Journal of Materials Science Research and Reviews

2(4): 474-479, 2019; Article no.JMSRR.51970

Hybrid Thermosetting Composite of Kenaf/Banana Fibres for Utilisation in a Passenger Car Bumper

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Authors' contributions

This work was carried out in collaboration among all authors. Author EUA designed the study and carried out the material processing. Authors CSE, GON and AAA performed the statistical analysis. Author OSM, CCO and OM proofread the manuscript. Authors FCN and ION managed the analyses of the study. Author CCI supervised and approved the R&D. All authors read and approved the final manuscript.

Article Information

Editor(s):
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Complete Peer review History: http://www.sdiarticle4.com/review-history/51970

Original Research Article

Received 28 August 2019
Accepted 01 November 2019
Published 07 November 2019

ABSTRACT

Due to the high performance material requirement for automotive application and impact sensitivity of car bumper as one of the main car parts used as protection for passengers from collision and the safety requirement of the material to improve crashworthiness during low impact collision was the essence of composite material hybridisation. Thermosetting hybrid kenaf/banana composites

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were fabricated after chemical modification of fibres. hand-lay up contact molding techniques were used for material fabrication. Fibre loading were set at 50% weight of the matrix with the hybrid materials at 1:1 ratio of short non-woven randomly oriented fibres, The catalyst and accelerator was added 2-3% by weight of the matrix. Hybrid material were hand-laid in the mold and the matrix were gradually applied to the fibre network in the precision, coverage and dimension of the mold. The fabricated materials were left to cure at ambient temperature for 24hrs. The tensile and flexural tests were carried out using Testometric testing machine, Model M500-25KN. In accordance to ASTM D638-90 and ASTM D790-90 respectively. The results showed improved mechanical properties for hybrid kenaf/banana composite than composite of kenaf and banana fibres reinforcement. Hybrid kenaf/banana composite (HK/B-C) at 50% fibre optimum loading shows improvement on mechanical properties of the composite than that of kenaf composite (K-C) and banana composite (B-C) respectively . Hybrid materials are being developed and design aiming to improve mechanical behaviour and application performance polymeric materials.

Keywords: Hybrid; car bumper; mechanical properties; composites.

1. INTRODUCTION

Modern materials require hybrid combination that cannot be met by monolithic materials especially for automotive material development. This is why Engineers and Auto-manufacturers are researching for smart materials in such a way that composite materials appear with a certain desired properties for high performance. Hybrid materials have many advantages over conventional materials. Most hybrid materials are made with light-weight components with significantly higher mechanical properties. The most potent way to improve the mechanical properties of natural fibres is to hybridize two different fibres for a better enhancement [1]. Hybrid fibre composites are attractive in automotive application because of reduced weight and cost. Hybrid composites are combined approach of two or more natural fibres into a single matrix for a balanced material performance. The material performance of hybrid composites are regarded as a sum behaviour of the individual reinforcement. With proper material design in hybrid composite one type of fibre could compensate for aspects performance that are lacking in the other [2].

kenaf fibre has being specifically reported by ford auto-manufacturers as a high performance economic material for saving over 300,000 pounds of oil based resin per year, with improved fuel economy and reduced weight [3]. Banana fibre is an extract from banana stem after harvesting of the fruit as the pseudo-stem has no regular or industrial use. The fibres appears to be strong, soft, flexible and coarse. Banana fibre has showed open opportunities for engineering materials application including automotive use due to good strength properties [4-5]. According to the food and Agricultural Organisation (FAO) report of 2009, farmers harvest around 35 million tons of natural fibres which has played fundamental role in the society by contributing to food security and poverty Alleviation [6]. Ligno-cellulosic fibres are inexpensive and are the most abundant polymers on earth, renewable with guaranteed industrial supply at all time. Natural fibres contribute to a large extent, the structural performance of polymer composites [7].

Thermosetting fibre composite materials has been reported and used in manufacturing so many automotive parts, in construction and in critical components in aerospace industry [8]. In Europe, approximately 1 million tonnes of composites are manufactured each year [9]. Their advantages include light weight, low-energy production and sequestration of carbon dioxide reducing the "greenhouse effect" [10]. Thermosets applications are wide due to their good adhesion, high thermal and chemical resistance and excellent mechanical properties [11].

