Experimental Study of the Mechanical Properties of Kenaf Fibers Epoxy Biocomposites with various Fiber Volume Contents

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ABSTRACT

This article aims at investigating the mechanical properties of kenaffibres epoxy biocomposites with various fibre volume contents. Ukam plant (kenaf)fibres are natural fibers which have many advantages capable of making them suitable reinforcement for composite development. In this article, density tests were carried out on kenaf fibers and epoxy resin while tensile tests were carried out on kenaf fiber polymer composites. Six samples ranging from 0% to 50% fiber volume fractions were studied. From the results, the liquid density of epoxy resin is 1.10g/cm^3 and cured density of epoxy resin is 1.03g/cm^3. The ultimate strength obtained from the stress against strain graphs were between 14.00MPa and 88.8MPa while the highest value of Young's Modulus at 50% fiber volume fraction is 10.67GPa. This shows that mechanical properties of fibre reinforced composites increase with increase in fibre volume fractions.

Keywords: *kenaf fiber, composite, density, ultimate strength, Young's modulus.*

1.0 INTRODUCTION

Biocomposites or biodegradable composites are the next generation in sustainability of building materials and structures. Biocomposites is one of main materials that are currently used in green buildings. Basically, natural fiber reinforced composite materials are materials that are sustainable, environmentally friendly, economically viable and healthy place to live and work **(Jamaludin*et al.,* 2011)**.These materials ensure that sustainability is achieved not only for the present day but for future generation.

Nowadays, biocomposites have been the subject of the extensive research specifically in construction and building industries due to their many advantages such as light weight and lower manufacturing costs. Biocomposite is the combination of natural fibers (biofibers) such as kenaf, jute, sisal, flax and rice straw with polymer matrices from both renewable and non-renewable resources that are competitive with synthetic fiber reinforced composites **(Richardson, 2008).**

There is interest growth in the use of biofibres as reinforcing components for both thermoplastic and thermoset matrices because of the special benefits offered by biofibres such as convenient renewability, biodegradability, low density, high specific strength and environmental friendliness. **(Jamaludin*et al.*,2011).**The utilization of biofibers has gained attention due to the reduction of waste disposal problems especially in agricultural fields, environmental pollution can be foundin various applications in engineering, building product, electronic and automotive fields**(Nishino *et al.*, 2003)**. In addition, biocomposites can decrease wearing of machines due to its low abrasiveness and absence of health hazard during processing, application and upon disposal **(Joshi *et al.*, 2003).**

The use of kenaf fiber as reinforcement has grown substantially in the past decade. Kenaf is one of the examples of the plant bast fiber other than flax, hemp and jute. Kenaf fiber known as Hibiscus Cannabinusis an annual herbaceous plant that originated from Africa. It has traditionally been a source of bast fiber in India, Iran, China, Bangladesh, Nigeria and Thailand. **(Shinichi *et al.*, 2005).**

As we approach the 22nd century, there is a greater awareness of the need for materials in an expanding world population and increasing affluence. At the same time, we are aware that our lands are filling up and our resources are getting deteriorated.Our planet is being polluted;non-renewable resources will not last forever.The need for environmentally friendly materials should however be taken into consideration.

Although, kenaf fibers have been introduced but still lots of research has to be done for improvements. Kenaf cultivation reveals that natural fibers could reduce the amount of carbon dioxide(CO_2) emissions. Kenaffibers tend to be more sustainable compared to glass fibers.

Fiber reinforced polymer (FRP) composites based on glass, carbon and aramid were introduced and until now was applied to the area of construction such as buildings, bridges and pipelines. Glass fibers are produces from silica from sea sand. However, sea sand will run out if been used continuously and the production of glass fiber will be adversely affected**(Nurulhuda, 2008).**

Biofibers have many desirable performance qualities including high temperature resistance, excellent thermal insulation, sound-damping properties and corrosion resistance. Among the various biofibers, kenaf fibers are chosen because it is a good potential reinforcement in polymeric materials. Further research has to be done to develop the suitability of kenaf fibers as reinforcements in structures in order to produce more economical polymer biocomposites, **(Muhammad and Bin, 2008).**

The main objectives of this article are:

- To study the physical properties of kenaf fiber epoxy biocomposites
- To investigate themechanical properties of kenaf fibers epoxy biocomposites with various fibre volume contents.

2.0: METHODOLGY

2.1: Sample Procedures

The samples were prepared after the mould was set up. Six samples were prepared according to the required size of 200mm x 25mm x 6mm as shown in Figure 2.1. One of these samples has no fibers(control sample). The control sample is used as a reference to observe the fiber contribution in the strength of the composite. The other five samples were prepared with different fiber volume fractions -10 %, 20%, 30%, 40% and 50%

The moulds were arranged on the transparent plastic A4 size. The transparent plastic was used as a base to absorb heat from epoxy resin and to avoid the sample from sticking to the base. It also gives a smooth surface to the sample afterward. A small amount of hardener is added to the resin to speed up the reaction. Methyl Ethyl Ketone Peroxide (M.E.K.P) is a hardener used with the epoxy resins. A total weight of solution is 2.99N after adding the hardener. The mixture is stirred for few minutes until it was properly mixed together.

