JMME. Vol. 12 September 2019 *ISSN: 2006-1919*
pp. 63-68

INVESTIGATION OF FLEXURAL AND IMPACT STRENGTH OF SISAL/GLASS HYBRID FIBER REINFORCED EPOXY COMPOSITES

I.C Ezema Ike-Eze [1*], V.S Aigbodion[1], A.D Omah[1], S.N Ude[1] and S.O. Edelugo[2]
1. Department of Metallurgical & Materials Engineering, University of Nigeria Nsukka
2. Department of Mechanical Engineering, University of Nigeria Nsukka
** Corresponding author: ikechukwu.ezema@unn.edu.ng;*

ABSTRACT

In this work, hybrid composites of unsaturated epoxy reinforced with sisal/glass hybrid fiber composites were prepared. The sisal fibers were surface treated with NaOH and silane solution while glass fiber was used without any treatment. Hand lay-up method was used in producing the composites in which unidirectional sisal fiber and random glass fiber mats were arranged in different patterns. The flexural and impact properties were studied. The results indicated that the flexural strength and flexural modulus of hybrid fiber composite decrease as degree of hybridization increases. The impact strength did not follow any particular trend as a result of hybridization instead it was more sensitive to the fiber arrangement (cross ply lay-up). However it increased with increase in mass fraction of the reinforcements.

Key Words: Polymer, Composite, Hybrid, Sisal, Glass Fiber, Flexural Strength, Impact Strength

1.0 INTRODUCTION

Almost all thermoset and thermoplastic polymers such as epoxy and unsaturated polyester resins are brittle at their pure state at certain temperatures. A great effort is ongoing to reinforce them with materials that will reduce their brittleness, increase their ductility and improve their fracture toughness. The challenges however are the choice of materials that will perform this function without affecting other properties especially thermal and mechanical properties. Bakar [1] reported that various materials and methods have been adopted by researchers such as using solid particles to improve on the mechanical properties of polymer resins. Kunz and Beaumont [2] used rubber particles, Spanoudakis and Young [3] used glass particles while Fellahi et-al [4] used kaolin to toughen epoxy. Also literature has reported the use of fibrous materials in reinforcements; Senthilnathan et-al [5] used a hybrid of coir and human hair fiber to reinforce epoxy which can find application in the aircraft, automobile industries and sports equipment etc. Abdul [6] used carbon fibers to reinforce epoxy which improved the wear resistance of the matrix. Yan et-al [7] reported of sisal fiber as a promising fiber for reinforcement of polymer matrices.

Sisal (Agave sisalana) from agave plant family can grow fast in many parts of the world and it has high multiplication capacity. Tanzania, Brazil and India are the chief producers of sisal [8]. The plant is known by its leaves which grow to a length of over one meter and its yield of strong fiber. Sisal plants can be grown from seeds of matured plants in almost all kinds of soil but the most common replication of planting is vegetative propagation through suckers and bulbils, [9]. The first cutting of leaves of sisal plant takes place 36 to 42 months after planting, and averages 25 mature leaves per plant. indicating maturity as most of it assume horizontal position and show other signs of maturity [10]. Harvesting is carried out by hand. All leaves, standing at an angle of more than 45 degrees to the vertical, are cut away close to the stalk with a sharp knife [11].

Extracted fibers are extensively washed during decortination and retting, sun dried, brushed to separate and align the individual fiber strands, graded and packed into bales for marketing. Sisal like every other natural fiber is renewable and cheaper but their mechanical properties are much lower than the synthetic fibers. The synthetic fibers exhibit good mechanical properties but they are costlier and non-renewable. Natural fibers as reinforcement are good and easily processed into fibers but the major drawback associated with their application as reinforcement in polymeric matrices is their high affinity for water due to the presence of hydroxyl and other polar groups. All natural fibers posses high affinity for water, which leads to weak bonding in the fiber/matrix interface [12], but the bonding can be improved by surface treatment of the fibers.

Zhaogian et-al [13] reported improved mechanical properties of polylactacid (PLA) composites as a function of modification of sisal fiber with two different macromolecular coupling agents in comparison with the untreated fibers. Again, Naidu et-al [14] reported increase in tensile strength of sisal/glass fiber hybrid unsaturated polyester composite with chalk powder as additive. Various other materials are been tried in recent times to improve on the bonding of natural fiber /polymer matrix interfacial bonding [15-17].

