FACTORS THAT IMPROVE THE IMPACT RESPONSES OF UKAM PLANT FIBRE REINFORCED COMPOSITE

C.C. Ugoamadi

Department of Mechanical Engineering, Michael Okpara University of Agriculture, Umudike, Umuahia, Abia State. Nigeria. ***Email:*** cardoso_kayode@yahoo.com

Abstract

Natural fibres around us have mechanical properties capable of making them compete effectively with synthetic fibres in the development of fibre reinforced composites. Synthetic fibres (such as glass fibres) and resins (such as polyester resin) have long been used in the development of structural components for car bodies, boat buildings, house and aircraft constructions. This project is concerned with the preparation of cashew nut shell liquid resin (natural resin) and the collection of Ukam plant fibres (natural fibres) and using them in the development of fibre reinforced plastic composites. Factors that improve their impact responses were considered in the development processes. These are fibre volume fractions, fibre treatment, fibre length, fibre orientation and the application of additives. Fifty different test specimens which involved the synthetic and the natural composites were developed using the hand lay-up method. The specimens were subjected to pendulum or notched Izod impact tests using ASTM D256 impact testing machine. The results of the impact tests show that: (1) Natural composites can withstand impact strengths like the synthetic ones, (2) Impact response of composites improves when the five factors indicated above are taken into consideration in composite development. Among these factors, the introduction of 20% by resin weight of additives yielded the best impact response for both natural and synthetic composites. For example at 40% fibre volume fraction, the natural composite test sample with additives developed an impact response of 86.4kJm-2 against 78.9kJm-2 impact response of the natural composite test sample without additives. This optimum impact response improvement was also observed with synthetic composite test samples with values of 96.5kJm-2 and 94.8kJm-2 for samples with additives and without additives respectively. From these results, it is obvious that structural components such as car bumpers could be developed from natural composites

Keywords: natural fibres, synthetic fibres, impact responses, mechanical properties, composite specimens

1. Introduction

Impact resistance in composites is the study of damage induced by striking of a foreign body on a material and the factors affecting it, which are generally recognised as the most severe threat to composite structures

(Kroschwitz 2005). This includes the study of the failure modes, initiation, development and extent of impact damage. Impact damage is normally initiated in laminated composites as a transverse matrix cracking, followed by delamination, fibre/matrix debonding and fibre fracture. Damage due to impact substantially reduces the residual strength after impact of a composite structure, even when damage cannot be visually observed(Sebe et al., 2000). For this reason, residual mechanical properties after impact are often measured. The principal mechanism of compressive strength reduction is local buckling of the sub-laminates formed in the delaminated area, whilst in tensile loading the strength reduction mechanism is dominated by fibre fracture (Hyper, 2008).

Two approaches are used to predict impact damage on laminated composites reinforced with man-made fibres (E-glass, carbon, Kevlar). The former is based on estimating the overall size of impact-damaged area, considering stress distribution in the area surrounding the impact points, and the latter on the detection of the appearance of the first matrix crack, followed by the study of the initiation and propagation of delamination. When dealing with plant fibre composites, both these approaches appear viable, at least in principle: however, a number of difficulties can be perceived in their application. First, the measurement of impact-damaged area can be considered particularly difficult, as an effect of the fibres becoming loose and suffering early debonding around the composites.

The objectives of this work are:

i) To determine the factors that are favourable for impact responses of Ukam plant fibers- a brand of natural fibers.
ii) To show that natural fibers have suitable mechanical properties capable of making them compete effectively with the conventional synthetic fibers.

2. Literature Review

There are very many situations in engineering where no single material will be suitable to meet a particular design requirement. However, two materials in combination may possess a feasible solution to the materials selection problem.

The principle of composite materials is not new. The use of straw in the manufacture of dried mud bricks, and the use of hair and other fibres date back to ancient civilizations [John, 1972].

A typical composite material is a system of materials composing of two or more materials (mixed and bonded) on a microscopic scale. For example, concrete is made up of cement, sand, stones and water. If the composition occurs on a microscopic scale (molecular level), the new material is then called an alloy for metals or a polymer for plastics [Nick et al., 2004].

