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Comparative Assessment of Mechanical Properties of Groundnut Shell and Rice Husk Reinforced Epoxy Composites

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Abstract A comparative assessment of mechanical behaviour of groundnut shell and rice husks as reinforcement in epoxy matrix has been investigated in this work. Six specimen each of groundnut shell reinforced epoxy and rice husk reinforced epoxy composites having 2.5%, 5%. 7.5%, 10%, 12.5% and 15% content of groundnut shell and rice husk were produced using the hand lay up technique and their mechanical properties (impact strength, hardness, flexural strength and tensile strength) were evaluated. The highest mechanical properties of the groundnut shell reinforced epoxy composites were: impact strength (7.91 J/mm^2 at 12.5%), hardness (7.8 HRF at 5%), flexural strength (43.43 N/mm^2 at 12.5%) and tensile strength (41.60 N/mm^2 at 2.5%) while the highest mechanical properties for the rice husk reinforced epoxy composites were: impact strength (4.91 J/mm^2 at 7.5%), hardness (8.7 HRF at 2.5%), flexural strength (28.21 N/mm^2 at 5%) and tensile strength (16.67 N/mm^2 at 5%). Results of this research work indicated that the groundnut shell reinforced epoxy composites have superior mechanical properties as compared to the rice husk reinforced epoxy composites. Since impact strength is the most important property in bumper design, sample E_{GSC} with 12.5% groundnut shell was prepared and used for the production of Bajaj tricycle rear bumper.

Keywords: *epoxy, groundnut shell, matrix, reinforcement, rice husk*

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1. Introduction

Interest in the use of natural fibers or particles as reinforcements in polymers to substitute the conventional synthetic reinforcements in some structural and other engineering applications has continued to grow. This is because even though synthetic fiber or particle reinforced polymer composites such as aramid fibers, glass fibers, carbon fibers etc have several advantages(high stiffness, high strength-to-weight ratio, etc) as compared with conventional materials like steel, wood concrete, their high initial cost and adverse environmental impact is limiting their use [9,15]. Currently, composites development is changing from synthetic fibers to natural fibers. This is because the composites with synthetic fibers such as glass fibers are not environmentally friendly, leading to problems of waste glass fiber, which cannot be decomposed by nature [30]. Composites developed with natural fibers have many significant advantages over composites made of synthetic fibers. These advantages include: low cost, lighter weight, do not cause skin irritation, high strength- to-weight ratio, high stiffness- to-weight ratio, elimination of corrosion and stress corrosion, available in the form of plants and wastes, non-toxicity, improved control of surface contour and smoothness, higher fatigue endurance limit (up to 60% of ultimate tensile stress), 30-40% lighter than any particular aluminum, structure designed to the same functional requirements, less noisy while in operation and provide lower vibration transmission than metals, more versatile than metals and can be tailored to meet various performance needs and complex design requirements.

The convenience of developing composites with natural fibers lies in the fact that the ingredients are obtained easily from natural or agricultural wastes and hence the composites can be relatively easily manufactured [30].

Natural fibers can be cultivated so that their availability is sustainable. However, natural fibers also have many weaknesses such as irregular dimensions, stiffness, susceptibility to heat, ease of water absorption, and quick obsolescence [30]. Ideally, composite materials are used in structures where strength-to-weight ratio is a major consideration. Attempts have equally been made to use natural fiber composites in non-structural applications.

Currently, a number of automotive components previously made with glass fiber composites are now being manufactured using environmentally friendly composites. The use of natural fiber composites in the automotive industry has two main advantages, namely, vehicle becomes lighter which means improved fuel efficiency, and improvement in the sustainability of production because natural fibers can be cultivated [7,11].

Nigeria is currently the highest rice producer in West Africa, producing an average of 3.2 million tons of paddy rice or 2.0 million tons of milled rice. It is also the largest consuming nation in the region, with the growing demand amounting to 4.1 million tons of rice in 2002 [8].

Rice husk is one of the most widely available agricultural wastes in many rice producing countries around the world. Globally, approximately 600 million tons of paddy rice is produced annually. Averagely 20% of the rice paddy is husk, giving an annual total production of 120 million tons [28]. In most of the rice producing countries, most of the husk produced from processing of rice is either burnt or dumped as wastes [28]. Burning of rice husk in ambient atmosphere produces a residue called rice husk ash (RHA). For every 1000kg of rice paddy milled, about 220kg (22%) of husk is produced, and when this husk is burnt in the boilers, about 55kg (25%) of rice husk ash (RHA) is generated [28].

It is worthy to note that rice husk (RH) removal during milling creates disposal problems due to less commercial interest. Also, handling and transportation of rice husk (RH) is problematic due to its low density. Rice Husk Ash (RHA) constitutes environment threat causing damage to land and surrounding areas where it is dumped.

The successful use of Rice Husk (RH) in commercial quantities as reinforcement for the production of composites will solve the disposal problems as well as create engineering components and articles with desirable properties.