In this work, sisal fibers mass fractions were surface treated with a combination of NaOH and silane solution and laminated in the same matrix with random E-glass fiber to produce hybrid composites. The aim is to investigate advantage of combining both natural and synthetic fibers to the flexural and impact properties of the composites.

2.0 MATERIALS AND METHODS

2.1 Materials

An epoxy laminating resin and its hardener as well as epoxy silane coupling agent were used as purchased from JuNENG Nigeria Limited. NaOH, Acetic acid, acetone and other solvents were purchased from Altran Chemicals Ltd,Nsukka Nigeria.The sisal fibers were cut from a local plant farm at Ngbakwu Ozi Edem, the leaves were soaked in a flowing stream for two weeks and thereafter, washed thoroughly in a flowing stream and dried under sun for 5 days days. The E-glass fibers were used as obtained from Ndidiamaka Chemicals, Enugu.

a


b


Plate 1: *(a) processed sisal fiber and (b) random E-glass fiber mat*

2.2 Production of Composite Panels

The Nomenclature for different treated sisal, glass and sisal/glass hybrid fiber-epoxy compositeproduced are given in Table 1. Hand lay-up molding method was adopted in the production of the composites.

Table 1: *Nomenclature of fiber-epoxy composites lamina/laminate*

Sample Code	No of plies		Sample pattern	Lamina Pattern	
	Glass (G)	*Sisal (S)*	*G + S Glass + Sisal*	*L=Unidirectional. T= Transverse C=chopped*	*Pattern Description*
0	0	0	0		Unreinforced Epoxy
A	1	1	$S_{UD}15$	L	Unidirectional Sisal-epoxy at 15% sisal fiber mass fraction
B	1	2	$S_{UD}20$	L	Unidirectional Sisal-epoxy at 20% sisal fiber mass fraction
C	1	1	SG	LC	Unidirectional Sisal-glass epoxy composite
D	2	1	GSG	CLC	Unidirectional glass-sisal-glass epoxy composite
E	1	2	SGS-0/0º	LCL	Unidirectional sisal-glass-sisal epoxy composite at $0^O/0^O$
F	1	2	SGS-0/90º	LCT	Unidirectional sisal-glass-sisal epoxy composite at $0^O/90^O$
G	1	1	S_RG	CC	Random sisal-glass- epoxy composite at $0^O/90^O$
H	1	-	G	C	Glass epoxy composite
I	-	1	S_R	C	Random sisal epoxy composite

Prior to moulding of the composites, the treated fibers were dried again under sun for 1 day and in an oven at 50^{o}C for 1 hour to remove all trace of moisture. They were carefully separated from their bundle with hand and comb and were thereafter matted in a unidirectional pattern with polyvinyl acetate soft binder.

2.3 Flexural Strength Test

The flexural strength testing was carried out according to the ASTM D 790 [18] standard test methods respectively for tensile and flexural properties of plastics. Samples were tested using a manual griping universal testing machine model TUE-C100 with serial No 2010132 made by Fine Spavy Associates & Engineers Pvt Ltd WIRAJ 416410 India using an approximate cross head speed of 5mm/min. Each sample was tested at three different fiber orientations 0^o, 90^o, and 45^o and was loaded to failure.

The flexural strength (F_S) was calculated using equation

$$Fs = \frac{3PL}{2bh^2} \quad \ldots\ldots\ldots \quad (1)$$

And the flexural strain is given by equation

$$\varepsilon = \frac{6Dh}{L^2} \quad \ldots\ldots\ldots. \quad (2)$$

With the flexural modulus (F_E) given by equqtion

$$F_E = \frac{L^3 m}{4bh^3} = \frac{L^3 P}{4bh^3 d} \quad \ldots\ldots\ldots. \quad (3)$$

Where P = the load on the specimen, L = length of support span (mm). b = width of the test specimen (mm), h = Thickness of the test specimen (mm), D = maximum deflection at the centre of specimen (mm), m = the slope of the tangent to the straight line portion of the load deflection curve, d = the deflection corresponding to load P = 9.8N.

