

The Mechanical Properties of Ukam Fibre-Reinforced Cashew Nut Shell Resin Composite

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Abstract : *The mechanical properties of ukam fibre cashew nut shell resin composite were studied for possible structural application in engineering. Basically, the hand lay-up method was employed to manufacture the test samples of the composite by 40:60 weight ratio and testing the samples' mechanical properties using the instron tensile machine and the izod impact machine respectively. Consequently, the experiments demonstrated that the ukam fibre reinforced cashew nut shell resin composite has a maximum tensile strength of 40.5MPa, the impact energy of 1.93J and a young tensile modulus of 1GPa. The above results indicate that ukam fibre- reinforced cashew nut shell resin composite is suited for low cost applications in engineering and is a good alternative to artificial glass fibres.*

Keywords: Mechanical properties; Ukam fibre; Reinforced; Cashew nut; Shell resin; Composite

Introduction

Researches in synthetic fibres were facilitated by their high cost and the health hazards posed by asbestos composites. As a result, natural fibres have been applied massively since their recognition as structural materials.

Composite materials were first employed in the making of sheets and tubes for electrical works since 1908, Rana [1]. Generally, these composite products were made in flat sheets and 2D shapes. Subsequently, stronger materials like metals received greater attention, leading to low need for natural fibre composite. Glass fibres were initially introduced in the 1940 with availability of polyester resins and filament fibre

Currently, natural fibres are gaining more attention in place of glass fibres due to weight saving, low cost, recyclability and renewability. Natural fibre composites are widely utilized in many areas of engineering, for example, the automotive industry has adopted the use of ukam, hemp, sisal and jute plant fibres. Oladele et al.[2] maintained that the micromechanical behaviour of the laminates is largely determined by the fibre/matrix weight ratio. High moisture absorption minimizes significantly the level of adhesion with matrix material. Consequently, this results in premature aging of the composite.

Natural fibres are normally used for rope, twine and sacking materials. A natural fibre is biodegradable and environmentally friendly. However, the mechanical properties of natural fibre composite can be enhanced by fibre treatment and modification.

The matrix-fibre stress transfer and the fabrication technique will determine the effectiveness of natural fibre composite [3]. In this research, the hand lay-up technique was adopted to produce ukam fibre- reinforced cashew nut shell resin samples whose mechanical properties were determined.

The investigation of the ukam fibre- reinforced cashew nut shell resin composite has drawn much attention due to ukam fibre increased trials in the Eastern Nigeria. The study also used simple manufacturing methods for fabricating the laminates with a view to recycling the composite.

1. Materials and Methods

1.1 Materials

1.1.1 Cashew Nut Shell Liquid

The cashew nut used in this study was sourced locally, precisely from Obollo-Afor market of Nsukka, Nigeria. The processing was done using the hot method of extraction.

1.1.2 Ukam Plant Fibres

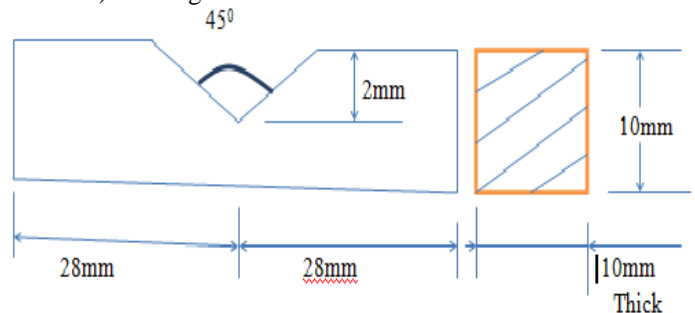
The ukam plant also was sourced locally from farmers in Nsukka area of Enugu state, Nigeria. The water retting processing method was employed. The required surface treatment and modification were carried out using saline solution, sodium hydroxide solution and acetic acids. The chopped strand matting technique was used because of its simplicity and improved strength of the composite.

1.2 Methods

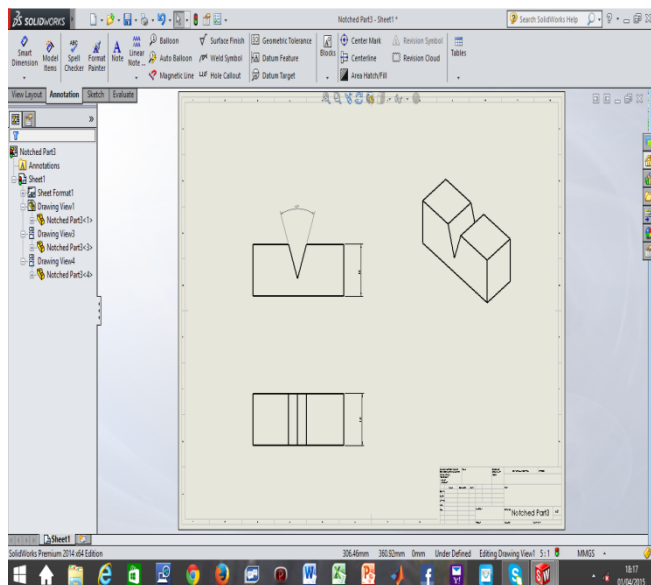
Two test samples of ukam plant fibre reinforced cashew nut shell liquid resin composite were prepared as follows:

1.2.1 Mould Preparation

The moulds were prepared according to standard test piece measurement. For the impact test, the standard test piece measurement is 56mm x 10mm x 10mm (with 2mm notch at the centre). See Fig. 1 below.



