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Research Article

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Special Issue

A Themed Issue in Honour of Professor Onukwuli Okechukwu Dominic (FAS).

This special issue is dedicated to Professor Onukwuli Okechukwu Dominic (FAS), marking his retirement and celebrating a remarkable career. His legacy of exemplary scholarship, mentorship, and commitment to advancing knowledge is commemorated in this collection of works.

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Development of Coir-Reinforced Composite for Automotive Parts Application

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Abstract
The demand for lightweight and fuel-efficient automobiles has led to the use of fiber-reinforced polymer composites in place of traditional metal parts. Coir, a natural fiber, offers qualities such as low cost, good tensile strength, and biodegradability, making it a potential filler material for automotive components. However, poor interfacial adhesion between coir and polymeric matrices has been a challenge. To address poor interfacial adhesion with polymeric matrices due to their moisture content and method of preparation, the extracted coir was chemically treated using NaOH. To develop a side view mirror encasement by investigating the mechanical effect of fiber percentage composition, fiber length and percentage composition of Epoxy in a coir fiber reinforced composite, polyester was adopted as the resin for the mould, while that of the product is Epoxy. Coir served as the filler material for the product. Specimens with varied compositions of fiber loading (15, 30 and 45) %, length (10, 15, 20, 30 and 45) mm, and (55, 70, 85) % weight of epoxy resin were fabricated using hand lay-up technique, while those specimens were later subjected to mechanical tests (Tensile, Flexural and Impact test). The results of the mechanical test showed that the optimal solution for the input factors is coir at 45%, epoxy at 54.543%, and 45mm coir length, which was used for the development of a vehicle's side view mirror encasement. The optimal solutions for the response parameters are 49.333 Mpa for tensile strength, flexural for 57.118 Mpa, impact strength for 34.787 KJ/M2, young modulus for 4.788 GPa, stress for 4.534 KN, and 20.483 mm for strain. The models which were developed using Design Expert software revealed that the input factors can achieve the response parameters in the system with 94% desirability. The study showed that coir is quite durable for filler material in an epoxy composite for automobile applications, and that there is a significant effect of fiber loading and length on the mechanical behavior of coir fiber-reinforced epoxy composites. The coir's low density, considerable tensile strength, and bio-degradability contribute to its eco-friendliness and potential for reducing the environmental hazards of synthetic automotive components.

Keywords: coir, composite, coir fiber, coconut husk, polymer, automobile, mechanical test

1. Introduction

The utilization of polymers in automotive parts has ushered in transformative improvements, leading to cost-effectiveness, resistance to corrosion, reduced weight, enhanced performance, innovative design, and heightened safety measures in vehicle manufacturing. This evolution has empowered automotive manufacturers to substitute conventional materials with polymer matrix, thereby streamlining the complexity of car assembly. An intriguing avenue in this trajectory is the emergence of Polymer Matrix Composites (PMCs), a class of materials defined as the incorporation of fibers within a polymer matrix, typically with approximately 60 percent volume fraction of reinforcing fibers (Hariprakash et al., 2019). These PMC possesses desirable attributes such as remarkable rigidity, strength, and corrosion resistance. However, despite these strengths, tensile strength of PMC remains a challenge when compared to metals, necessitating reinforcement for optimal performance.

Coconut fiber also known as coir is one of the fifteen primary plant and animal fibers in the world, it is extracted from the outer shell of a coconut. The shell contains a corky tissue called firth along with water, fibers, and soluble solids. Munawar, Umemura and Kawai (2007), carried out research on natural fiber (Ramie bast, Kenaf bast, Abaca, Pineapple, Sansevieria, Sisal, and Coconut) to determine its strain and stress. The result showed that elongation at

break varies between 3% and 24% for each fiber. Most of the fibers have a low strain (3% - 6%) and high stress varies between (400 - 800 MPa), except for coconut fibers which have a high strain (up to 24%) and low stress of 200 MPa. Coir fiber composites are composite materials that are reinforced with fibers, particles, or platelets which are derived from coconut (Onukwuli, Okpala, and Okeagu, 2022). Coir composites were chosen for this research because of their availability, low cost, as well as high resistance when compared to other commercial fibers. Other advantages of coir fiber include: low density, acceptable specific properties, coarse nature, good sound insulation, ease of separation and extraction, increased energy recovery, and high lignin content which makes it suitable for applications requiring slow degradability. Because of its properties and quantity, coir fiber is considered one of the most essential natural fibers.
The aim of this study was to develop a coir fiber-reinforced composite for automotive parts, specifically a side view mirror encasement. The objective was to investigate the mechanical effects of fiber percentage composition, fiber length, and percentage composition of epoxy in the composite.