2.4 Impact Strength Test

The impact test was conducted to measure the toughness of materials using Samuel Demson Ltd Leeds impact testing machine, LS102DE England SN-EXT94064/6705CE with an impact velocity of 5.24m/s. The test was carried out using a universal impact-testing machine based on Charpy test method in which a hammer like weight strikes a specimen and the energy-to-break it determined from the loss in the kinetic energy of the hammer. In Charpy test, the specimens measuring 10mm x 55mm x 4mm were given a 2mm notch of the ball and the impact strength was calculated from the relation of equation (4) in line with the work of Abbas [19]

$$G_c = U/A \ (J/m^2) \quad \ldots\ldots. \quad (4)$$

Where, G_c= Impact strength, U= Energy of fracture in (Joule), A=cross section area in (m^2).

3.0 RESULTS AND DISCUSSION

3.1 Flexural Properties

The flexural properties of composites are presented in Table 2, Figure 1.and Figure 2

Table 2: *Flexural properties of sisal-glass hybrid epoxy composite*

Sample Code	Sample pattern	Peak Load (kN)	Strain ε
O	-	0.8725	0.0861
A	S	0.8667	0.0441
B	S	0.2200	0.0228
C	SG	0.9550	0.0518
D	GSG	0.1267	0.0302
E	SGS	0.4900	0.0230
F	SGS	0.1467	0.0414
G	SG	0.0667	0.0186
H	G	0.0450	0.0266
I	S	0.0328	0.0484

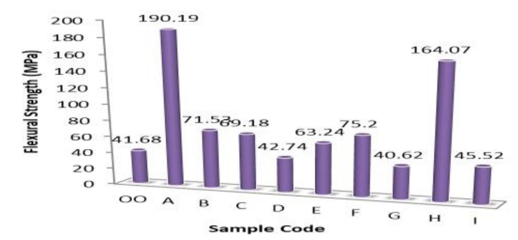

Figure 1: *Effect of hybridization on the flexural strength of sisal-glass fiber hybrid epoxy composite*

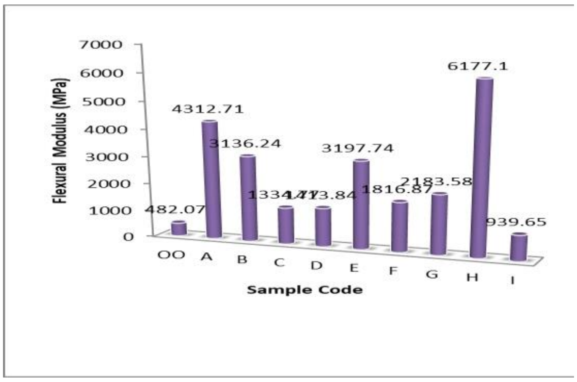

Figure 2: *Effect of hybridization on the flexural modulus of sisal-glass fiber hybrid epoxy composite.*

From Figure 1 and Figure 2, it was observed that the hybrids SG, SGS and GSG exhibited lower flexural strength and modulus while single lamina (non-hybrid) composite such as unidirectional sisal epoxy (sample A and B) and glass-epoxy (sample H) showed higher flexural properties. This seems to show that the flexural properties decreases as hybridization increases. Jie [20] reported that when flexural force is applied on a sandwich composite panel, the outer layer materials carry the load more than the core. However, Jie's [20] report was not well followed here, since GSG that is supposed to have higher flexural properties because of its stronger glass outer layer again is lower than that of SGS. This poor performance can only be attributed to weak bonding between the core sisal (hydrophilic) and the outer layer glass fiber (hydrophobic). Such weak bond will normally be more pronounced under bending forces than tensile forces. Also the flexural failure in the GSG may have initiated and propagated through weak sisal-glass interface rather than glass-epoxy interface observed with SGS.

In summary, from Figure 1 and 2, it was observed that the hybrid composites SG, SGS, GSG showed negative hybrid effect in their flexural properties while all non-hybrid samples of S and G groups showed positive flexural effect.

3.2 Impact Properties

The result of the impact test conducted is depicted in Table 3 while Figure 3 represents the analysis.