Generally, a composite material is composed of reinforcements (fibres, particles, flakes, and/or fillers) embedded in a matrix (polymers, metals, or ceramics). The matrix holds the reinforcements to form the desired shape while the reinforcements improve the overall mechanical properties of the matrix. When designed properly, the resulting material exhibit better strength than the constituent materials (Terry, 1987).

Fibres have age long history as engineering materials. There were also early engineering uses of fibres, for example the use of straws to reinforce bricks. Also Mongolian normads discovered that sheep wool kept under the saddle later formed a film strong structure. Placed on wooden frames, the resulting fabric becomes an excellent exterior wall for yurts(Wood,1980). It would be said that the wool has been compacted by mechanical action. Since these early applications, fibres and fibrous structures have been investigated by many branches of science and engineering in order to design efficient processes of fibre manufacturing and to improve their properties.

Fibres with well known chemical, physical, mechanical, electrical and optical properties can be assembled alone or in combination with other materials, into well defined structures with effective engineering properties. Glass fibres, which are the most abundant, exist in many forms chopped fibres, chopped strand mat, woven rovings, surface tissues, continuous strand mat and woven cloth webbing.

In fibre reinforced composites, high-strength fibres are incased within a tough matrix. The functions of the matrix are to bond the fibres together, protect them against damages and transmit load from fibre to another. According to Harris 1986, the stresses induced in the fibres and matrix are related to the fibre volume fraction for each composite .this is given by:

$$\sigma_c = \sigma_m V_m + \sigma_f V_f \qquad (1)$$

Harris 1986, also developed a relationship between the Youngs Modulus of the entire composite and the fibre volume fraction and this is given by:

$$E_c = E_m V_m + E_f V_f \qquad (2)$$

Where σ_m is the failure stress of the matrix, σ_f is the tensile strength of the fibres, V_m is the volume fraction of the matrix, V_f is the volume fraction of the fibres, E_m and E_f are the Modulus values for the matrix and fibres respectively.

3. Experimental Procedure

First of all, two sets of fibres were obtained these were the Ukam plant (natural) fibres and the E-glass (synthetic) fibres. The impact responses of the natural composites was to be compared with that of the synthetic ones and the factors that improve this mechanical property were to be determined. The factors investigate are:

(a) Fibre condition (treated and untreated)
(b) Application of additives (crushed stone particle)
(c) Fibre length (short and long)
(d) Fibre orientation (bi-directional and uni-directional)
(e) Fibre volume fraction.

3.1. Ukam plant fibre extraction

The Ukam plant fibres were sourced from Ikem in Isi-Uzo Local Government Area of Enugu State, and were soaked in sodium hydroxide (NaOH) solution for about 3 hours to prepare the surface of the fibres for lamination. Treatment with saline solution (6% ethanol + 4% water) aided in ridding the fibres of cellulose. The fibres were then washed with dilute tetra-oxosulphate (vi) acid (H_2SO_4) to neutralize the base. Rinsing with water followed, and then fibres were dried and ready for matting.

3.2. Test samples

The materials used for the development of test samples consisted of polyester resin reinforced with layers of woven roving E-glass and Ukam plant fibres.

The test specimens were cut approximately to the dimensions of 300mm length; 20mm width 3mm thickness (fig. 1). Five identical test specimens were prepared and tested. Each sample composition was prepared at ambient temperature of 27°C in the laboratory under dry condition. Average data for the five specimens for each of the impact responses were then computed for each point of Fig.4 through Fig.14.

3.3. Impact testing

The impact properties of the material are directly related to the overall toughness which is defined as the ability to absorb applied energy. Area under the stress-strain curve is proportional to the toughness of a material. Nevertheless, impact strength is a measure of toughness. In this research, pendulum impact test – Notched Izod Impact Test was utilized as shown in Fig. 2.

Figure 1: Impact testing specimens of Ukam plant fibre reinforced specimens.

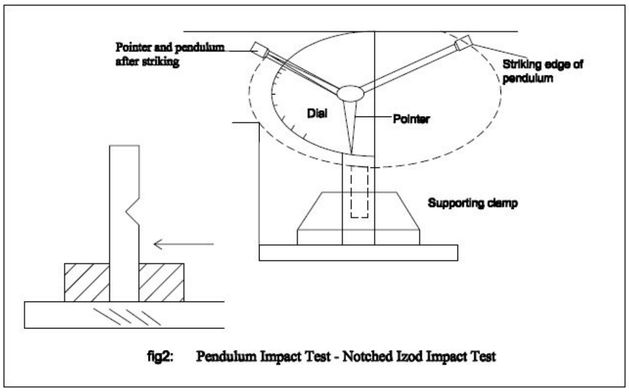

Figure 2: Pendulum Impact Test – Notched Izod Impact Test.