Before casting the samples, the moulds were arranged properly on the table and clamped with G-clamp. A wax was layered inside the mould to ensure partial hardening of the sample and also for easier cutting out from the mould and to avoid the sample from sticking to the mould. Then, the fibers were put manually in the mould. This process is called hand lay-up technique. However, no fibers were needed for preparing the control sample. Therefore, for preparing kenaffiber reinforced polymer composite samples, the fibers are properly arranged as shown in Figure 2.2. A small stick was used to arrange the fibers according to the alignment and to ensure that the fibers dispersed properly in the mould. A roller was also used to ensure that the fibers were properly arranged.

After 45 minutes, which was the time for the epoxy to partially harden, the sample was cut out from the mould by using a cutter. Then, the samples cured under room temperature for 24hours. All samples were roughed at the end of the tab by using chisel. The roughening process is to create a rough surface on the sample for gripping purpose during tensile test as illustrated in Figure 2.3.

However, before conducting a tensile test, the strain gauge was installed at the centre of each sample. Two strain gauges were installed at each sample at vertical and horizontal directions by using super glue as shown in Figure 2.4. The type of strain gauge used was BFLA-5-8 which was the only suitable strain gauge for composite samples. The strain gauge was installed to determine the strain value.

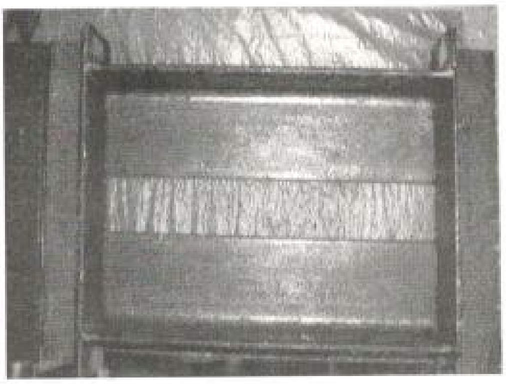

Figure 2.1: Mould used for curing the samples

Figure 2.2: Fibers arranged inside the mould

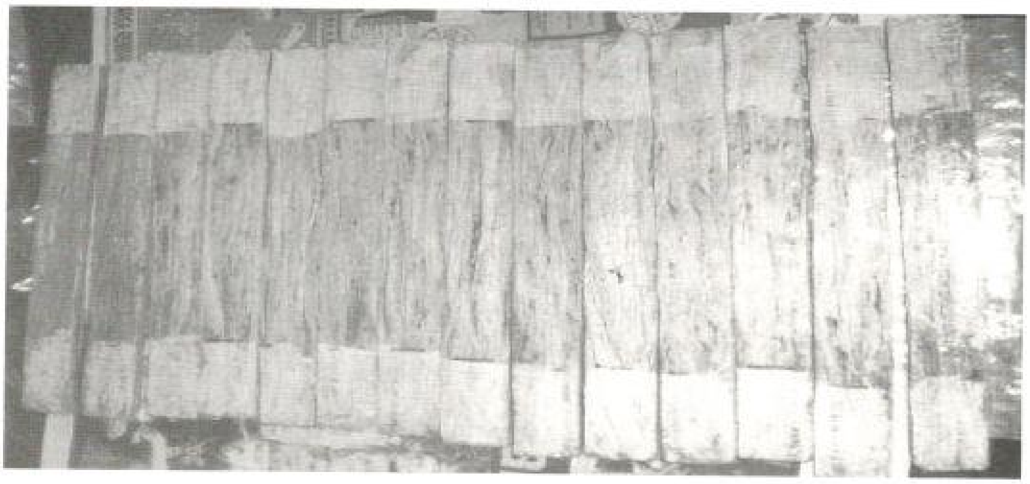

Figure 2.3: Samples after roughened at the end

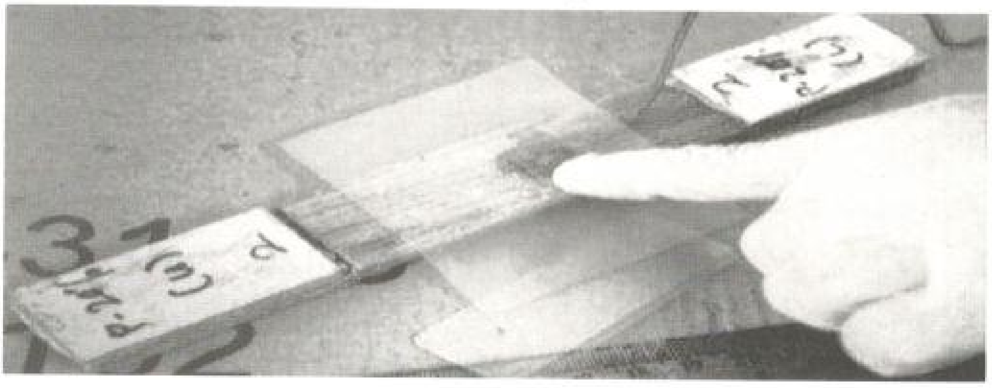

Figure 2.4 Strain gauge installed on the sample

2.2: Testing Methods

Two density tests were conducted on the fibers and resins. The other test was tensile test on composites. Density test was carried out by using Mettler Toledo. The Buoyancy Method was applied in a density test. This method was attributed to the water because of the ability of the fibres to float on water due to their high cellulose contents.