2. Literature Review

Coir : Coir is categorized under the plant fiber family. It is a natural fiber that is derived from the husk of the coconut fruit. It is a coarse, thick and durable fiber. India ranks second in the world behind the Philippines in terms of coconut production (Shandilya, Gupta and Verma 2016). The husk includes coir fiber as well as pith, which is a corky tissue. Due to its high lignin concentration, the husk is composed of water, fibers, and small quantities of soluble solids, and it has a higher biodegradability than other natural fibers. Coir is relatively water-resistant and resistant to saltwater and microbial deterioration, and its recent research as a polymer matrix reinforcement has yielded good results (Manu et al., 2022). Because of its remarkable performance in a wide range of applications, coir fiber polymer composite material is a promising alternative to other natural fiber polymer composites. The durability of coir fibers when compared to other natural fibers can be ascribed to its increased lignin content which makes it quite appropriate for use especially where gradual bio-degradability is needed."

Retting: Retting is defined as the subjecting of crop or deseeded straw to chemical or biological treatment in order to make the fiber bundles more easily separable from the woody section of the stem in order to ease fiber bundle removal (Vijay and Srikantappa, 2016). Coir fiber is the thickest and toughest commercial natural fiber; it is a byproduct of the coconut industry, manufactured from processed coconut husks that have their biological components removed. The exocarp (coconut husk) is made up of a fibrous zone (mesocarp), and a smooth water-repellent outer layer (epicarp). The mesocarp is composed of coir fibrovascular bundle threads embedded in non-fibrous parenchymatous connective tissue (Chand and Fahim, 2020). Un-extracted coir fiber in coconut husks are shown in Figure 1.

Figure 1: Un-extracted Coir Fiber

Coconut retting, which can be in the form of dew or water retting, is a biological and moisture process that dissolves or removes the coconut husk (exocarp), allowing the coir (mesocarp) fiber to be removed from the coconut. It is achieved by soaking coconut husk in water for six to twelve months, during which the fibers and husk's bonding components disintegrate. The harvested coconut is dispersed evenly across grassy fields in dew retting, which is common in places with limited water supplies, where the combined action of bacteria, sun, air, and dew creates fermentation, dissolving most of the exocarp and mesocarp binding force.

Coconuts are submerged in water during water retting, which is the most extensively used method. Water that enters the exocarp swells the inner cells, shattering the external layer and increasing moisture and decay-causing bacteria absorption. Dew-retted fiber is darker in color and poorer in quality than water-retted fiber. The salinity of the water, the type of the husk, the season, and the depth of the water are all elements that influence the retting process.

Coir Fiber Extraction: During the coir fiber extraction process, a large quantity of coir residue is generated. After soaking the coconut husk for six to ten months, the extracted coir fiber was divided into two types: brown fiber from mature coconuts and finer white fiber from immature coconuts. To extract white fiber, retted husks are taken from the retting enclosure, washed to remove any clinging slime, dirt, or sand, and the exocarp is easily peeled off. The husks are pounded with wooden mallets on tree trunks or stones to separate the fibers. The fibers were then washed, dried, and stacked together. The wet husks are put through spiked breaker drums to remove the fragile fiber. The drums are pushed at high speeds in opposing directions to separate the long and short fibers. The brittle fibers that pass between the drums are gathered and cleaned by running them through another pair of drums with closer nails, followed by washing and drying. Extracted coir fiber is depicted in Figure 2.

Figure 2: Extracted Coir Fiber

Coir Fiber Treatment: The coir must be surface treated before being included into the matrix. Many researches on coir treatment have already been done to discover how it affects both the physical and chemical characteristics of the coir. Rout et al. (2001), studied the impact of coir treatment with 2% alkali on polyester composite, and the findings showed enhanced tensile strength and a decrease in strength above 2% sodium hydroxide (NaOH) concentration. The mechanical characteristics of coir fiber can be enhanced by eliminating lignin and hemicelluloses from wet alkali-treated coir polyester (Arrakhiz et al., 2012). The chemical properties of coir fiber are depicted in Figure 3.

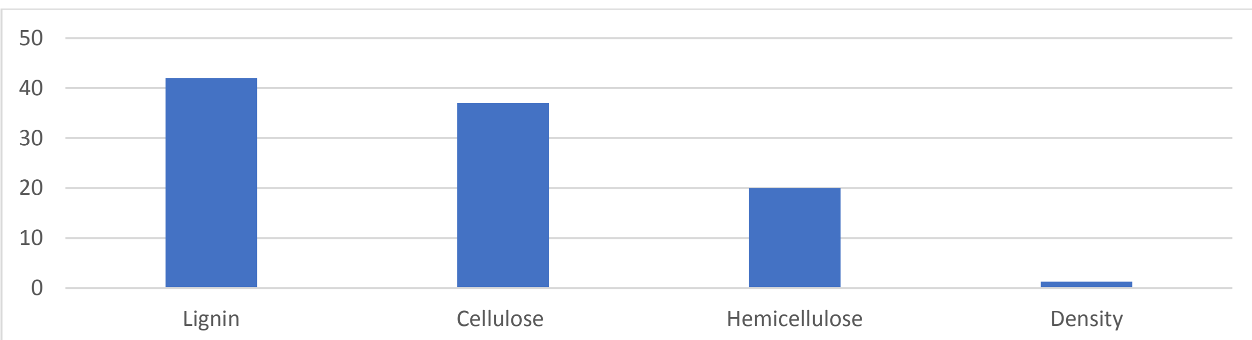

Figure 3: Chemical Properties of Coir Fiber. Source: Okpala, Onukwuli and Ezeanyim (2021),