Botanically, groundnut belongs to Araches hypogaea Linn of leguminous family. Groundnut is a self pollinated, annual and herbaceous legume crop. A complete seed of groundnut is called a pod and contains one to five kermils which develop underground in a needle- like structure called peg which grows into the soil and then converts into a pod. Groundnut has tap root system which has many nodules, present in root and lateral roots. These nodules contain Rhizobium bacterial, which are symbiotic in nature and focus atmospheric nitrogen. Outer layer of groundnut is called groundnut shell. The shell constitutes about 25 – 35% of the pod. The seed accounts for the remaining portion (65 – 75%) [20].

In fact, groundnut is the 5th most widely grown crop in sub-Saharan Africa behind maize, sorghum, millet and corn. Nigeria produces 30% of Africa's total groundnut output, followed by Senegal and Sudan each with 8%, then Ghana and Chad with about 5% each. Nigeria produced up to about 2.699 million metric tons of groundnut in 2002. Groundnut shells are found in large quantities as agricultural farm wastes in several states in Nigeria, Benue and Kaduna states inclusive.

Over the decades, groundnut shells have constituted common solid wastes especially in developing countries like Nigeria. Its potential as a useful material has not been extensively studied. It is however envisaged that the utilization of groundnut shells (GS) as reinforcements in the production of composites will lead to cost savings in the management of wastes; reduce environmental pollution and increase the financial proceeds of the farmers as well as produce engineering components and structures which will meet certain desired properties.

Utilization of groundnut shells and rice husks for commercial applications will reduce open burning of same and hence preserve the environment. The use of these natural fibers will eliminate off-gassing of toxic compounds.

The use of rice husks and groundnut shells will lead to job creation as a result of processing of these wastes for use as natural fibers and the attendant utilization in various applied technologies for the production of new products.

The utilization of these natural fibers as reinforcements will also increase local content for various structural and engineering components, thereby saving foreign exchange.

The mechanical properties of composites produced from rice husks and groundnut shells are being investigated with the hope of finding them suitable for the production of Bajaj RE tricycle rear bumpers.

2. Review of Related Literatures

The works of the following researchers; Sreenivasulu et al, on the mechanical properties evaluation for bamboo fiber reinforced composite materials, Surata et al, on the mechanical properties of rice husk fiber reinforced polyester composites manufactured by the hand lay-up technique, Olusegun et al, on the mechanical properties of ukam, banana, sisal, coconut, hemp and E-glass fiber reinforced laminates and their suitability for use in engineering applications, Kumar et al, on the properties and industrial applications of rice husk, Agunsoye et al on the mechanical behaviour of coconut shell reinforced polymer matrix composite and several other authors as reflected in the reference have been reviewed and acknowledged in this work.

Obviously, a lot of researches have been carried out on natural fiber reinforced polymer composites but research on groundnut fiber in epoxy matrix is rare. It is against this background that this present research is being undertaken with the main objective of comparing the mechanical properties of rice husk fiber reinforced polymer composites and groundnut shell fiber reinforced polymer composites with those of synthetic fiber composites, and identifying areas of application of these composites reinforced with rice husk fiber and groundnut shell fiber.

3. Materials, Equipment and Methods

3.1. Materials

The following major raw materials were used in this research work; Groundnut shells, Rice husks, Epoxy resin (Bisphenol – A – diglycol ether), Hardener (Tetraethylenepentamin), Sodium hydroxide(NaOH), Acetic acid and Distilled water.

The matrix material - epoxy resin (bisphenol-A-diglycol ether) and curing agent or hardener (tetraethylenepentamine) were commercially obtained from Tony International Enterprise, Ojota; Lagos. The epoxy resin has a density of 1.169g/ml at 25°C, viscosity of 40 – 100 poise at 25°C and molecular weight average Mn of 348.

Plate 1. Rice Husk

Plate 2. Groundnut Shell

Plate 3. Measurement of Rice Husk size

3.2. Equipment

The major equipment used in the research work are; Glass moulds, Beakers, Aluminum foil paper, Aluminum drying trays, Digital weighing balance (0 – 500g), Glass stirrer, Stainless steel spatula, Glass funnel, Standard ASTM copper sieves (0.840mm and 1.4mm sizes), Vaseline (wax), Charpy Impact Testing Machine (Model: Cat Nr. 412) with capacity 15J and 25J, Indentec Universal HardnessTesting Machine (Model: 8187.5 LKV(B), Universal Materials Testing Machine (Enerpac ,100KN) and Monsarto Tensometer type W.