2.2.1 Density Test

2.2.1.1 Density Test on KenafFiber and Epoxy Resin

Before conducting the test, kenaf samples were curled together to reduce the void between the fibers as shown in Figure 2.5.

The density of kenaffibre (ρ) was obtained using equation 2.1 while that of the resin also using equation 2.2.

$\rho = A / (A–B) \times \rho_0$ (g/cm^3).. (2.1)

Where

ρ = Density of the solid

A = Weight of the solid in the air

B = Weight of the solid in the auxilliary liquid

ρ_0= Density of the auxiliary at the given temperature (27.2 ^{0}C) = 0.9948

Density, $\rho_r = M/V$ (g/cm^3).. (2.2)

Where

ρ_r= Density of the resin

M = Mass of the resin

V = Volume of the resin

Figure 2.5: Kenaf samples for density test

2.2.1.2 Tensile Test

The mechanical testing methods that were carried out were based on American Standard Testing Methods (ASTM), namely Tensile Test (ASTM D3379-75). Universal Testing machine of standard ASTM E139was used at cross-head speed of 0.10mm/sec in carrying out the tensile test.

3.0: RESULTS

The tests conducted were density and tensile tests. The density results were obtained using equations 2.1 and 2.2. However, tensile test was conducted using Universal Testing Machine. A stress against strain diagram was obtained from the test. The mechanical properties of kenaf fiber obtained from the test were ultimate tensile strength and Young Modulus, *E*. The performances were compared between samples without fibers and samples with increasing fiber contents. The results are presented in the tables 3.1-3.3 and figures 3.1-3.6.

3.1 Density Test

3.1.1 Density Result of Epoxy Resin

The density results of epoxy resin obtained from the experiment were compared with liquid and cured epoxy resins.Table 1 shows the liquid density result of epoxy resin while Table 2 shows the cured density result of epoxy resin, from the experiments carried out.

Table 1: Liquid Density Result of epoxy Resin

Samples	Height, H (m)	Diameter, Ø (m)	Mass, M (g)	Volume, V (m^3) 10^{-6}	Density, ρ (g/cm^3)
1	0. 01	0. 06986	0. 0399	3. 833	1. 041
2	0. 01	0. 06986	0. 043	3. 833	1. 122
3	0. 01	0. 06986	0. 0428	3. 833	1. 117

4	0. 01	0. 06986	0. 0421	3. 833	1. 098
5	0. 01	0. 06986	0. 0423	3. 833	1. 104

Table 2: Cured Density Result of epoxy Resin

Samples	Average Thickness, t (cm)	Average Area, A (cm^2)	Volume, V (cm^3)	Density, ρ (g/cm^3)
1	0. 580	2. 602	10. 558	1. 075
2	0. 556	2. 685	10. 442	0. 929
3	0. 571	2. 612	10. 440	0. 979
4	0. 539	2. 628	9. 914	1. 044
5	0. 561	2. 706	10. 626	1. 111