The significance and potential of composite materials for automotive industry has increased because of the light weight and its environmental friendliness. Natural fibre composite could contribute to 20% cost reduction and 30% weight reduction of an automotive part which leads to lower fuel consumption and reduced greenhouse emission [12]. The socio-economic development of composite materials are enormous as the future holds a lot in their application pathways across many different industries.

2. MATERIALS AND METHODS

2.1 Materials

Naturally extracted banana (*musa sapentium*) and kenaf (*Hibiscus cannabinus)* fibres were obtained from experimental garden of Polymer

Table 1. Physical and mechanical properties of crude kenaf and banana fibre (Akubueze et al.2015)

S/N	Properties	Kenaf fibre	Banana fibre
1	Cellulose (wt%)	57.7-69.2	55.02-60.5
2	Lignin (wt%)	19.2-20.0	8.50-10.07
3	Hemicellulose (wt%)	18.06-20.03	12.05-18.00
4	Ash (wt%)	0.6-2.23	0.8-2.45
5	Moisture (wt)	8.5-10.05	9.01-10.89
6	Tensile Strength(MPa)	550-816.7	400-650
7	Elongation@Break(%)	1.4-2.8	1.8-2.6
8	Young"s Modulus(GPa)	20.0-39.0	25-36
9	Fibre Length(mm)	2.0-2.7	1.50-2.8
10	Fibre Diameter(µm)	17.7-21.1	15-25
11	Density (g/cm^3)	1.27	1.3

and Textile Technology division, Federal Institute of Industrial Research Oshodi, Nigeria. The matrix used (unsaturated polyester resin), catalyst and accelerator (cobalt naphthenate and methyl ethyl ketone), PVA as mold releasing agent were supplied by Tony Nigeria Enterprises, Ojota, Lagos, Nigeria.

2.2 Modification of Fibres

Mercerisation process was employed for fibre modification which has been research proven for extracting lignin and hemicellulose in a control conditions. Lack of interfacial adhesion between the hydrophilic fibres as a reinforcement material with the hydrophobic polymer matrix as a binder has been addressed by so many researchers by the use adhesion enhancement agents such as compatibilizers, coupling agent and chemical modifying treatment. The present study applied Alkali treatment. Naturally extracted fibres were modified with 10% wt NaOH solution for 2 hours. Followed by continuous washing and drying at 10ºC.

2.3 Hybrid Composite Fabrication

Fibre loading were set at 50% weight of the matrix with the hybrid materials at 1:1 ratio of short non-woven randomly oriented 60mm chopped fibres, which gave a total batch production weight of 100% hand layup process. The catalyst and accelerator was added as 2-3% by weight of the matrix. The materials were mixed and stirred at low speed. Releasing agent was applied to the mold and allowed to dry for 5 minutes. Hybrid material was hand-laid in the mold and the matrix were gradually applied to the fibre network in the precision, coverage and dimension of the mold. The fabricated materials were left to cure at ambient temperature for 24hrs. The tensile and flexural tests were carried out using Testometric testing machine, Model M500-25KN, at Material Testing Laboratory of FIIRO.

2.4 Mechanical Test

The fabricated hybrid composite material were cut into required dimension for mechanical testing. In each test, three samples were tested and their mean value were reported.

2.5 Tensile Strength

The tensile test specimen were prepared according to the ASTM D638-90 standard. The dimensions (150 mm x 30 mm x 5 mm) and cross-head speed of 200 rev/min were chosen. The specimen was mounted and subjected to tension in a testometric testing machine Model M500-25KN. The specimen were tensioned till failure and the respective loads and extensions recorded digitally by the machine.

2.6 Flexural Strength

The flexural specimens were prepared according to the ASTM D790-90 standard, by 3-point flexure test on hybrid composites. The specimen deflection were measured by the crosshead position. Flexural test measures the force required to bend the material under three point loading condition.