3. Methodology

Coir, which serves as the filler material for the reinforcement of epoxy composite was prepared through a multi-step process, which involved extraction down to treatment of coir. Figure 4 provides an overview of the various stages involved in the preparation of coir, which culminated in the production of a high-quality filler material for the composite.

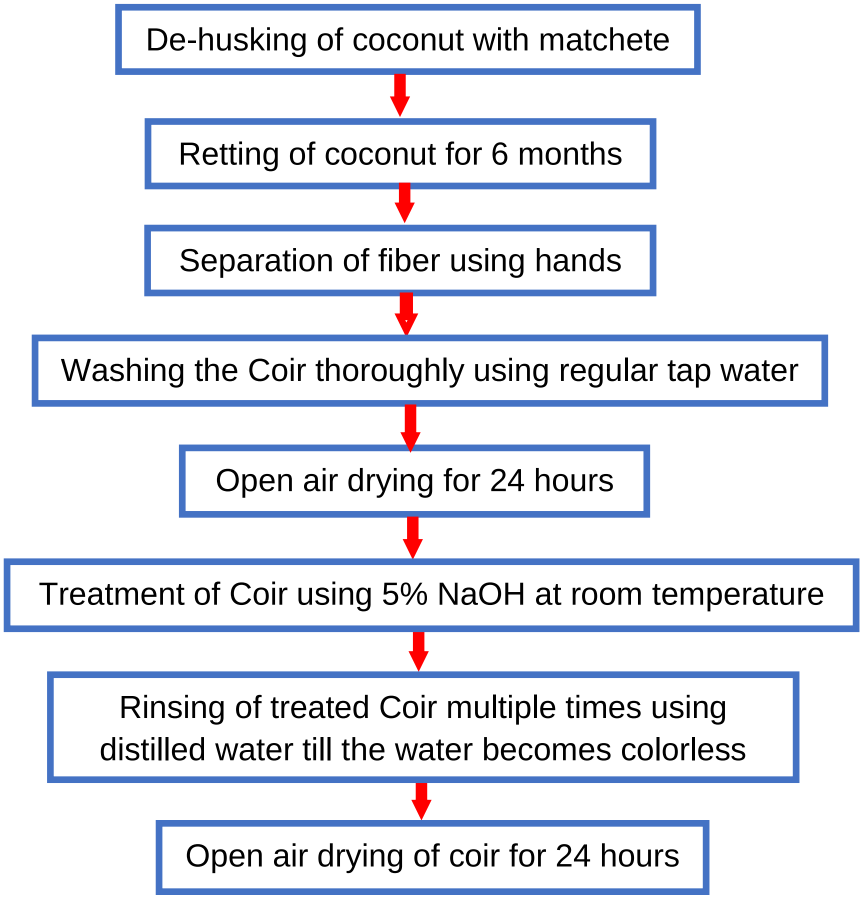

Figure 4: Stages involved in the preparation of coir

Coir Surface Treatment: Mercerization which is a chemical treatment or modification were carried out on the extracted fibers. The first procedure was to wash the extracted coir thoroughly with regular tap water in order to remove all dirt or other particles on the surface of the fibers; the coir was exposed on open air for 24hours to dry. Next, based on the recommendations of Ihueze, Obiafudo and Okafor (2017), to produce a solution of 1 mole of NaOH, 40g of NaOH was dissolved in 1000ml of water. For the extracted fiber set, a total of 7 moles of NaOH solution was used. Consequently, as the quantity of fiber increases, the number of moles of the solution also increases. After preparing the required volume of the solution, the fiber was soaked in the NaOH solution for a duration of 60 minutes. During this time, the mixture was stirred at 10-minute intervals. After one hour of soaking, the mercerized fiber was thoroughly rinsed with distilled water to minimize any further effects of sodium hydroxide (NaOH) on the fiber, then dried in open air for 24 hours.

Mold design and specification: The choice of molds designed for this research are based on the mechanical properties of the developed materials that will be investigated, these includes; tensile, flexural and impact. Models were therefore designed in accordance with; ASTM D638, ASTM D790 and ASTM D6110, specifications respectively. These molds are made of wood with reasonable thermal strength and thickness.