3.2 Tensile Test

3.2.1 Stress against Strain Diagrams

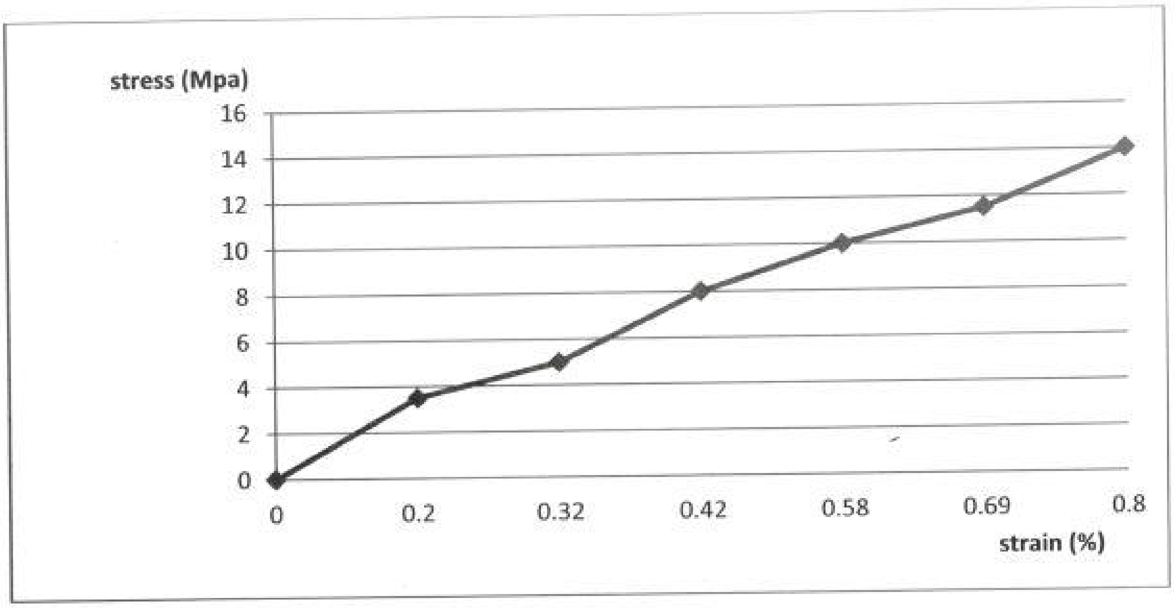

Figure 3.1 Stress against Strain for control sample (neat)