3.3. Methods

3.3.1. Preparation of Composites

Clean and dried groundnut shells and rice husks respectively were initially washed in warm water to remove sand and other impurities. The washed groundnut shells and rice husks were later chemically treated with 10% NaOH solution for 30 minutes and 90 minutes respectively and then neutralized by washing with acetic acid, and thereafter washed with distilled water until all traces of acetic acid and NaOH were eliminated. Subsequently, both the groundnut shells and rice husks were solar dried. The groundnut shells were hammer milled and thereafter ground in a grinding machine to reduce their sizes. The particles were sieved through 840mm and 1600mm BS sieves to obtain fine uniform sizes. The 840mm sieved particles were used as reinforcement in the polymer matrix to produce the groundnut shell - epoxy composite laminates by the hand lay-up technique. The short dried rice husks obtained after chemical treatment and solar drying were directly used as reinforcement fibers in the polymer matrix to also produce the rice husk – epoxy composite laminates using the hand lay-up technique.

3.3.2. Casting of Composites

Twelve moulds of 200mm x 120mm x 6mm wholly made of glass were used for casting the composite sheets. For quick and easy removal of the composite sheets, an aluminum foil paper (mould release sheet) was placed over each glass mould cavity and vaseline (wax) lightly rubbed on the aluminum foil paper. The weight percentages of groundnut shell and rice husk respectively (2.5, 5.0, 7.5, 10.0, 12.5 and 15.0 Weight %) were mixed with the matrix material consisting of epoxy resin and hardener in the ratio of 2:1. Utmost care was taken to ensure homogenity of the mixture and also avoid the formation of air bubbles during pouring. The mixture was allowed to cure at room temperature for 24 hours. After curing, the laminates were cut into required specimen shapes and sizes for the various mechanical tests.

The specimens for mechanical tests were formulated as shown in Table 1 and Table 2 below:

Table 1. Specimen Formulation for Groundnut shell- Epoxy Composite

SPECIMEN DESIGNATION	GROUNDNUT SHELL (%)	EPOXY RESIN (%)	HARDENER (%)
A_{GSC}	2.5	65.0	32.5
B_{GSC}	5.0	63.3	31.7
C_{GSC}	7.5	61.7	30.8
D_{GSC}	10.0	60.0	30.0
E_{GSC}	12.5	58.3	29.2
F_{GSC}	15.0	56.7	28.3

Table 2. Specimen Formulation for Rice Husk- Epoxy Composite

SPECIMEN DESIGNATION	RICE HUSK (%)	EPOXY RESIN (%)	HARDENER (%)
A_{RHC}	2.5	65.0	32.5
B_{RHC}	5.0	63.3	31.7
C_{RHC}	7.5	61.7	30.8
D_{RHC}	10.0	60.0	30.0
E_{RHC}	12.5	58.3	29.2
F_{RHC}	15.0	56.7	28.3

3.4. Mechanical Tests

The following tests were carried out on both the groundnut shell- epoxy composite samples and the rice husk – epoxy samples respectively and the results obtained compared:

IMPACT TEST

The Charpy impact test was carried out in accordance with ASTM D256 - 05, ISO 179 standard.

HARDNESS TEST

The hardness test was carried out in accordance with ASTM D785 – 08, ISO 2039 standard.

FLEXURAL TEST

The flexural tests also referred to as bending tests were performed using the three-point bending method in accordance with ASTM D790-03. The composite samples were tested at room temperature to evaluate the value of the flexural strength (FS).

TENSILE TEST

Tensile tests were performed on flat composite samples with gauge length (40mm), width (10mm) and thickness (6mm). The test was performed in accordance with ASTM D638-03 standard method of testing plastics.

4. Results, Analysis and Discussion

4.1. Impact Test Result

The results of impact tests for groundnut shell – epoxy composite are indicated in Table 3.

The results of impact tests for rice husk – epoxy composite is indicated in Table 4.

Table 3. IMPACT TEST RESULTS FOR GROUNDNUT SHELL-EPOXY COMPOSITES

SPECIMEN	WIDTH (mm)	THICKNESS (mm)	AREA (mm^2)	IMPACT ENERGY (J)	AVERAGE IMPACT ENERGY(J)	IMPACT STREGTH(J/mm^2)
A_{GSC1}	13	6	78	450		
A_{GSC2}	13	6	78	480	460	5.90
A_{GSC3}	13	6	78	450		
B_{GSC1}	13	6	78	480		
B_{GSC2}	13	6	78	500	493	6.32
B_{GSC3}	13	6	78	500		
C_{GSC1}	13	6	78	500		
C_{GSC2}	13	6	78	510	500	6.41
C_{GSC3}	13	6	78	490		
D_{GSC1}	13	6	78	500		
D_{GSC2}	13	6	78	550	517	6.63
D_{GSC3}	13	6	78	500		
E_{GDC1}	13	6	78	600		
E_{GSC2}	13	6	78	650	616.6	7.91
E_{GSC3}	13	6	78	600		
F_{GSC1}	13	6	78	350		
F_{GSC2}	13	6	78	300	333	4.27
F_{GSC3}	13	6	78	350		