2.7 Material Absorption Measurements

2.7.1 Water absorption test

The effect of water absorption on hybrid composite material was investigated and performed according to ASTM 570-98 by subjecting the hybrid composites to an aggressive hydrothermal condition of 90ºC for 5 hours [13].

$$W.A = [(W_1 - W_0)/W_0] \times 100$$

Where:

W_0 = Weight of material before aggressive condition
W_1 = Weight of material after aggressive condition for a period of time

3. RESULTS AND DISCUSSION

3.1 Effect of Hybrid Kenaf/Banana Composite on Tensile Strength

The hybrid Load carrying material showed significant reinforcement effect with the matrix as the strength and rigidity increased. The illustration in the Fig. 1 shows strength enhancement from 43.7 Mpa (banana composites), 45.6 MPa (kenaf composites), to 55.5 MPa hybrid kenaf/banana composites.

3.2 Effect of Hybrid Kenaf/Banana Composite on Flexural Strength

According to Fig. 2, the hybrid kenaf/banana fibres significantly affected the flexural strength of the composites. The flexural strength increased from 60.0 MPa (banana composite), 63.7 MPa (kenaf composite), to 68.5 MPa hybrid kenaf/banana composites. This indicated that fibres hybridisation increase the stiffness of the composite.

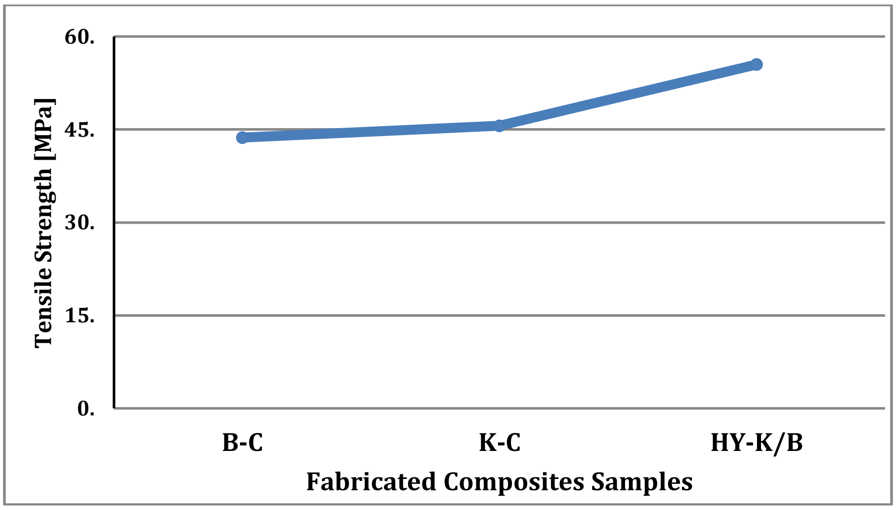

Fig. 1. Tensile strength of banana fibre composite (B-C), Kenaf fibre composite(K-C) & hybrid Kenaf/Banana composite (HY-K/B)

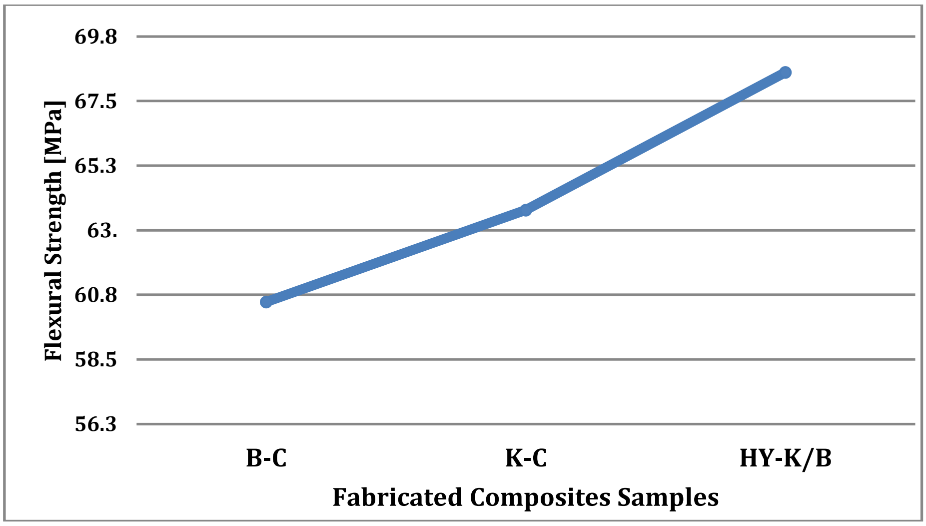

Fig. 2. Flexural strength of banana fibre composite (B-C), Kenaf fibre composite (K-C) & hybrid kenaf/banana composite (HY-K/B)