Design for quantities of fiber and resin (Matrix): The weight fraction of fiber was used to estimate the mass of fiber and mass of resin necessary for the experiment. Composite design was carried out using standard specifications of ASTM D638, ASTM D790 and ASTM D6110 for tensile, flexural and impact tests respectively. The weight fraction of fiber (W_{fr}) which is the ratio of fiber to the weight of composite (W_c) can be expressed as

$$W_{fr} = \frac{(w_f)}{w_c} \quad (1)$$

Different composites were fabricated using the hand lay-up technique. The matrix was made by mixing Epoxy LY556 and hardener HY951 in a ratio of 10:1 by weight, as specified in the product data sheet. It was later stirred until the mixture became smooth. Also, efforts were made to ensure that and any trapped air bubbles were released. The molds were coated with wax to facilitate easy removal of the composite after fabrication.

The mixture was then poured into the mold, afterwards is the laying of coir on the epoxy using the percentage weight of the experimental design and compacted with hands. This process was repeated continuously till the required ASTM specifications for the three tests were achieved. The composite was then covered with glass plate, and allowed to cure under room temperature. The curing process involves an exothermic reaction, and the epoxy resin can cure at any temperature from 5 to 150^{0}C depending on the curing agent used (Pascault and Williams, 2010). Curing agents include amines, polyamides, phenolic resins, anhydrides, and isocyanates. Each composite cast was cured under a load of 7 kg for 24 hours before being removed from the mold, and then post-cured at room temperature for an additional 24 hours. Specimens of the appropriate dimensions were prepared for mechanical testing according to the appropriate ASTM standards, and care was taken to ensure uniformity and homogeneity of the composite.

Mold design and specification: The choice of molds designed for this research are based on the mechanical properties of the developed materials that will be investigated, these includes; tensile, flexural and impact. Models were therefore designed in accordance with; ASTM D638, ASTM D790 and ASTM D6110, specifications respectively. These molds are made of wood with reasonable thermal strength and thickness.

Mechanical Testing: ASTM standards were maintained during the tests to determine the mechanical properties of the composites. The specific tests used were ASTM D638 for tensile testing, ASTM D790 for flexural testing, and ASTM D6110 for impact testing. The testing of samples was conducted at Midwal Engineering Service Lagos, Nigeria. The equipment used for the mechanical test includes Analog ASTM Charpy Impact Testing Machine (model TFIT-300; 300J), 3383 Floor Model Universal Testing Machine. Figure 5 shows the 15 samples before the commencement of mechanical tests.

Figure 5: 15 Samples Before the Mechanical Testing

Mould Design and Material Specification: The methodology for mold development in this project commenced with the design phase using SolidWorks software, with the proposed mould design in Figure 6 serving as a reference. Subsequently, materials including earthenware clay, Portland cement, polyester resin, catalyst (hardener), and reinforcement (mat emulsion) were gathered for the construction process.

The mold was fabricated using the designed model as a guide on the earth clay, followed by the application of polyester resin. The curing process, was allowed to complete, ensuring proper hardening.

Product Development

The process of developing the side mirror encasement involves utilizing the hand lay-up technique. The fabrication process begins with the application of wax onto the surface of the mold already developed for this study. This step is crucial to ensure easy detachment of the final product from the mold. Next, the epoxy resin was applied to the waxed mold surface and left at room temperature for approximately three minutes before the application of coir. This process was repeated until the desired thickness is achieved. To eliminate air bubbles or voids that could cause defects, each layer of epoxy and coir was manually compacted. Once the product has cured after 24 hours at room temperature, it was carefully removed from the mold. After the inspection of the product for defect detection, the excess coir layers were cut off, after which hand files and abrasives were used to smoothen the moulded side mirror encasement as shown in Figure 7

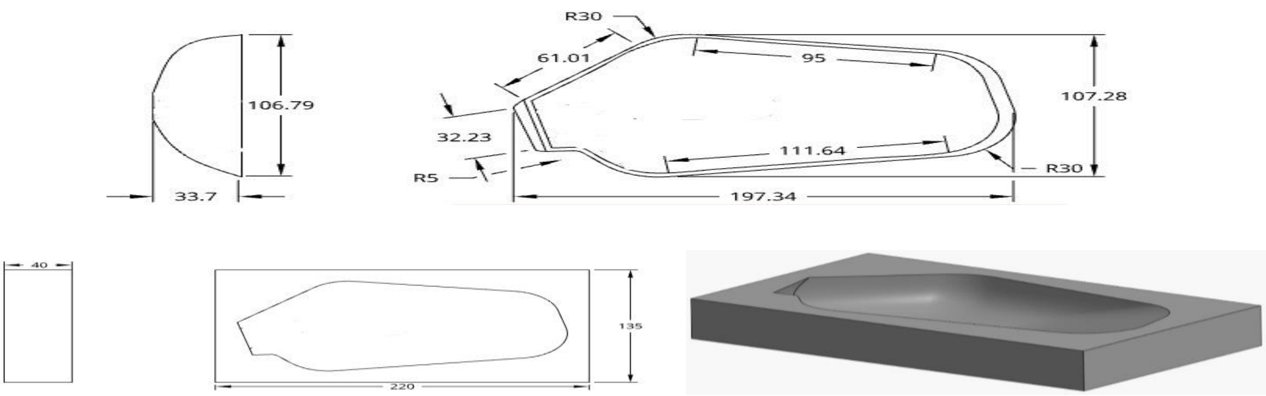

Figure 6: The Mould Design.