(a)



(b)
Fig.1 Standard impact test piece

For the tensile test, the width and thickness of each sample were approximately 20mm and 11mm respectively with a gage of 150mm(see figure 2 below)

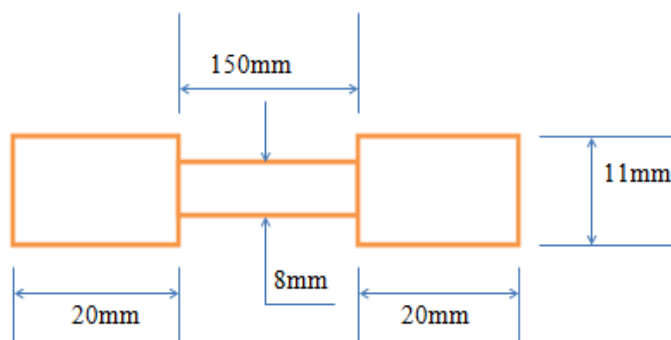


Fig.2 Standard tensile test piece

Formica and glossy paper were utilized for the preparation of the mould. The fibre mat was cut according to the size of the mould. Four piles of the fibre mat were required to produce one specimen sample.

1.2.2 Lamination

Both cobalt-based accelerator and methylethyketone catalyst were employed as curing agents for the cashew nut shell liquid resin. These chemical components were uniformly and thoroughly mixed before introducing the mixture into the mould. The ukam fibres were also added for reinforcement. After this process, the composite system was allowed to cure for 24 hours, after which it was demoulded. For the impact test piece, a notch was introduced at the centre of the laminate with the aid of a hand saw or a filing machine.

1.3 Material Characterization

1.3.1 Tensile Testing

The tensile strength was determined on 2 specimens (the average tensile strength was recorded). The tensile properties of the ukam plant fibre- reinforced cashew nut shell liquid composites were measured with an instron model 4302 testing machine (ASTM-D-638). The elastic young modulus was calculated from the stress-strain curve.

1.3.2 Impact Testing

The impact strength of the samples was measured using an izod impact testing machine. The method used for the impact strength testing was according to ISO 180. Two samples were tested and the mean value of the absorbed energy taken.

2. Results

2.1 The Static Tests

From the static tests on 2 test pieces, the following are the results:

Test Sample 1

Table 1

Load(KN)	1.5	2.5	4.5	6.5	8.5
Extension(m)	10 ⁻³	1.5x10 ⁻³	2.3x10 ⁻³	3x10 ⁻³	3.5x10 ⁻³

From table1, the stress-strain table of values is prepared as follows:

$$\text{Stress} = \frac{P}{A} \text{ ----- (1)}$$

Where P is the load (KN)

A is the area of specimen and is expressed as thickness multiplied by width of the specimen.

Therefore, area, A = 20mm x 11mm

$$= 220\text{mm}^2 \text{ or } 220 \times 10^{-6}\text{m}^2$$

$$\text{Gage length} = 5.65\sqrt{A} \text{ ----- (2)}$$

$$= 5.65\sqrt{(220 \times 0.000001)}$$

$$= 0.084\text{m}$$

$$\text{Strain, } \xi = \text{Extension } (\Delta L) / \text{Gage length} \text{ -----(3)}$$

Table 2

Stress (MPa)	6.82	11.36	20.45	29.45	40.00
Strain, ξ	11.90x10 ⁻³	17.90x 10 ⁻³	26.80x 10 ⁻³	35.70x 10 ⁻³	41.70 x 10 ⁻³

The stress-strain curve is shown in Fig.3 as per test sample 1. From this graph, the elastic young modulus of the test sample 1 was estimated thus:

$$\text{Young Modulus, } E_1 = \Delta \text{stress} / \Delta \text{strain}$$

$$= 959.233\text{MPa or } 0.9592\text{GPa}$$

Test Sample 2

Table 3

Load P(KN)	1	2	4	7	9
Extension (m)	0.8×10^{-3}	1.1×10^{-3}	2×10^{-3}	3.4×10^{-3}	4×10^{-3}

From table 3, the stress-strain table of values is derived using equations 1, 2&3. This is illustrated as table 4 below.

