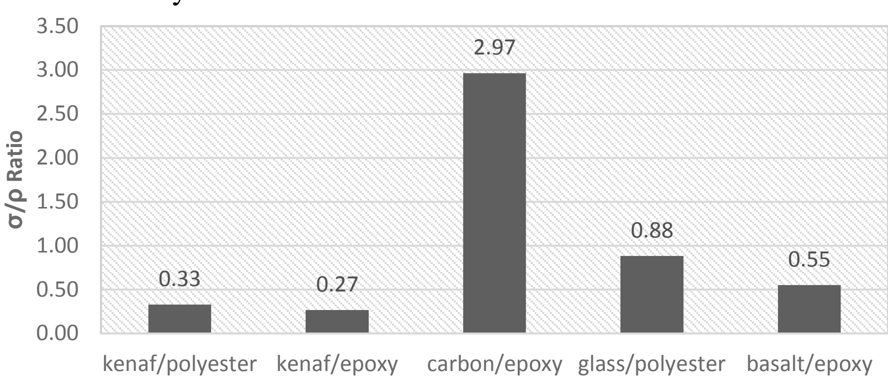

Fig.4 Specific strength comparison of different composite tubes

CONCLUSION

The compressive strength performance of kenaf filament wound composites tubes have been identified. Compressive strength is increased with decreasing of kenaf winding angle, not directly proportional with increasing the number of layers of this natural fibre tubes. Even though with good strength, the kenaf filament wound composite tubes had a significantly lower results when compared to e-glass, basalt and carbon reinforced epoxy tubes. The kenaf/epoxy tubes were tested to identify the potential of epoxy resin to be reinforced with natural fibres in load-bearing applications. Instead of polyester resin that is practically compatible to combine with kenaf fibre, the epoxy resin showed a better combination with kenaf and also with basalt, e-glass and carbon fibres materials which are created a lot of ideas to extending their usage especially in the low load bearing product where the application that does not require a very high modulus material.

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