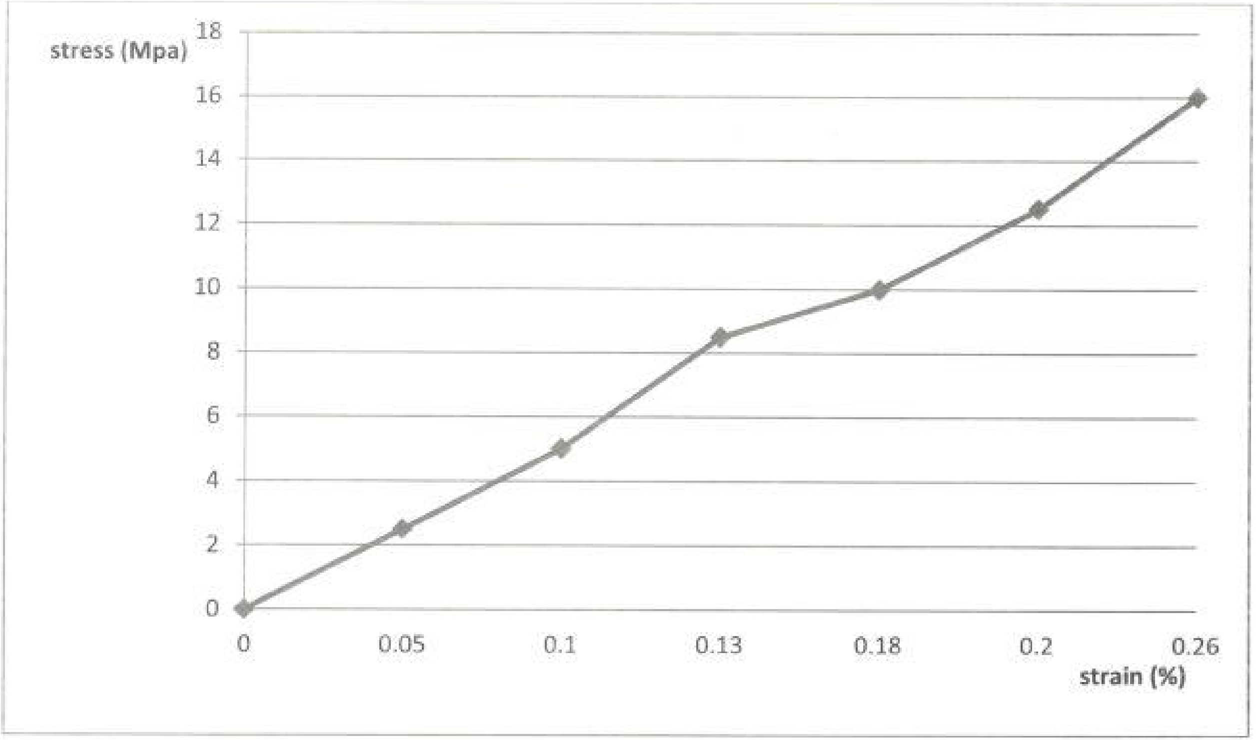

Figure 3.2 Kenaf Fiber epoxy Biocomposites Samples at 10% volume fraction

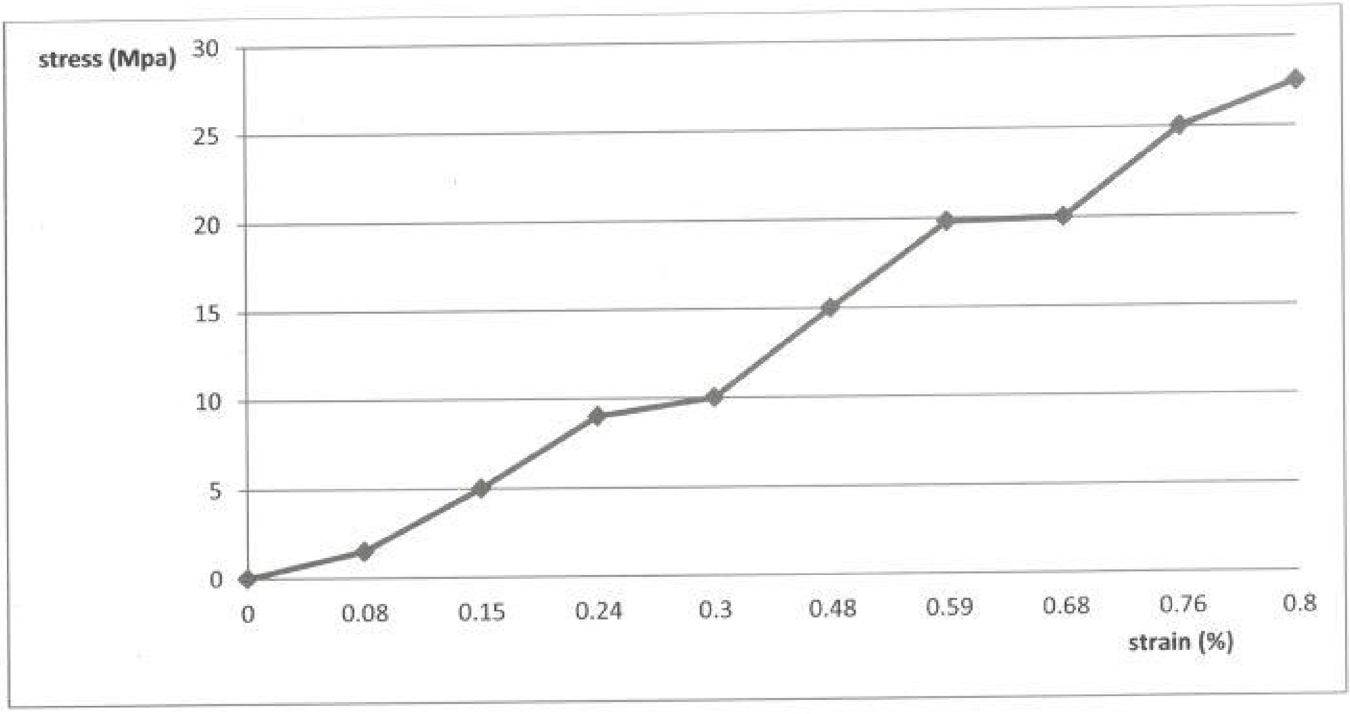

Figure 3.3: Kenaf Fiber Epoxy Biocomposites Samples at 20% volume fraction