Figure 7: The Moulded Driving Mirror Encasement

4. Analysis of Results

The experimental design result is shown in Table 1. The mechanical tests led to the evaluation of the performance and properties of the composite material, thereby providing valuable insights into its structural integrity and potential applications.

Table 1: Experimental Design Results

		Factor 1	**Factor 2**	**Factor 3**	**Response 1**	**Response 2**	**Response 3**	**Response 4**	**Response 5**	**Response 6**
Std	Run	A:Coir	B:Epoxy	C:Coir Length	TENSILE	FLEXURAL	IMPACT STRENGTH	YOUNG MODULUS	STRESS	STRAIN
		%	%	mm	MPa	MPa	kj/m^2	GPa	GPa	
11	A	15	85	10	20.66	37.11	11.89	2.59	2.60	7.54
3	B	15	85	15	30.54	42.99	15.39	2.89	2.80	8.09

2	C	15	85	20	32.62	45.01	21.53	3.39	3.10	10.51
10	D	15	85	30	39.80	46.79	24.88	3.80	3.40	12.92
15	E	15	85	45	40.32	49.66	25.43	3.85	3.60	13.86
5	F	30	70	10	33.40	44.87	17.70	3.13	2.90	9.08
8	G	30	70	15	34.61	47.44	19.31	3.33	3.20	10.65
12	H	30	70	20	37.21	48.79	23.38	3.98	3.60	14.33
6	I	30	70	30	48.65	58.65	29.03	4.31	4.10	17.61
1	J	30	70	45	43.12	52.66	26.28	3.83	3.90	14.94
14	K	45	55	10	35.42	45.22	22.78	3.55	3.30	11.72
9	L	45	55	15	33.73	51.21	24.74	4.07	3.70	15.06
13	M	45	55	20	45.27	53.6	27.63	3.94	4.10	16.15
7	N	45	55	30	44.94	55.56	30.47	4.27	4.50	19.22
4	O	45	55	45	46.02	54.69	33.78	4.58	4.80	21.98

Experimental Design Analysis

Table 2 shows the report and analytical results of the experimental runs. The runs show that the experimental trials are fit and adequate for the experimental analysis of tensile strength.

Table 2: Report of the Tensile Strength Analysis

Run Order	Actual Value	Predicted Value	Residual	Leverage	Internally Studentized Residuals	Externally Studentized Residuals	Cook's Distance	Influence on Fitted Value DFFITS	Standard Order
1	20.66	21.09	-0.4297	0.854	-0.508	-0.467	0.151	-1.127	11
2	30.54	28.73	1.81	0.841	2.048	4.564	2.214$^{(1)}$	10.486$^{(1)}$	3
3	32.62	33.18	-0.5573	0.487	-0.352	-0.319	0.012	-0.311	2
4	39.80	39.68	0.1205	0.646	0.092	0.082	0.002	0.111	10
5	40.32	38.65	1.67	0.577	1.163	1.217	0.185	1.423	15
6	33.40	33.55	-0.1460	0.602	-0.105	-0.094	0.002	-0.116	5
7	34.00	33.18	0.8227	0.487	0.520	0.478	0.026	0.466	8
8	37.21	38.11	-0.9026	0.498	-0.577	-0.534	0.033	-0.532	12
9	48.65	49.57	-0.9170	0.787	-0.899	-0.878	0.298	-1.687	6
10	43.12	41.90	1.22	0.859	1.473	1.752	1.325$^{(1)}$	4.328$^{(1)}$	1
11	35.42	38.71	-3.29	0.407	-1.936	-3.459	0.258	-2.868$^{(1)}$	14
12	33.73	35.09	-1.36	0.853	-1.609	-2.073	1.508$^{(1)}$	-5.002$^{(1)}$	9
13	45.27	44.55	0.7187	0.691	0.585	0.542	0.076	0.809	13
14	44.94	44.22	0.7158	0.586	0.504	0.462	0.036	0.550	7
15	46.02	45.49	0.5311	0.824	0.572	0.530	0.153	1.145	4

Figure 8 shows the predicted and the actual data variation of the tensile strength material composition.