Table 4. IMPACT TEST RESULTS FOR RICE HUSK-EPOXY COMPOSITES

SPECIMEN	WIDTH(mm)	THICKNESS(mm)	AREA (mm^2)	IMPACT ENERGY(J)	AVERAGE IMPACT ENERGY(J)	IMPACT STREGTH(J/mm^2)
A_{RHC1}	13	6	78	350		
A_{RHC2}	13	6	78	350	333	4.27
A_{RHC3}	13	6	78	300		
B_{RHC1}	13	6	78	350		
B_{RHC2}	13	6	78	350	350	4.49
B_{RHC3}	13	6	78	350		
C_{RHC1}	13	6	78	350		
C_{RHC2}	13	6	78	400	383	4.91
C_{RHC3}	13	6	78	400		
D_{RHC1}	13	6	78	350		
D_{RHC2}	13	6	78	350	350	4.49
D_{RHC3}	13	6	78	350		
E_{RHC1}	13	6	78	300		
E_{RHC2}	13	6	78	350	333	4.27
E_{RHC3}	13	6	78	350		
F_{RHC1}	13	6	78	350		
F_{RHC2}	13	6	78	300	300	3.85
F_{RHC3}	13	6	78	250		

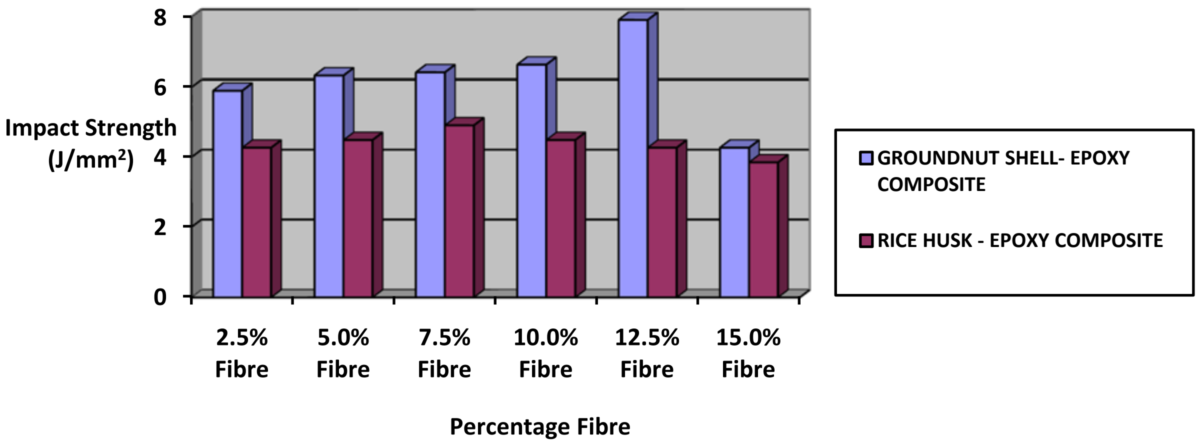

Figure 1. Comparison Chart of Impact Strength for Groundnut shell – Epoxy composite and Rice Husk – Epoxy composite

The impact strength (Figure 1) for groundnut shell – epoxy composite increased gradually from 5.90J/mm^2 at 2.5% groundnut shell content up to a maximum of 7.91J/mm^2 at 12.5% groundnut shell content, and thereafter fell to 4.27J/mm^2 at 15% groundnut shell content. For rice husk – epoxy composite, the impact strength increased slightly from 4.27J/mm^2 at 2.5% rice husk content attaining a peak of 4.91J/mm^2 at 7.5% rice husk content and thereafter reducing gradually to 3.85J/mm^2 at 15% rice husk content. On the whole groundnut shell – epoxy composite displayed higher impact strength compared to rice husk – epoxy composite for the same percentage of reinforcement. These results are expected and agreed with the work of other authors. The strength of the composite heavily depends on the volume of fibre present and its nature (long, short or particulate). Groundnut fibres are longer than rice husk fibres and therefore has higher impact strength. The reduction in impact strength from the peek is due to poor bonding between of the reinforcements and the matrix as a result of insufficient epoxy to react with the necessary fibers.

4.2. Hardness Test Results

Table 5 below shows the Rockwell hardness values for ground nut shell- epoxy composites.

The results of the hardness tests using Rockwell scale for rice husk- epoxy composite is indicated in Table 6.