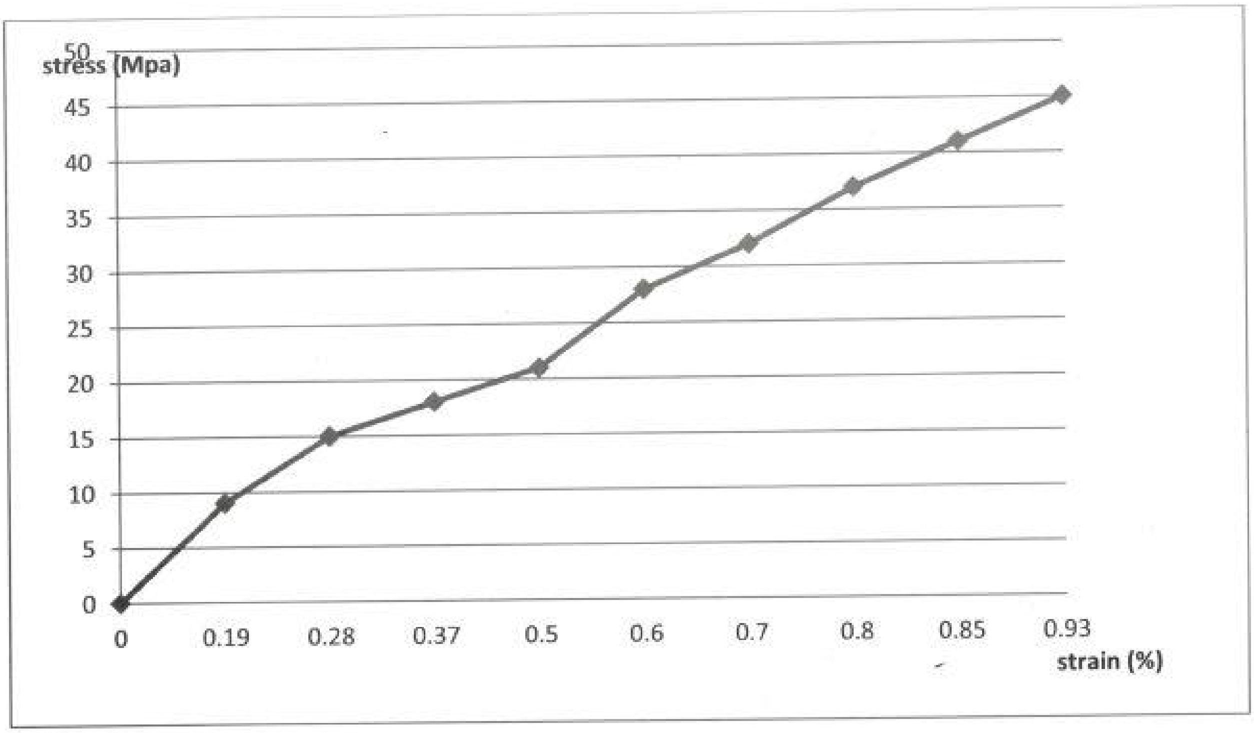

Figure 3.4: Kenaf Fiber Epoxy Biocomposites Samples at 30% volume fraction

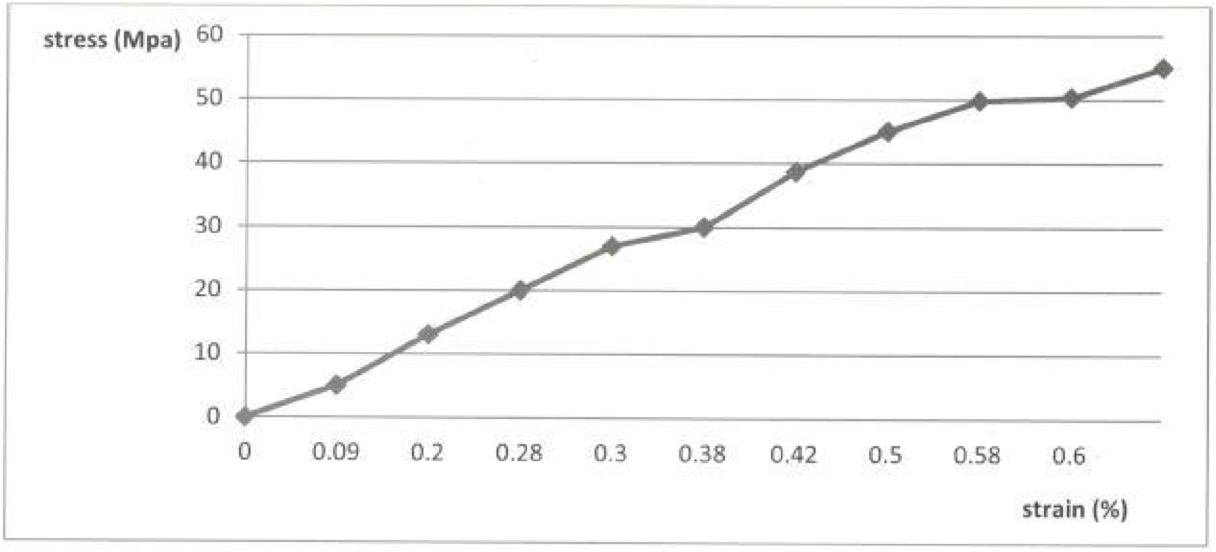

Figure 3.5: Kenaf Fiber Epoxy Biocomposites Samples at 40% volume fraction