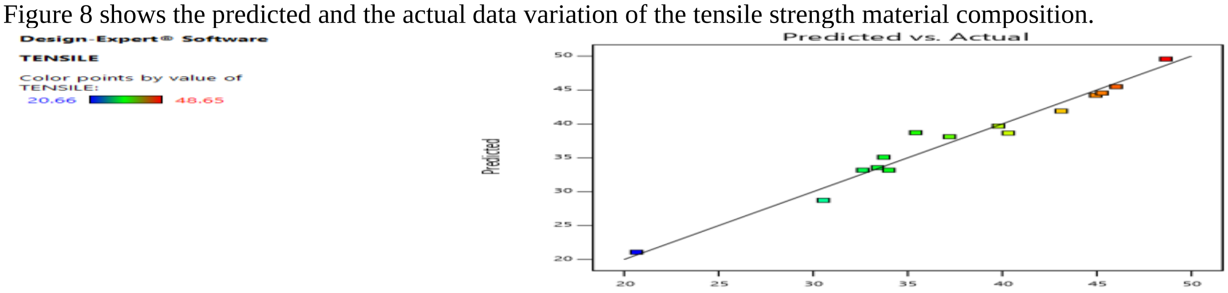

Figure 8: Predicted versus Actual Plot

The variations within the predicted and the actual for the tensile strength experiment trials are insignificant and the residual plot of the tensile strength, which expressed the difference of the actual data and the predicted is insignificantly very low. The plot also shows that the residual lack of fit is insignificant.

Figure 9 depicts the three-dimensional (3-D) plot of the coir material and coir length input factors and its effect on the tensile strength response parameter.

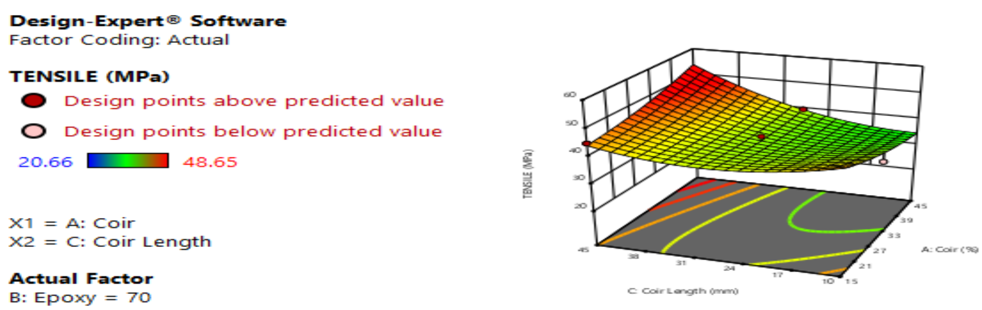

Figure 9: 3-D Surface Plot of the Tensile Strength, Coir and the coir length

The plot reveals that an increase in coir length will slightly increase the tensile strength of the composition. However, the increase in coir material will slightly and insignificantly increase tensile strength.
Figure 10 shows the three-dimensional (3-D) plot of the coir length and epoxy input factors and its effect on the tensile strength response parameter.

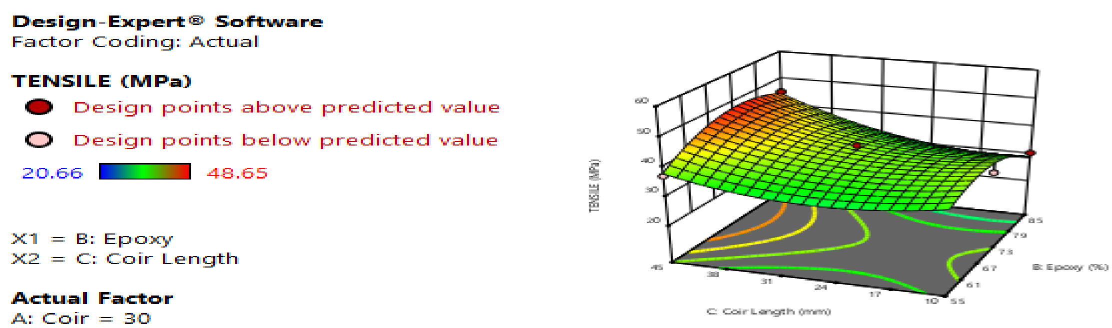

Figure 10: 3-D Surface Plot of the Tensile Strength, the coir length, and Epoxy

The plot shows that the increase in epoxy slightly increases the tensile strength towards the middle and slightly decreases the tensile strength as epoxy material increases towards the maximum. However, the increase in coir length input parameter slightly increases the tensile strength composition.

4.2 Optimization Solutions

Before the optimization solutions, experimental design analysis were also carried out to determine the coir fiber's flexural strength, impact strength, Young modulus, stress, as well as strain. Table 3 shows the number of solutions found in the System. In the study, Response Surface Methodology (RSM) was applied to systematically optimize the parameters of the coir fiber reinforced epoxy composite for the automobile side view mirror encasement. The goal was to determine the optimal parameters for achieving desired mechanical properties in the composite.