Table 3 *Experimental Impact test result of test samples with 0° of fiber orientation*

Sample Code	C.S.A (m^2)	Absorbed energy (J)
O	3.784	0.333
A	2.4	0.467
B	4.13	1.567
C	4.32	0.933
D	3.08	0.267
E	4.56	0.667
F	3.92	1.80
G	3.32	0.367
H	1.48	0.433
I	2.30	0.633

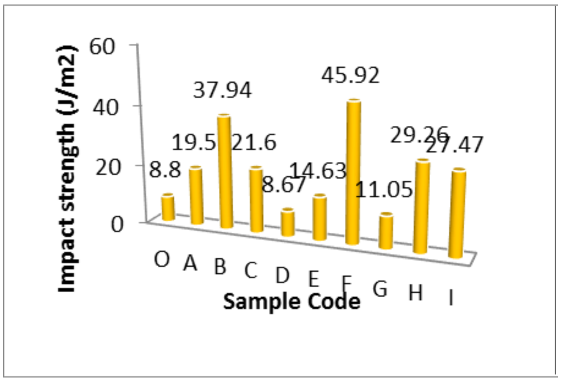

Figure 3: *Effect of hybridization on the impact strength of the sisal –glass epoxy composite*

From Figure 3, It was observed that the impact strength of sample B is higher than that of sample A, which means that impact properties are sensitive to the mass/volume fraction of the reinforcement. It was further observed that the impact strength of the Hybrid composites did not follow any particular trend. The intimately mixed hybrid composites (samples C, D, E) showed low impact strength while samples (B, and F) showed high impact strength. This indicates that impact strength is more sensitive to inter–ply lay ups and angle–ply lay-up rather than simple hybridization, such that the SGS-0/90°

sandwich specimen with cross ply exhibited the highest impact strength of 45.92J/m^2. Again, it was observed that the non-hybrid composites samples (B, H and I) had good impact strength more than the non cross-ply hybrid composites of SG, SGS-0/0^o and GSG (samples C, D and E). In an optimum arrangement, the core ply thickness should be very small such that when a crack tip approaches a fiber, the crack crosses the fiber and cuts them as well as the matrix and then the crack changes its direction and moves through the matrix parallel to the fibers. Such debonding fracture mechanism consumes more energy by creation of more surface area within the sample according to Pothan et-al [21]. The poor bonding between hydrophilic sisal and hydrophobic glass at their interface created an ineffective load transfer from the matrix to the longer sisal fibers. Good bonding at their interface could have allowed the system to absorb more energy because of the flexibility of the longer fiber (sisal in this instance) that will slide out of the matrix but will not break, which amplifies the energy needed to rupture the specimen.

In conclusion, it was observed that the stacking sequence and cross ply arrangement is more important than mere composition, in determining toughness of a hybrid fiber polymer composite. This means that different lay-ups maximize different toughness parameters such as total energy, initiation energy or propagation energy.

4.0 CONCLUSION

The effect of sisal fiber direction and laying sequence on the flexural and impact properties of sisal/glass fiber hybrid reinforced epoxy composites have been studied and the following conclusions drawn

(1) Flexural strength and flexural modulus of a hybrid fiber composite decrease as degree of hybridization increases when compared with non hybrid (single lamina) composites.

(2) The impact strength of the hybrid fiber reinforced composites did not follow any particular trend as a result of hybridization. It was rather sensitive only to the mass/volume fraction and the fiber cross ply /stack sequence arrangements. This means that different lay- ups maximize different toughness parameters such as total energy, initiation energy or propagation energy.

ACKNOWLEDGEMENT

This research was jointly funded by World Bank STEP-B under 2010 Innovators of Tomorrow (IOT) grant and under University of Nigeria disbursement 2010.

REFERENCE

1 Bakar Mohamed, MarcinKostrzewa, Monika Janiszek, Katarzy Borkowska (2005): Properties of Epoxy Hybrid Composites, *Materials Science (Medžiagotyra)*. Vol.11, No. 2. Pp129-132

2 Kunz,S. C., Beaumont, and P. W. R (1981): Low Temperature Behavior of Epoxy-Rubber Particulate Composites *Journal of Materials Science* 16: pp. 3141 – 3152.