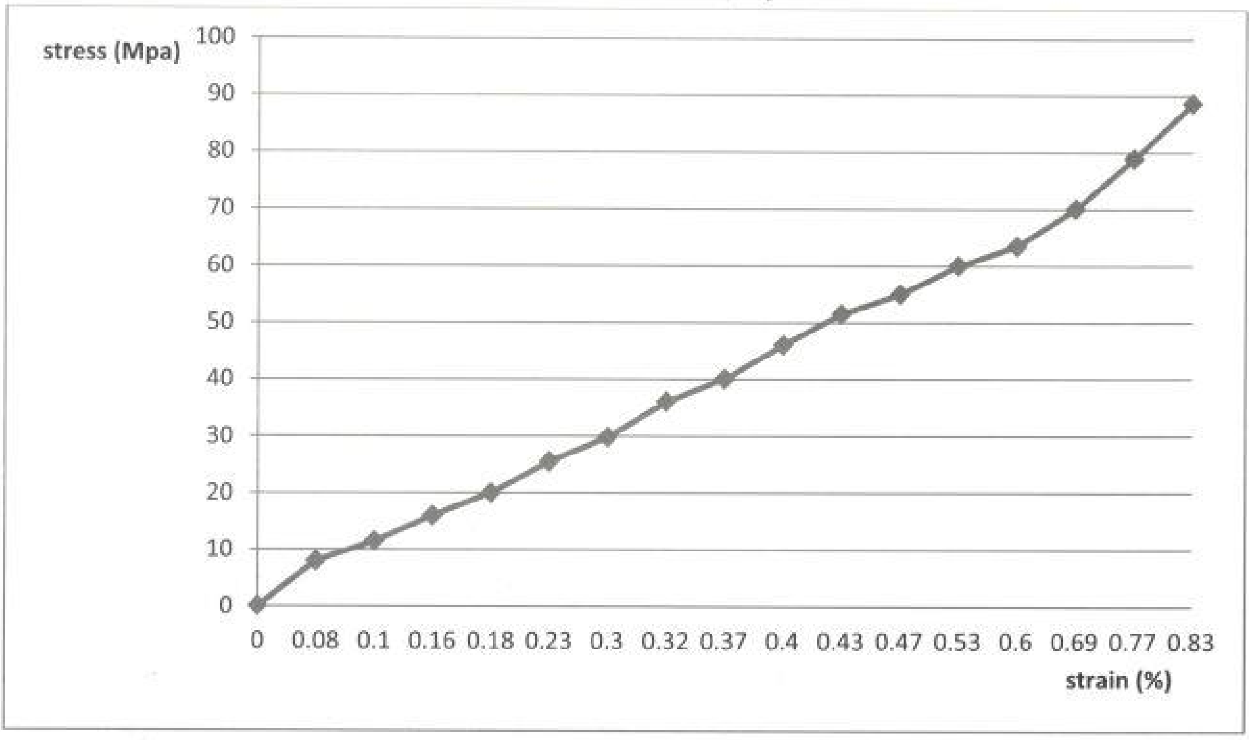

Figure 3.6: Kenaf Fiber Epoxy Biocomposites Samples at 50% volume fraction

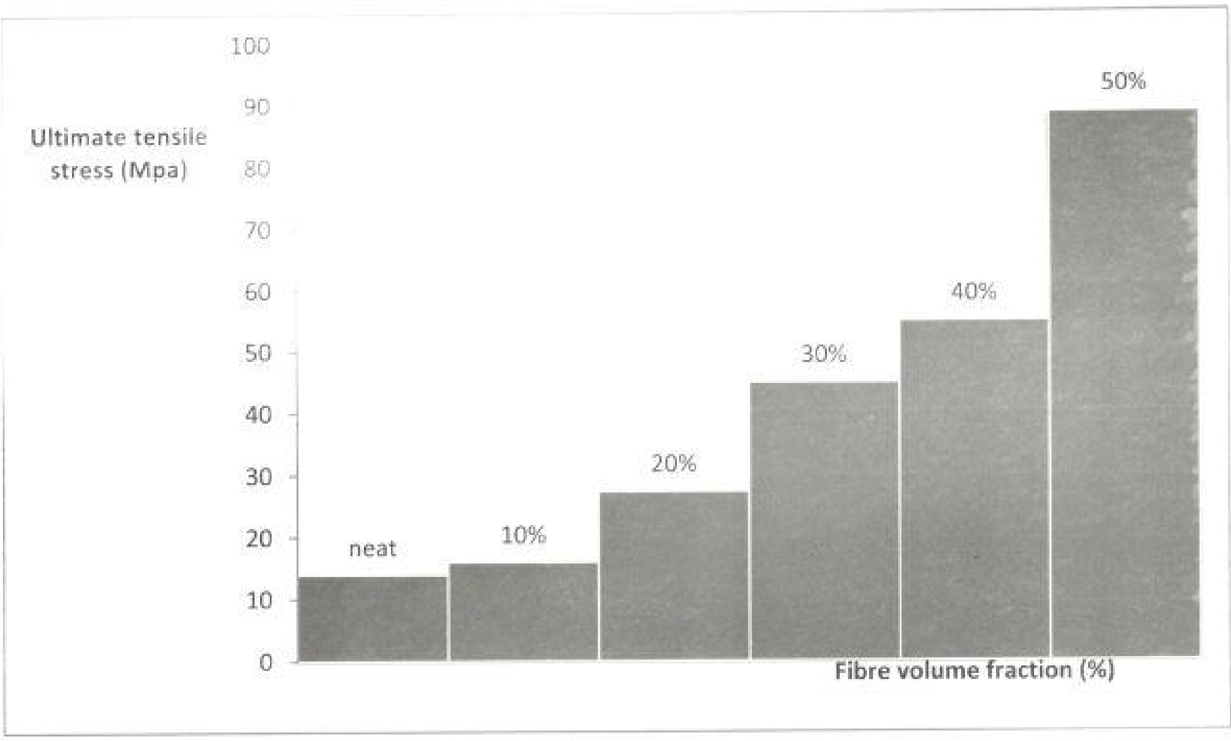

Figure 3.7: Ultimate Tensile Strength (MPa) against Fiber Volume Fraction (%)