The results show that the optimal solution for the input factors that is the coir is 45.000%; epoxy is 54.543% and coir length is 45.000mm. However, the optimal solutions for the response parameters are 49.333MPa for tensile strength, flexural for 57.118MPa, impact strength for 34.787 KJ/M^2, young modulus for 4.788 GPa, stress for 4.534KN, and 20.483 units for strain. The optimal solution results show that the desirability of achieving the selected result is 94.9% (that is 0.949). This shows that the selected results can be achievable and it's realistic.

Table 3: Number of Solutions found in the System

S/N	Coir	Epoxy	Coir Length	TENSILE	FLEXURAL	IMPACT STRENGTH	YOUNG MODULUS	STRESS	STRAIN	Desirability	
1	**45.000**	**54.543**	**45.000**	**49.333**	**57.118**	**34.787**	**4.788**	**4.534**	**20.483**	**0.949**	**Selected**
2	45.000	54.465	45.000	49.277	57.089	34.762	4.786	4.535	20.493	0.949	
3	45.000	59.652	45.000	49.411	57.158	34.820	4.790	4.532	20.469	0.949	
4	45.000	60.012	45.000	49.665	57.289	34.929	4.798	4.526	20.423	0.949	
5	45.000	60.642	45.000	50.091	57.510	35.104	4.809	4.516	20.342	0.949	
68	15.000	72.861	16.069	42.343	53.366	29.528	4.249	3.807	14.980	0.693	
69	15.000	75.001	16.885	41.440	53.108	29.154	4.235	3.849	15.263	0.691	
70	15.000	76.710	21.273	39.869	52.354	28.405	4.198	3.911	15.655	0.680	

Figure 11 shows. The input factors show that the rates of desirability for the three input factors are 100% each. The rate of desirability for tensile strength response parameter is 100%. The rate of desirability for flexural response parameter is 92.89%. The rate of desirability for impact strength response parameter is 100%. The rate of desirability for young modulus response parameter is 100%. The rate of desirability for stress response parameter is 87.91%.

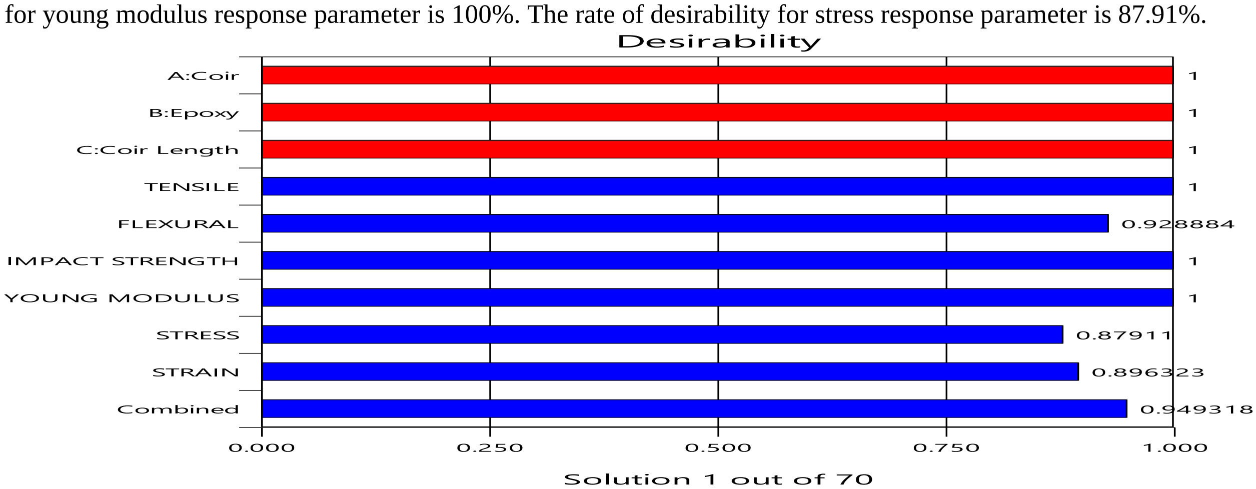

Figure 11: Desirability Optimization Plot

The rate of desirability for strain response parameter is 89.63%. However, the average combined desirability for the input factors and the response parameters is 94.9 %. The result revealed that 94.9% of the independent variables can averagely achieve 94.9% results of the response parameters in the system.

Validation of the Optimized Solution

Table 4 shows the validation of the Optimized Solution. The result of the optimal solution generated using linear programming is close to that of response surface method when compared with the results. The response surface method is the more appropriate model than linear programming optimization method based on the sequential probability values and the lack of fit probability values of the models selected. Furthermore, the models developed with response surface method have reduced errors, which confirmed the model fitness statistically before selection of the models.

The application of linear optimization tool which gave similar values validated the results of the response surface method. The results developed are achievable and realistic, as the models showed that the input factors can averagely achieve the response parameters in the system.