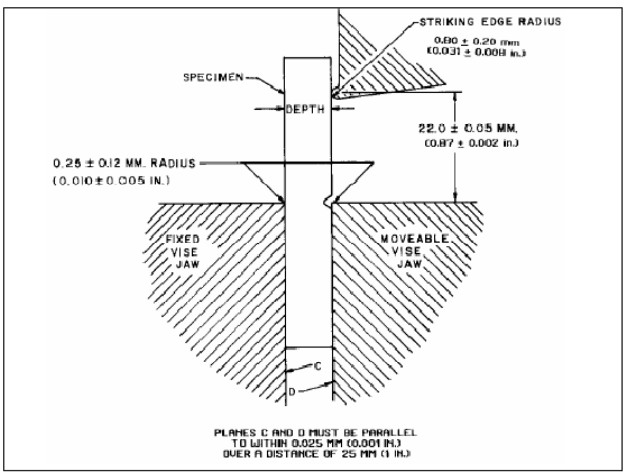

Figure 3: Relation of Vise, Specimen and Striking Edge to Each Other for Izod Test Method A in ASTM D256.

According to ASTM D256, test method A (Izod type) was used for testing. The apparatus involved was Cantilever Beam (Izod Type) Impact Machine and the specimens were notched. Notching was done because it provides a stress concentration area that promotes a brittle rather than a ductile failure. Furthermore, notching also drastically reduces the energy loss due to the plastic deformation.

In the testing, specimens were clamped vertically as a cantilever beam and then struck by a single swing of the pendulum released from a fixed distance from the specimen clamp. The line of initial contact is at a fixed distance from the specimen clamp and from the centerline of the notch and on the same face of the notch.

Figure 3 shows the relation of vise, specimen and striking edge to each other for Izod Test. A total of five consistent testing results were selected for each fibre loading in cashew nut shell resin matrix. In this research work, RAY-RAN Universal Pendulum Impact System for Izod-Charpy-Tension and Puncture were used to measure the work of fracture for fibre reinforced composite. There are a few parameters that are set according to the standard for instances, Hammer Velocity = 3.46 m/s and Hammer Weight = 0.905 kg.

4. Results and Discussions

The results of the various factors that determine the impact responses of the natural composites are presented in Figs 4-14. The impact strength increases as the fibre volume fraction increases. It improves with increase in fibre volume fractions, fibre treatment, fibre length, fibre orientation and the addition of additives. Of all these favourable conditions for energy absorption capacity per unit volume of composites, the introduction of particles of stones (additives) yielded the highest impact strengths for both the natural and synthetic composites. However, the energy absorption mechanism of fracture built in com-

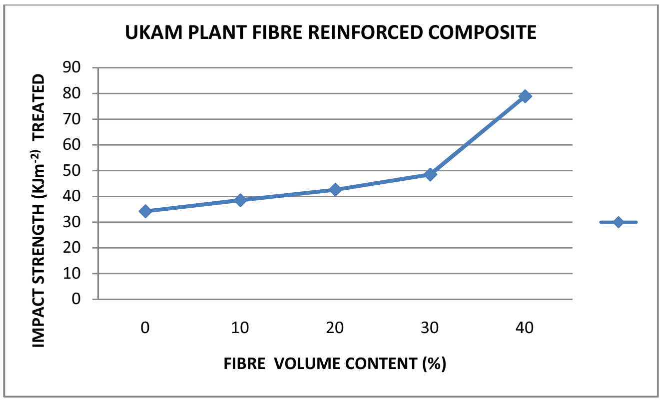

Figure 4: Graph of Impact Strength against Fibre volume content for a treated Ukam plant fibre reinforced composite.