Table 5. ROCKWELL HARDNESS TEST RESULTS FOR GROUNDNUT SHELL-EPOXY COMPOSITES

SPECIMEN	HARDNESS (HRF)	AVERAGE HARDNESS (HRF)
A_{GSC1}	8.0	6.6
A_{GSC2}	6.4	
A_{GSC3}	5.3	
B_{GSC1}	7.5	7.8
B_{GSC2}	8.1	
B_{GSC3}	7.9	
C_{GSC1}	7.6	7.7
C_{GSC2}	7.2	
C_{GSC3}	8.2	
D_{GSC1}	7.5	6.2
D_{GSC2}	5.5	
D_{GSC3}	5.7	
E_{GDC1}	7.2	6.8
E_{GSC2}	6.5	
E_{GSC3}	6.7	
F_{GSC1}	6.4	5.3
F_{GSC2}	4.7	
F_{GSC3}	4.7	

Table 6. ROCKWELL HARDNESS TEST RESULTS FOR RICE HUSK-EPOXY COMPOSITES

SPECIMEN	HARDNESS (HRF)	AVERAGE HARDNESS (HRF)
A_{RHC1}	**9.6**	
A_{RHC2}	**7.5**	**8.7**
A_{RHC3}	**9.1**	
B_{RHC1}	**6.6**	
B_{RHC2}	**6.1**	**6.3**
B_{RHC3}	**6.2**	
C_{RHC1}	**7.7**	
C_{RHC2}	**5.2**	**6.8**
C_{RHC3}	**7.6**	
D_{RHC1}	**5.8**	
D_{RHC2}	**4.6**	**6.0**
D_{RHC3}	**7.0**	
E_{RHC1}	**7.7**	
E_{RHC2}	**6.0**	**6.9**
E_{RHC3}	**7.0**	
F_{RHC1}	**8.2**	
F_{RHC2}	**9.0**	**8.1**
F_{RHC3}	**7.0**	

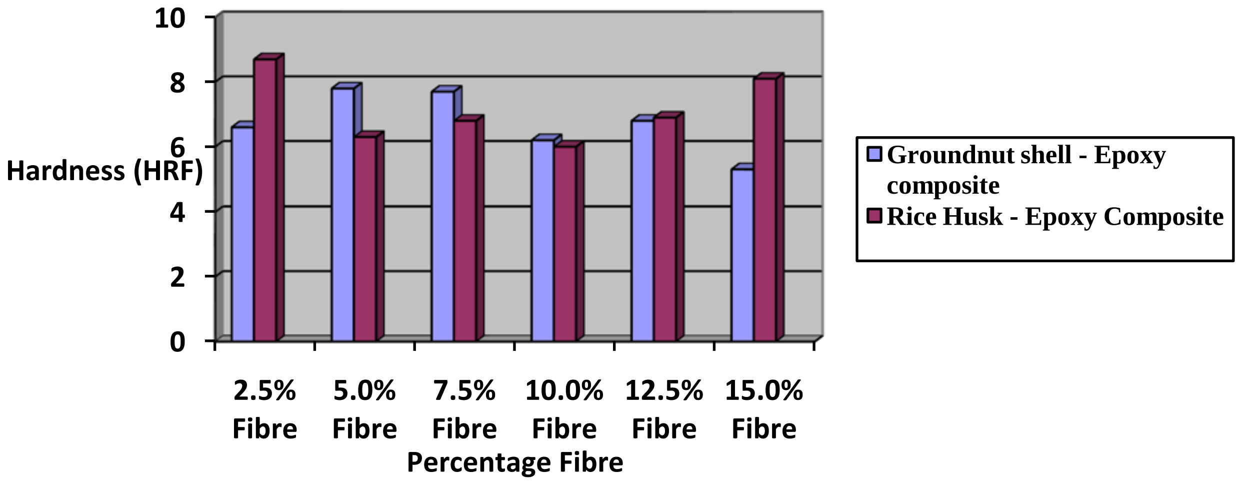

Figure 2. Comparison Chart of Rockwell Hardness for Groundnut shell – Epoxy composite and Rice Husk – Epoxy composite

Figure 2 shows the Rockwell hardness results for groundnut shell – Epoxy and rice husk – Epoxy composites. Hardness is the material property that displays its ability to resist penetration or indentation. Groundnut shell – epoxy composite displayed hardness values slightly higher than rice husk – epoxy composite, except at 2.5% fiber content where rice husk – epoxy composite had higher values for the same fiber content.

The hardness for the two composites attained a near equal value at 12.5% fiber content. Beyond this point, the hardness for groundnut shell – epoxy composite decreased radically to a value of 5.3 while that of rice husk – epoxy composite increased radically to 8.1 at 15% fiber content. The result revealed that hardness increases as the fibre content increases up to an optimal value of 12.5% fibre content or beyond which the resin present was no longer enough to bond the fibres thereby resulting in a loose composite with low hardness value.

4.3. Flexural Test Results

The results of the bending stress for groundnut shell-epoxy composites are indicated in Table 7.

The results of the flexural stress for rice husk- epoxy composite are indicated in Table 8.