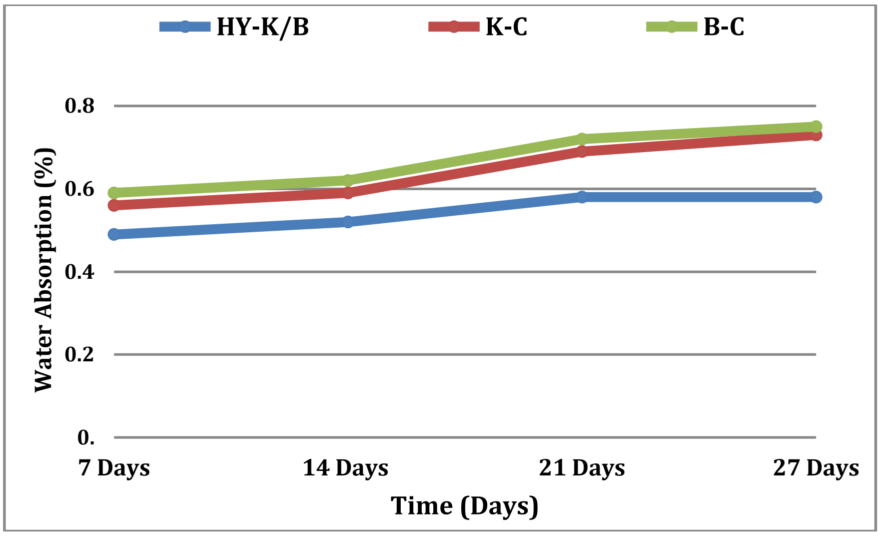

Fig. 3. Water absorption behaviour of hybrid kenaf/banana Composite (HY-K/B), kenaf fibre composite (K-C) & banana fibre composite (B-C) and time of immersion

3.3 Effect of Hybrid Kenaf/Banana Composite on Water Absorption

The effect of hydrophilic fibres on water absorption characteristics of Banana Fibre Composite (B-C), Kenaf Fibre Composite (K-C) & Hybrid Kenaf/Banana Composite (HY-K/B) was investigated. The test specimen was subjected to aggressive condition. The water absorption was determined by measuring the mass percentage changes. The result presented in Fig. 3 shows a lower moisture uptake for hybrid composites. The alkaline modification pathway disrupted the hydrogen bonding in the network structure, thereby removing lignin, increasing surface roughness and interfacial bonding with hydrophobic matrix. Alkali treatments have been reported and proven effective in removing impurities from the fibre, decreasing moisture sorption and enabling mechanical bonding and thereby improving matrix reinforcement interaction as one the major defect associated with the use of natural fibres in composites materials are their high moisture sensitivity leading to severe reduction of mechanical properties [14].

4. CONCLUSION

The mechanical behaviour of kenaf/banana hybrid fibres composites were studied.

- From the results it was observed that the hybrid kenaf/banana fibres reinforced unsaturated polyester composites shown better mechanical properties when compared with kenaf fibre reinforced unsaturated polyester composite and banana fibre reinforced unsaturated polyester composite
- The behaviours of hybrid composites can be regarded as sum performance of the individual components in which there is a more favourable balance and superior properties.
- Hybrid composites are an effective way of improving the quality of parts regarding the economic and technical feasibility.
- Tensile and flexural strength test are the critical control for performance evaluation of composite material.
- Reducing the weight of the material used in automotive application without compromising material safety and integrity will increase fuel efficiency.
- Energy absorption capacity is more in hybrid composites than single carbon fibre composites.
- Continuous development of hybrid composites materials, optimisation of fibre -matrix synergy, nano-sizing of filament and particulate fibres, engineering and re-enginering of thermoset and/or thermoplastic will bring the expected improvement for the properties of composites materials.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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ISSN:2277–4106,ISSN:2347-5161.

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Peer-review history:
The peer review history for this paper can be accessed here:
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