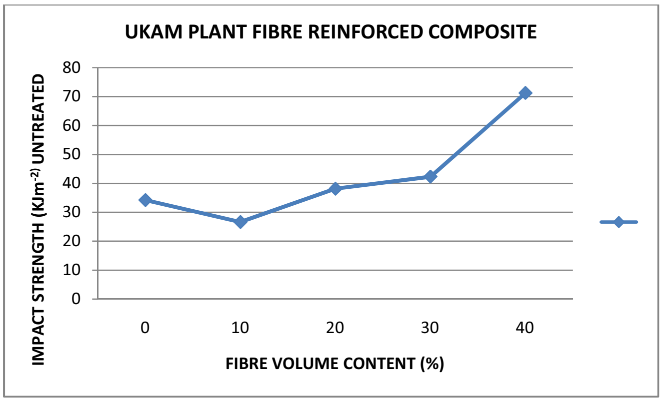

Figure 5: Graph of Impact Strength against Fibre volume content for an untreated Ukam plant fibre reinforced composite.

posite include utilization of energy required to debond the fibres and pull them completely out of the matrix using a weak interface between fibres and matrix (Enetanya 2000) . In practical interest, a significant part of energy absorption during impact takes place through the fibre pullout process.

5. Conclusion

Natural fibres and resins were obtained readily at low cost and the production of the composites required minimum tooling. The fibres could be used to develop Fibre reinforced plastic composite components in use in engineering applications.

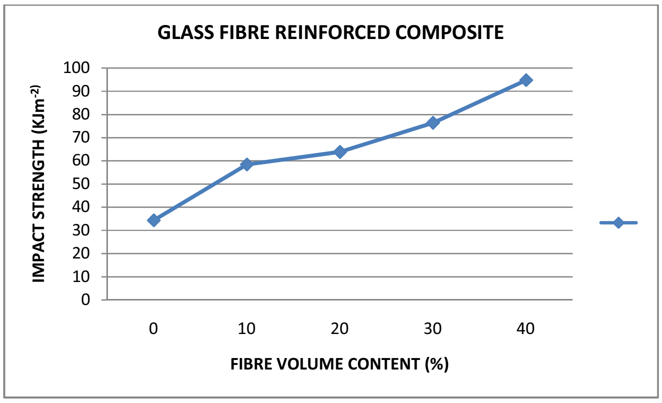

Figure 6: Graph of Impact Strength against Fibre volume content for a Glass fibre reinforced composite.

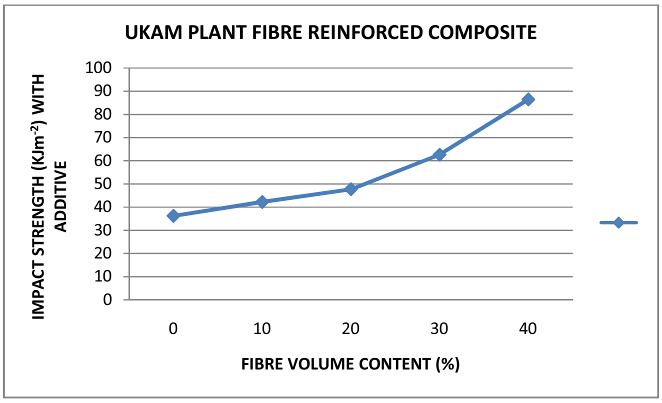

Figure 7: Graph of Impact Strength against Fibre volume content for Ukam plant fibre reinforced composite with additives.

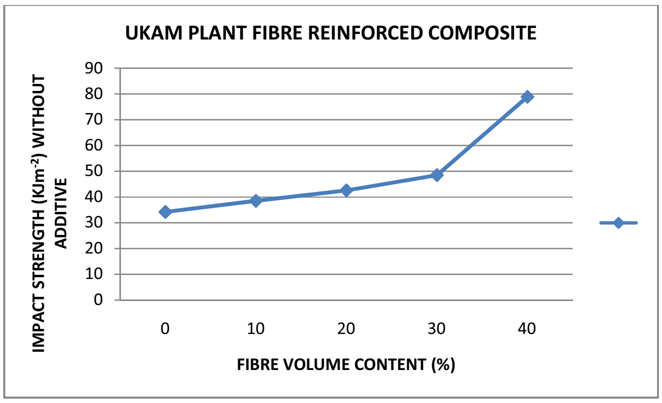

Figure 8: Graph of Impact Strength against Fibre volume content for Ukam plant fibre reinforced composite without additives.