Table 4: Validation of the Optimized Solution

Mechanical Property	Response Surface Method	Linear Programming
Tensile Strength (MPa)	49.333	46.63
Flexural Strength (MPa)	57.118	58.65
Impact Strength (KJ/M^2)	34.787	27.21
Young Modulus (Gpa)	4.788	4.21
Stress (KN)	4.534	4.10
Strain (mm)	20.483	15.31

Findings: The optimal solution for the input factors was found to be 45% coir, 54.543% epoxy, and 45mm coir length. The developed side view mirror encasement showed desirable mechanical properties including tensile strength, flexural strength, impact strength, young modulus, stress, and strain. The models developed using Design Expert software indicated that the input factors could achieve the desired response parameters with 94% desirability.

Theoretical Importance: This study demonstrated the suitability of coir as a filler material in epoxy composites for automotive applications. It also highlighted the significant influence of fiber loading and length on the mechanical behavior of coir fiber-reinforced composites. The low density, good tensile strength, and biodegradability of coir contribute to its eco-friendliness and potential for reducing environmental hazards compared to synthetic automotive components.

Data Collection and Analysis Procedures: Coir fibers were extracted and chemically treated. Specimens with different compositions were fabricated using hand lay-up technique. Mechanical tests were conducted on the specimens. Data from the tests were analyzed to determine the optimal solution for the input factors and to assess the mechanical properties of the developed side view mirror encasement.

Questions Addressed: The study addressed the following questions: How does fiber percentage composition, fiber length, and epoxy composition affect the mechanical behavior of coir fiber-reinforced composites? Can coir be a suitable filler material for automotive parts? How can the interfacial adhesion between coir and polymeric matrices be improved?

4.3 Limitations of the Study

The major limitation of the research is that the study focused primarily on the mechanical properties of the composite material itself, but did not extensively delve into how the coir fiber reinforced epoxy composite will interact with other factors of the automobile side view mirror system. Factors like vibration damping, interactions with electronic components, and long-term effects of exposure to environmental conditions were not thoroughly investigated, thereby leaving potential insights unexplored.

4.4 Recommendations for Future Research

Based on the study's findings, it is recommended that future research should focus on paying close attention to the composition of the fiber reinforcement, explore the composite’s interaction with vibration, and also adapt models for prediction and optimization of the mechanical properties of coir. This will enable automobile manufacturers to fully maximize the benefits of coir reinforced epoxy composite, and also enhance the overall performance of side view mirror encasements, as well as other automotive parts such as bumpers, fenders, door panels, etc.

5. Conclusion

Exploration of coir fiber as a reinforcement material for polymer matrix composites presents a unique opportunity to intersect the realm of automotive innovation with the imperatives of circular economy and sustainable development. By advocating for the adoption of renewable resources like coir, contributes to the paradigm shift towards more environmentally responsible practices within the automotive industry thus, reshaping the future of automotive materials and design.

The samples were analyzed using Response Surface Method (RSM), and the optimal solution from RSM was further validated using Linear Programming. The Response Surface Method indicated that the optimal input factors for product development were found at the seventieth (70) solution. The results revealed that the optimal solution for the input factors, including coir content, epoxy content, and coir length, were determined to be 45.000%, 54.543%, and 45.000mm, respectively. Furthermore, the optimal solutions for the response parameters, such as tensile strength, flexural strength, impact strength, Young's modulus, stress, and strain, were determined to be 49.333 MPa, 57.118 MPa, 34.787 KJ/M2, 4.788 GPa, 4.534 KN, and 20.483 mm, respectively. The desirability of achieving the selected result was found to be 94.9% (0.949), as determined by the optimal solution results. These findings were further validated through the use of a linear optimization tool, which yielded similar values to those obtained from the Response Surface Method.

Coir has proven to be one of the most suitable filler materials for automotive part composites, enabling the automotive manufacturing industry to reach new levels of achievement and production of cars that are economical, environmentally friendly, and ecologically sustainable, without compromising customers' satisfaction. Affordability, is a crucial factor in automobile production as it encompasses the expenses associated with the entire life cycle of a car, including manufacturing, operating, and maintenance costs. Carbon fiber, widely used in automotive parts, fails to meet affordability requirements due to the high costs and time consumption associated with its rigorous composite preparation, ranging from thermal pyrolysis to the transformation of raw carbon material into carbon fiber. In contrast, utilizing coir as an alternative to synthetic fiber can significantly reduce production costs and maintenance expenses in automotive parts.

The study concluded that coir is a durable filler material for epoxy composites in automotive applications. The mechanical properties of the coir fiber-reinforced composite were influenced by fiber loading and length. The developed side view mirror encasement showed desirable mechanical properties. Coir's low density, good tensile strength, and biodegradability makes it an eco-friendly alternative to synthetic automotive components.

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