Table 7. FLEXURAL TEST RESULTS FOR GROUNDNUT SHELL-EPOXY COMPOSITES

SPECIMEN	WIDTH (mm)	SPAN (mm)	THICKNESS (mm)	LOAD (N)	DEFLECTION (mm)	FLEXURAL STRENGTH (N/mm^2)	AVERAGE FLEXURAL STRENGTH (N/mm^2)
A_{GSC1}	30.6	70	4.5	160	3.65	27.11	37.75
A_{GSC2}	30.1	70	4.4	250	3.60	45.05	
A_{GSC3}	30.2	70	4.6	250	3.74	41.08	
B_{GSC1}	30.0	70	4.2	200	3.65	39.68	34.62
B_{GSC2}	30.5	70	4.3	190	3.66	35.38	
B_{GSC3}	31.0	70	4.2	150	3.56	28.80	
C_{GSC1}	31.2	70	4.9	260	3.02	36.44	29.10
C_{GSC2}	31.2	70	4.8	200	3.10	29.21	
C_{GSC3}	30.3	70	4.9	150	2.30	21.65	
D_{GSC1}	30.5	70	4.5	160	3.60	27.20	25.65
D_{GSC2}	30.8	70	4.9	200	3.32	28.40	
D_{GSC3}	30.9	70	5.2	170	2.00	21.36	
E_{GSC1}	31.0	70	5.3	380	2.72	45.82	43.43
E_{GSC2}	30.1	70	5.1	340	3.17	45.59	
E_{GSC3}	31.0	70	5.6	360	2.95	38.88	
F_{GSC1}	30.4	70	6.3	300	3.05	26.10	28.34
F_{GSC2}	30.2	70	5.9	380	1.62	37.95	
F_{GSC3}	31.8	70	7.1	320	2.78	20.96	

Table 8. FLEXURAL TEST RESULTS FOR RICE HUSK-EPOXY COMPOSITES

SPECIMEN	WIDTH (mm)	SPAN (mm)	THICKNESS (mm)	LOAD (N)	DEFLECTION (mm)	FLEXURAL STRENGTH (N/mm^2)	AVERAGE FLEXURAL STRENGTH (N/mm^2)
A_{RHC1}	30.3	70	4.6	170	3.62	27.84	23.54
A_{RHC2}	30.5	70	4.7	160	1.80	24.94	
A_{RHC3}	32.0	70	4.7	120	3.30	17.83	
B_{RHC1}	30.8	70	4.8	210	2.88	31.07	28.21
B_{RHC2}	31.0	70	5.4	230	3.04	26.72	
B_{RHC3}	30.1	70	4.7	170	1.85	26.84	
C_{RHC1}	30.7	70	4.8	170	2.62	25.24	19.61
C_{RHC2}	30.1	70	5.0	110	3.25	15.35	
C_{RHC3}	31.9	70	5.2	150	2.72	18.26	
D_{RHC1}	32.0	70	6.2	70	1.94	5.98	5.68
D_{RHC2}	30.7	70	6.1	100	1.90	9.19	
D_{RHC3}	30.1	70	6.1	20	1.94	1.88	
E_{RHC1}	30.2	70	6.9	340	2.90	24.83	22.72
E_{RHC2}	31.5	70	6.2	290	3.13	25.15	
E_{RHC3}	30.0	70	6.8	240	3.44	18.17	
F_{RHC1}	30.6	70	7.0	210	3.82	14.71	9.45
F_{RHC2}	31.4	70	7.3	130	3.84	8.16	
F_{RHC3}	31.2	70	7.0	80	3.86	5.49	

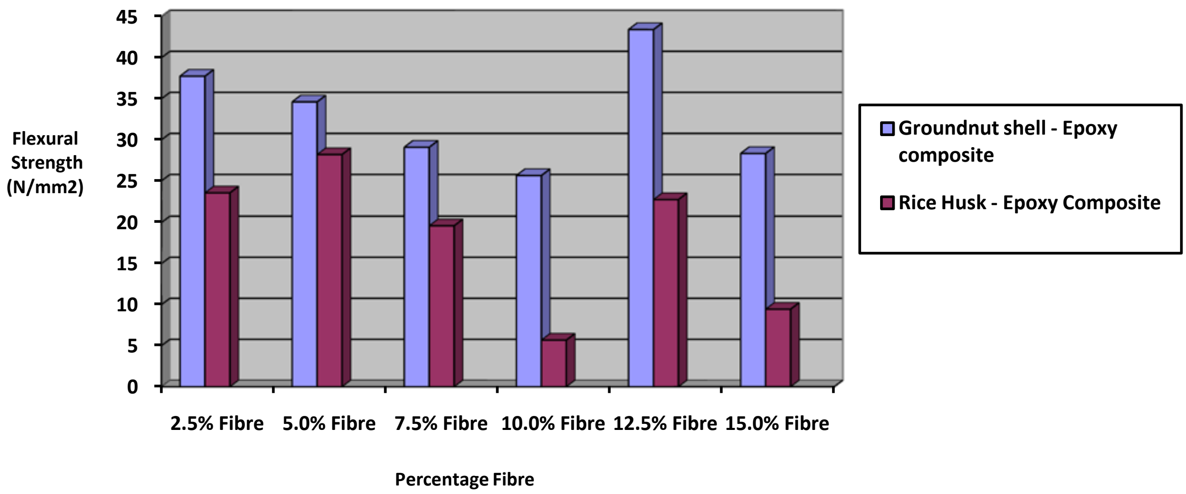

Figure 3. Comparison Chart of Flexural Strength for Groundnut shell – Epoxy composite and Rice Husk – Epoxy composite

Flexural strength is the property of a material which determines its ability to resist bending and/or deflection when subjected to bending loads. The flexural strength reduces as the reinforcement content increases for both groundnut shell and rice husk. The best composition for groundnut shell is at 12.5% fiber content while the best property for rice husk is at 5% fiber content. This is reflected in Figure 3 above.