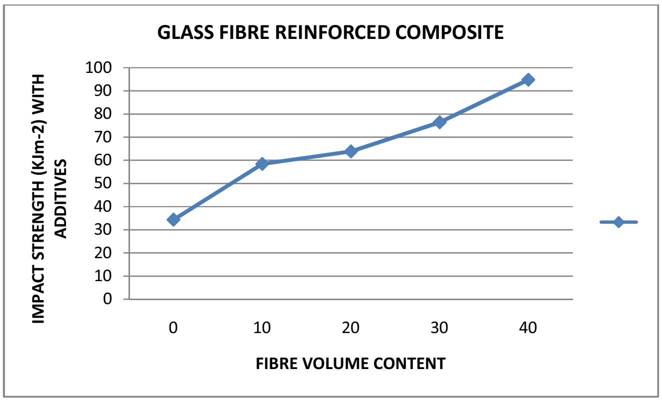

Figure 9: Graph of Impact Strength against Fibre volume content for Glass fibre reinforced composite with additives.

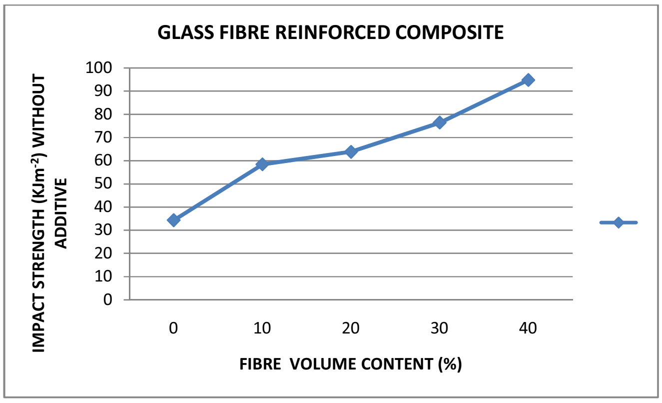

Figure 10: Graph of Impact Strength against Fibre volume content for Glass fibre reinforced composite without additives.

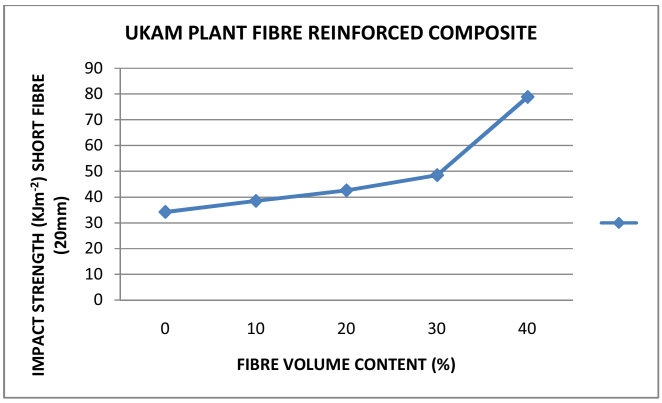

Figure 11: Graph of Impact Strength against Fibre volume content for Short Ukam plant fibre reinforced composite.

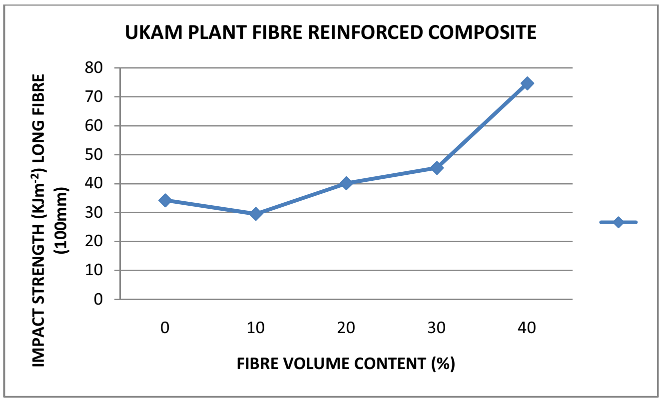

Figure 12: Graph of Impact Strength against Fibre volume content for Long Ukam plant fibre reinforced composite.