Table 4

Stress (MPa)	4.55	9.09	18.18	31.82	40.91
Strain, ϵ	9.52×10^{-3}	13.10×10^{-3}	23.81×10^{-3}	40.48×10^{-3}	47.62×10^{-3}

The stress-strain curve is also shown in Fig.3 as per test sample 2. From this graph, the elastic young modulus of test sample 2 was estimated as:

$$\text{Young modulus, } E_2 = \Delta \text{stress} / \Delta \text{strain}$$

$$= 859.092 \text{MPa or } 0.8591 \text{GPa}$$

Hence, the mean young modulus for the ukam fibre-reinforced cashew nut shell resin composite is:

$$E = (E_1 + E_2) / 2 = (0.9592 + 0.8591) / 2$$

$$= 0.909 \text{GPa} \sim 1 \text{GPa}$$

Also, from table 2 &4, the mean tensile strength of the composite, $\sigma = (40 + 40.91) / 2$

$$= 40.5 \text{MPa}$$

2.2 The Impact Energy

The impact energy or impact strength is the fracture energy of a material [4]. From the charpy test on 2 test specimens, carried out in the Mechanical Laboratory of the University of Nigeria Nsukka, the following are the results.

For test sample 1,
Maximum breaking stress, $\sigma_{\max} = 1.5 \text{Kgf/cm}^2$
 $= 15 \text{N} / 10^{-4} \text{m}^2$
 $= 1.5 \times 10^5 \text{Pa}$

Volume of specimen, $V = 0.01 \times 0.01 \times 0.056 \text{m}$
 $= 5.6 \times 10^{-6} \text{m}^3$

Energy absorption capacity of the material, U is expressed as:
 $U = (\sigma_{\max})^2 \times a_0 / E$ -----
 --- (4)

Where a_0 = original length of specimen (i.e.0.056m)
 E = mean young modulus of elasticity calculated from the static test.

σ_{\max} = maximum breaking stress
 Substituting in equation 4
 $U_1 = (1.5 \times 10^5 \text{Pa})^2 \times 0.056 \text{m} / 0.909 \times 10^9 \text{Pa}$
 $= 1.386 \text{J}$

For test sample 2,
 Maximum breaking stress (σ_{\max}) = 2Kgf/cm^2
 $= 20 \text{N} / 10^{-4} \text{m}^2$

$$= 2 \times 10^5 \text{Pa}$$

Volume of specimen, $V = 5.6 \times 10^{-6} \text{m}^3$
 Energy absorption capacity of the material is:
 $U^2 = (\sigma_{\max})^2 \times a_0 / E$
 $= (2 \times 10^5 \text{Pa})^2 \times 0.056 / 0.909 \times 10^9 \text{Pa}$
 $= 2.464 \text{J}$

Therefore, the mean energy absorption capacity of the ukam fibre composite is determined as:

$$U_m = (U_1 + U_2) / 2$$

$$= (1.386 + 2.464) / 2$$

$$= 1.925 \text{J}$$

$$\sim 1.93 \text{J}$$

3. Discussion of Results

Using tables 2 & 4, the stress-strain curves can be generated as shown below as Fig.3.

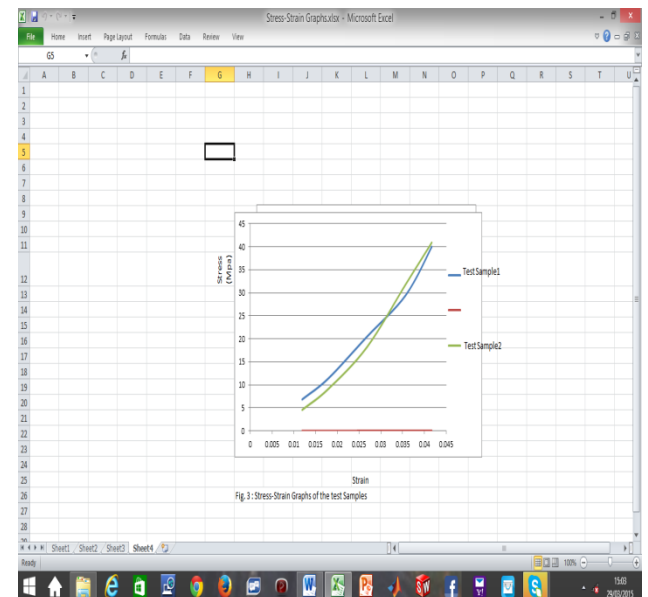


Fig. 3 The Stress-Strain Graphs of the Test Samples

From tables 2 &4 and the accompanying graphs (Fig.3above) the following observations and deductions have been made.

- (1) The maximum tensile strength of the ukam fibre – reinforced cashew nut shell resin composite is 40.5MPa, which compares well with that of E-glass laminate.
- (2) The energy absorption capacity of the ukam fibre composite is 1.93J while its young modulus of elasticity is 0.909GPa.
- (3) The bonding between the fibre and resin can be strengthened through alkalization treatment of the fibres. This consequently would generate composites with enhanced mechanical characteristics. It is maintained that fibre modification optimizes the mechanical properties of the laminates [5].

4. Conclusions

The following conclusions have been made regarding this study.

- (1) Both the resins and the fibres were processed at relatively low cost and the fabrication process was easy and simple.
- (2) The tensile strength and impact strength of ukam fibre-reinforced cashew nut shell resin composite were found to be 40.5MPa and 1.93J respectively.
- (3) The mechanical properties of the ukam fibre composite were improved through alkalization process.
- (4) The ukam fibre composite is a good alternative to glass fibre laminates.

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