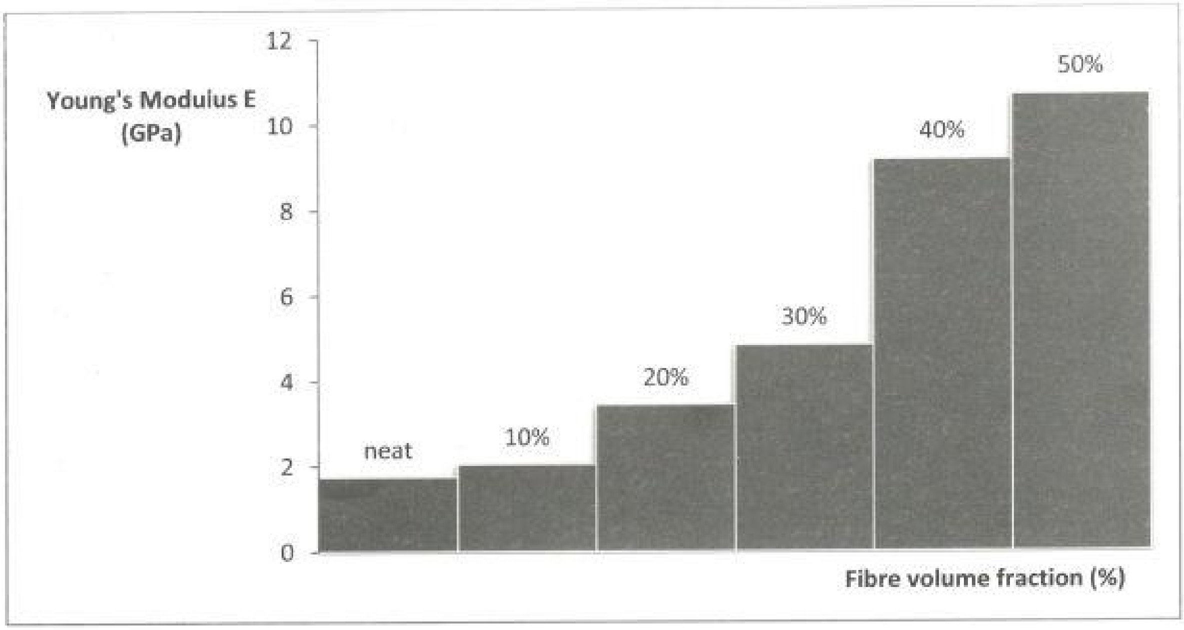

Figure 3.8: Young Modulus (GPa) against Fiber Volume Fraction (%)

DISCUSSIONS

The average density of the epoxy resin in liquid was 1.10g/cm³ while that of the cured epoxy resin was 1.03g/cm³. This shows that the liquid epoxy resin is denser than the cured one. This also shows that epoxy resin is denser than water with density of 1.0g/cm³. Thus epoxy resin submerges in water due to its higher density value.

All the samples,Fig. 3.1-3.6, show the same behaviour where the graph started to rise and failed at a certain point. For control sample (neat) which contains no fibers, the highest strength is 14.00Mpa.In the case ofKenaf Fiber Epoxy Biocomposites with 10% volume fraction, the highest strength is 16.00MPa while for 20% volume fraction, the highest strength is 27.50Mpa.

KenafFiber Epoxy Biocomposites at 30% volume fraction yielded ultimate tensile strength of 45.00Mpa. For 40% increment, the maximum strength is 55.00Mpa. However, for Kenaf Fiber Epoxy Biocomposites at 50% volume fraction, the ultimate tensile strength is 88.60Mpa. This shows that the tensile strength of kenaffibre reinforced composites increase with increase in fibre volume fractions.

Figure 3.7 indicates the variation of ultimate tensile strength against fiber volume fraction of Kenaf Fiber Epoxy Biocomposites (KFEB). Through careful observation, the greater value of ultimate tensile strength (UTS) is due to the increase in fiber volume fraction.

Mechanical properties of natural fiber reinforced composites rely on factors such as matrix phase on curing issues, interfacial bonding between matrix and fibers. The arrangement and orientation have significant influence on the strength of composites **(Ugoamadi, 2011).**

The highest ultimate tensile strength (UTS) achieved was at 50% sample, the result obtained being 88.60MPa. The increase in the strength of the fibers might be due to the amount of fibers available to absorb the stress. As the quantity of fiber content increases from 10% to 50% samples, the strength of Kenaf fiber Epoxy Biocomposites (KFVB) sample increases. Appropriate orientation of fibers ensures high load transfer to the entire composite **(Enetanya, 2000).** However, the bonding between the fibers and matrix will start to deteriorate as the fibers become too close to each other. As a result, the tensile strength will decline due to the bond failure of the composite caused by the excessive fiber content.

It can be observed from Figure 3.8 that the Young's Modulus increases with increase in the fiber volume fraction of KenafFiber Epoxy Biocomposites (KFEB). The result obtained for each increment from neat to 50% samples shows that the highest Young's Modulus of 10.67GPa was obtained at 50% volume fraction,while the lowest value of 1.75GPa was obtained at the 0% volume fraction.Between 10% and 50% samples the Young's Modulus increasesfrom 2.04GPa to 10.07GPa. The high value of the Young's Modulus was dependent on the increased amount of fiber content. However, the compatibility between fibers and matrix which leads to their high interfacial bonding also contribute to the increase intheir Young's Modulus values(**Ude*et al.*, 2010).**

4.0: CONCLUSION

The research was carried out to investigate kenaf fibers as reinforcement in polymer composites. The article was on the mechanical properties of kenaf fibers and the effect of fiber content on tensile strength of composites.

All the stress against strain diagramspresented the same linear pattern. This means that the tensile strength of FRP composites increases gradually with fiber contents.

Further research on kenaf fiber epoxy biocomposites should be encouraged for the purpose of contributing knowledge to the development of kenaf fibers as reinforcements in composite developments.Kenaffibre reinforced composite which is six times less in weight than an equivalent size of steel and two times less in weight than an equivalent size of concrete exhibits similar mechanical properties.

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