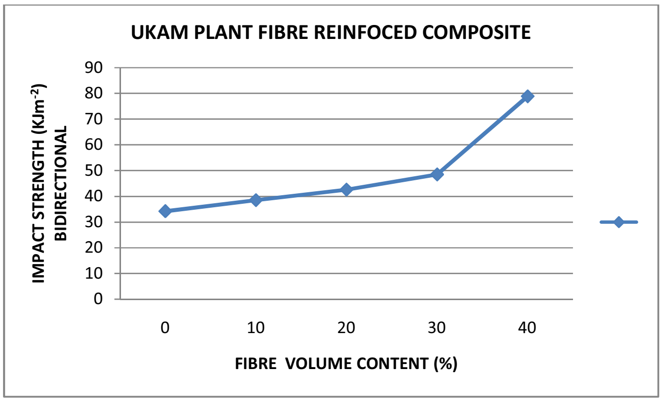

Figure 13: Graph of Impact Strength against Fibre volume content for a bi-directional Ukam plant fibre reinforced composite.

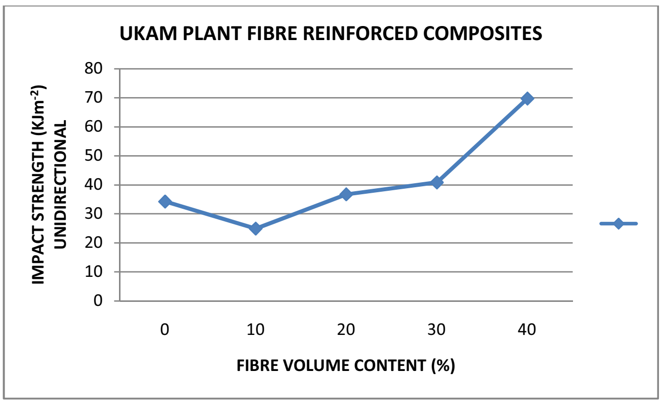

Figure 14: Graph of Impact Strength against Fibre volume content for a unidirectional Ukam plant fibre reinforced composite.

In this article, the recommended production technique is the hand-lay-up method. It is a labour intensive method and requires no expensive tooling. It is however, suitable for a developing country like Nigeria for the purpose of poverty alleviation.

Light weight, low modulus and low strength plastics reinforced with natural fibres have been proved to posses mechanical properties capable of making them compete effectively with the synthetic ones. Various factors improve the impact response of fibre reinforced composites. These include fibre volume fraction, fibre condition, application of 20% by resin weight of additives, fibre length and ply sequence. The application of additives however, yielded the best result in terms of impact response on the account that the presence of additives increases the compressive strength of any fibre reinforced plastic composites.

Steel castings are widely used in the design and production of engineering structures and components. At low speed impact the performance of plastics is superior to that of metals. Large deflections of plastics recover without permanent damage (Enetanya, 2000). This means that in the near future , natural fibre reinforced plastic composites will even be preferred to steel castings in terms of important engineering applications such as automobile, boat and air craft constructions.

Acknowledgement

I am particularly grateful to my mentor, Engr.(Dr) O. Onuba for guiding me in the course of carrying out this research. My profound gratitude also goes to the Technologist, Engr. Ugochukwu Okenwa for his assistance in conducting various test in the Mechanical Engineering laboratory.

References

1. Kroschwitz, J. I. (2005) *High performance polymer composites* John Wiley and sons, New York.
2. Sebe G, Cetin, N. S, Hill, C. S. A and Hughe (2000). RTM Hemp Fibre-Reinforced Polyester Composites, *Applied Composite Materials* (in press)
3. Hyper, M. W. (2008) *Stress Analysis of fibre reinforced composite materials.* Mc Graw-Hill companies, Inc. USA.
4. John, V.B. (1972) *Intoduction to Engineering materials* The English Language Book Society, London.
5. Nick, I. and Mark, J. (2004). *Low environmental impact polymers.* Int. Automotive Research Center, University of Warwick.
6. Terry, R (1987) *Composites: A design guide.* Industrial press Inc. 200 Madison Avenue New York.
7. Wood, R. (1980) *Car Body Works in Glass reinforced Plastics* Pentech Press: Plymouth, London.
8. Harris, Bryan (1986) *Engineering composite materials* The institute of Metals: London.
9. Enetanya, A. N (2000) Improving the compressive strengths of hand-lay up GRF composites. *Global Journal of Mechanical Engineering* vol.2 (page 7-18)