3 Spanoudakis, J., Young, R. J. (1984): Crack Propagation in a Glass Particulate-Filled Epoxy Resin.*Journal of Materials Science*19: pp. 473 – 486.

4 Fellahi, S., Chikhi, N., Bakar, M. (2001): Modification of Epoxy Resin with Kaolin as a Toughening Agent. *Journal of Applied Polymer Science*82: pp. 861 – 878.

5 Senthilnathan D, GnanavelBabu A, Bhaskar G.B, Gopinath KGS (2014): Characterization of Glass Fiber – Coconut Coir– Human Hair Hybrid Composites, *International Journal of Engineering and Technology (IJET*) Vol 6 No 1 pp 75-82

6 Abdul Munium Razoki Majeed Algbory (2011): Wear Rate Behavior of Carbon/Epoxy Composite Materials at Different Working Conditions, *The Iraqi Journal for Mechanical and Material Engineering*, Vol.11, No.3, pp 475-485

7 Yan Li, Yiu-Wing Mai, Lin Ye (2000) Sisal fiber and its composites: A Review of Recent Developments. *Composites Science and Technology* 60 (2000) pp 2037-2055

8 Chand N, Tiwary RK, RohatgiP. K. (1988): Bibliography resource structure properties of natural cellulosic fibers Ð an annotated bibliography. *Journal of Materials Science*; 23: pp381-387.

9 Frank E conter: the cultivation of sisals in Hawaii, www.ctahr.hawaii.edu/oc/freepubs/pdf/B-4.pdf; download 12/01/2016

10 Murherjee P. S, Satyanarayana K.G. (1984): Structure and Properties of some Vegetable Fibres, Part Sisalfibre. *Journal of Materials Science* 19 pp 3925-3934.

11 REA Vipingo: Sisal plant and Extraction www.reavipingo.com/extraction.htm; online download 22/10/2014

12 X. Li, Tabil L.G, and S. Panigrahi S (2007): Chemical Treatments of Natural Fiber for use in Natural Fiber-Reinforced Composites: A Review," *Journal of Polymers and the Environment*, vol. 15, no. 1, pp. 25–33.

13 Zhaoqian Li, Xiaodong Zhou and Chonghua Pei (2011): Effect of Sisal Fiber Surface Treatment on Properties of Sisal Fiber Reinforced Polylactide Composite; Int. J of Polymer Science doi:10.1155/2011/803428;

14 Naidu V.N.P, Kumar. M.A, Reddy G.R Khanam P.N, Reddy. M.M and, Chakradhar K.V.P (2011): Tensile & flexural properties of sisal/glass fiber reinforced hybrid composites. *International Journal of Macromolecular Science* 1(1): pp 19-22

15 Uma Devi, L., Bhagawan, S.S. and Thomas, S. (1997). Mechanical Properties of Pineapple Leaf Fiber-Reinforced Polyester Composite. *Journal of Applied Polymer Science.* 64: 1739-1748.

16 Shao-Yun Fu and Bernd Lauke.(1996): Effects of fiber length and fiber orientation distributions on the tensile strength of Short-fiber-reinforced polymers. *Composite Science and Technology* 56 pp1179-1190

17 Hossain M.R, Islam M.A, Vuurea A.V, and Verpoest I (2013): Effect of Fiber Orientation on the Tensile Properties of Jute Epoxy Laminated Composite*J. Sci. Res*. 5(1), pp43-54

18 ASTM D790-10***D790* - *10*** Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials, flexural properties, plastics. www.**astm**.org/Standards/**D790**.htm. Online download 09/10/2012

19 Abbas Qayes Abdullah (2011): Effect of water absorption on impact strength for epoxy-glass fibers composite. J. of University of Anbar for Pure Science: Vol.5:NO.2, ISSN: 1991-8941, pp1-7

20 JieChenq (2000): The Influence of Fiber Hybridization on Dynamic Mechanical Behaviour of Natural Based Composite; M.Eng Thesis, Department of Mechanical Engineering, Victoria University of Technology. Pp36-49.

21 Pothan L.A, Sabu Thomas and George J. (2012): Tensile and Impact Properties of Banana Fiber/Glass Fiber Hybrid Polyester Composites; ICCM-12 Conference Paris July 99th, paper 1267, ISBN 2-9514526-2-4;