The major problem encountered was the issue of fibre misalignment during production which heavily affects the flexural strength of the composite. Slight delamination of composite was noticed especially for rice husk composite. The delamination was as a result of geometric discontinuities. This is a usual problem when dealing with short fibres.

4.4. Tensile Test Result

The results of the tensile strength for groundnut shell-epoxy composite are as shown in Table 9.

The tensile strength results for various compositions of rice husk – epoxy composites are indicated in Table 10.

Table 9. TENSILE TEST RESULTS FOR GROUNDNUT SHELL-EPOXY COMPOSITES

SPECIMEN	GAUGE LENGTH (mm)	WIDTH (mm)	THICKNESS (mm)	AREA (mm^2)	AVERAGE AREA (mm)	BREAKING LOAD (N)	AVERAGE BREAKING LOAD (N)	AVERAGE TENSILE STRENGTH (N/mm^2)
A_{GSC1}	40	9.8	4.4	43.12		1650		
A_{GSC2}	40	9.7	4.5	43.65	43.47	2000	1808.33	41.60
A_{GSC3}	40	9.7	4.5	43.65		1775		
B_{GSC1}	40	9.8	4.5	44.10		1250		
B_{GSC2}	40	10.2	4.4	44.88	44.76	1650	1525.00	34.07
B_{GSC3}	40	10.3	4.4	45.32		1675		
C_{GSC1}	40	9.3	4.1	38.13		1050		
C_{GSC2}	40	9.4	4.0	37.60	37.24	975	958.33	25.73
C_{GSC3}	40	9.2	4.0	36.00		850		
D_{GSC1}	40	10.0	4.2	42.00		1225		
D_{GSC2}	40	9.2	4.2	38.64	40.52	1000	1123.33	27.72
D_{GSC3}	40	9.3	4.4	40.92		1145		
E_{GDC1}	40	9.8	5.1	49.98		1375		
E_{GSC2}	40	10.0	5.1	51.00	39.33	1500	1441.67	36.66
E_{GSC3}	40	10.0	5.1	51.00		1450		
F_{GSC1}	40	10.7	5.5	58.85		1150		
F_{GSC2}	40	10.0	5.1	51.00	52.62	1000	1233.33	23.44
F_{GSC3}	40	10.0	4.8	48.00		1550		

Table 10. TENSILE TEST RESULTS FOR RICE HUSK-EPOXY COMPOSITES

SPECIMEN	GAUGE LENGTH (mm)	WIDTH (mm)	THICKNESS (mm)	AREA (mm^2)	AVERAGE AREA (mm)	BREAKING LOAD (N)	AVERAGE BREAKING LOAD (N)	AVERAGE TENSILE STRENGTH (N/mm^2)
A_{RHC1}	40	9.2	5.0	46.00		825		
A_{RHC2}	40	10.0	4.8	48.00	47.67	575	783.33	16.43
A_{RHC3}	40	9.8	5.0	49.00		950		
B_{RHC1}	40	9.8	4.4	43.12		750		
B_{RHC2}	40	10.0	4.2	42.00	42.99	725	716.67	16.67
B_{RHC3}	40	10.2	4.3	43.86		675		
C_{RHC1}	40	9.8	5.1	49.98		675		
C_{RHC2}	40	9.8	5.0	49.00	48.02	575	658.33	13.71
C_{RHC3}	40	9.8	4.6	45.08		725		
D_{RHC1}	40	10.1	6.0	60.10		713		
D_{RHC2}	40	9.8	6.0	58.80	58.70	894	702.33	11.97
D_{RHC3}	40	9.8	5.9	57.82		500		
E_{RHC1}	40	9.8	6.9	67.62		1100		
E_{RHC2}	40	10.1	6.9	69.69	68.21	825	866.67	12.71
E_{RHC3}	40	9.9	6.8	67.32		675		
F_{RHC1}	40	9.5	6.9	65.55		827		
F_{RHC2}	40	10.0	7.1	71.00	69.08	1000	850.67	12.31
F_{RHC3}	40	10.1	7.0	70.70		725		

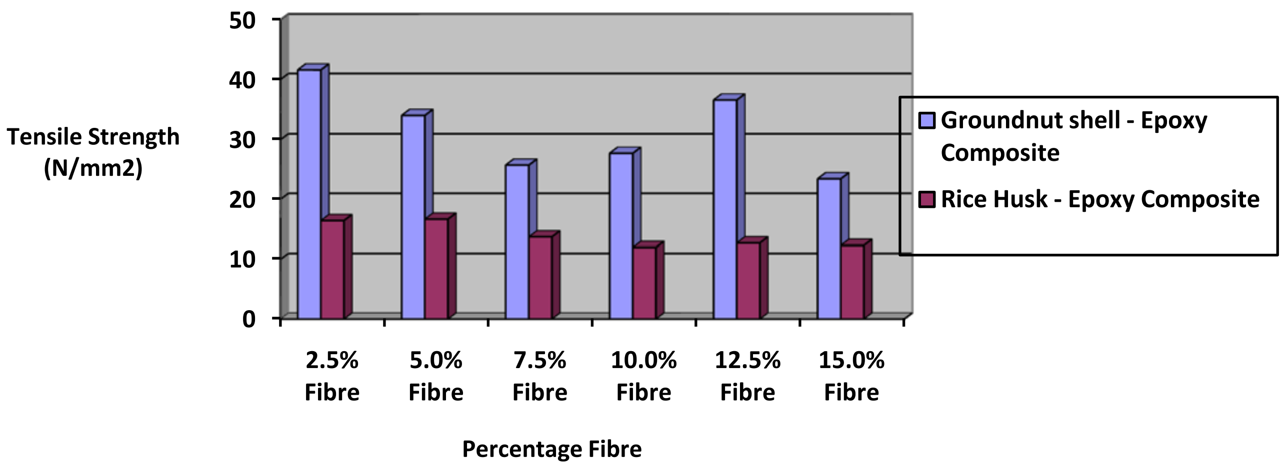

Figure 4. Comparison Chart for Tensile Strength of Groundnut shell – Epoxy composite and Rice Husk – Epoxy composite

The tensile test is a property of a material which determines the ability of the material to withstand axial tensile loading. The tensile test results (Figure 4) obtained indicate that the tensile strength for groundnut shell – epoxy composite is relatively higher than that of rice husk – epoxy composite at the same fiber loading levels. The lowest tensile strength for groundnut shell – epoxy composite was 23.44N/mm^2 at 15% groundnut shell content while that of rice husk – epoxy composite was 11.97N/mm^2 at 10% rice husk content. The highest value of tensile strength for groundnut shell – epoxy composite and rice husk – epoxy composite were 41.60N/mm^2 and 16.67N/mm^2 occurring at 2.5% groundnut shell content and 5% rice husk content respectively. This result is obvious because groundnut shells had longer fibres than rice husk. Ordinarily, the tensile strength is expected to increase as the fibre content increases, this result however did not agree with this due to the problem of fibre misalignment. As the fibres become less aligned with the principal stress, more shear stress is carried than compressive stress. Even small angle of misalignment as it is the case especially for rice husk will have strong effect on the strength.

5. Conclusion and Recommendations

5.1. Conclusion

This research work aimed at determining and comparing the mechanical properties of composite samples formulated and produced with groundnut shell and rice husks respectively. This has been successfully achieved. In general, the groundnut shell – epoxy composites displayed higher mechanical properties as compared to the rice husk - epoxy composites. This behaviour is expected as groundnut shell particulate fibers are relatively harder and more brittle than the corresponding rice husk fibers.

The following conclusions can be drawn from the work:

(i) The experimental investigation revealed that the mechanical properties viz: impact strength, hardness flexural strength and tensile strength for groundnut shell reinforced epoxy composite material and rice husk reinforced epoxy composite are greatly influenced by the percentage of reinforcements present in the composite.

(ii) The impact strength and composite hardness increases steadily as the content of fibres increases for both composite while the tensile and flexural strengths were observed to decrease with increasing percentages of the fibres. This were attributed to the problem of fibre misalignment and delamination noticed during the experimental work.

(iii) The optimal composite developed has been employed in the production of Bajaj tricycle rear bumper. The mechanical properties of the bumper compared favourably with that produced using steel and E-glass fibre in Epoxy composite

(iv) The mechanical properties of these natural reinforcements in epoxy matrix compare favourably with the results obtained using other natural reinforcements such as coconut fiber, palm kernel fiber as reinforcement in epoxy. This is in agreement with the works of Sreenivasulu et al, Alok et al, Shivapa et al and Akindapo et al.

5.2. Recommendations

In the course of this work, new interesting and valuable areas for further research have been identified. These include:

(i) Determination of the mechanical properties of a hybrid composite of groundnut shell and rice husk reinforcements in epoxy resin.

(ii) Determination of the density and hydrophilic characteristic of both groundnut shell reinforced epoxy composite and rice husk reinforced epoxy composite so as to completely determine their suitability for application in the interior parts of an aircraft, motor car and automobiles where materials with good tensile strength and low density are required.

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