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Research Article

Optimization on the Mechanical Properties of Aluminium 8079 Composite Materials Reinforced with PSA

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AA 8079 with variable percentages of peanut shell ash (PSA) was created by stir casting (2.5 percent, 5 percent, 7.5 percent, 10 percent, 12.5 percent, and 15 percent). Compared some of the physical and mechanical properties of the composite material were to the alloy matrix alloy (density; porosity percentage; hardness; wear index; tensile strength; and impact strength). Peanut shell ash reinforcements were found to be distributed uniformly throughout the Aluminum Matrix, with pockets of agglomerated reinforcement particles. The hardness, wear index, and density of the composite were enhanced by adding PSA particles. Compared to the matrix alloy without reinforcement, the composites had lower tensile and impact strengths. Mixture design with Design-Expert (Stat EASY) software package indicated the appropriate matrix and reinforcing combination proportions and how they influenced composites' studied properties. Composites' physical and mechanical properties were predicted and optimized using regression models created and the ideal mixture of matrix and reinforcement wt. According to optimization findings, the components for optimal composite characteristics' responses are 93.48 and 6.52 percent of matrix and reinforcement wt% particles. They can utilize PSA-reinforced AA8079 core materials to make automotive components that need lighter, stackable, and wear-resistant.

1. Introduction

In the recent time, there have been increasing interests in researches on the use of naturally sourced and agro-waste based reinforcements in composite materials due to their ease of fabrication, as well as a growing worldwide effort to conserve the environment and stricter global penalties for noncompliance, flexibility, regenerative, and lower costs are all important factors [1]. The main benefit of aluminum composite materials is the combination of strength and rigidity with light weight. Manufacturers may generate qualities that precisely match the needs for a specific construction for a particular purpose by selecting the right combination of reinforcement and matrix material. Natural fibre and agro-wastes reinforced composites are environmentally benign materials with promising applications in various fields, especially where environmental and energy conservation are of great concern. They are considered as suitable materials to replace the expensive and highly dense Lighter, strong, and energy-saving applications for composite polymers, their related products, and other industrial waste [2, 3]. The real advantages of natural fibre is flexible and light weight. The wide variety of fibre reinforcing elements makes composite materials more versatile and expands their potential. Composite materials could benefit from the use of natural fibres and agricultural wastes [4]. Because they are biodegradable, renewable, recyclable, and may be found in a wide variety of natural and cultivated forms, natural fibres are superior than synthetic ones. While artificial fibres (like silicon carbide and carbon) are manufactured in advanced developed countries, natural fibres of plant and animal origin are commonly grown in underdeveloped countries as agricultural waste or waste products, [5–8]. A large source of income for the local economies in these underdeveloped countries will be generated by this project. Large amounts of solid wastes, like palm kernel shell, coconut shell and wood charcoal as well as peanut shell, periwinkle husk and rice husk can be generated by the mining of several minerals in India [9, 10]. It is possible to utilize these solid agricultural leftovers individually or in combination to make environmentally-friendly composite materials for diverse uses, including the environment seen in automotive disc brakes [11].

The wide range of applications for aluminium metal matrix composites (AMMCs) in many industries, including aviation, automobile, aviation, maritime, thermal protection, and electrical and electronic engineering, and sporting goods, has made this research area a hotbed of activity [12, 13]. Most commonly, the manufacturing of AMMCs has utilised aluminium alloys from the 2000, 5000, 6000, and 7000 series range as a matrix. AMMCs due to their light weight, they exhibit a high stability ratio [14]. excellent stiffness-to-weight ratio and excellent thermal conductivity. Additionally, AMMCs exhibit superior deformation and creeping resistance [15]. Aluminium alloy AA8079 with the major alloying elements are silicon and magnesium is utilised in the aerospace and automobile industries. When reinforced with properties and low thermal expansion coefficients, high hardness, high tensile strength, and superior durability, composite materials can be tailored to satisfy specific physical and mechanical requirements. AMMCs can be reinforced by continual or intermittent fibres, bristles, or particles [16–19]. These more affordable AMMCs are commonly made by strong (powder metallurgy) or liquid-state techniques (stir casting, infiltration, and in-situ operations). By including minimal and regenerative particulate material fillers such as coconut shell, peanut shell, palm kernel, charcoal, and peanut shell into the alloy matrix, the overall cost of AA8079 and its end products can be decreased. Composites can be used in lightweight, load-bearing, and wear-resistant automotive and aeronautical applications [20, 21]. Figure 1 reveals the schematic diagram of Metal matrix composites advantages and applications.

The Design of Experiment (DOE) tool can be used to run minimal experiments by altering input components between their respective positions, statistically analysing their relevance, creating model equations, and verifying model accuracy and applicability using input-output data [22]. Previously, researchers have employed tools and approaches for Analytical method techniques include response surface analysis (RSA), box Behnken design (BBD), combination testing, factorial design, and the Taguchi approach etc. to optimise and predict composite materials production process factors and attributes [23]. Furthermore, the results showed that it is an excellent tool for the design, composite material simulation and improvement. Factorial, response surface, and mixture designs of the DOE can be used to examine the interplay of MMCs fabrication process factors and their impacts on physical and mechanical properties (response variables) under the conditions of experimentation and predictive modelling [24–26]. For the most part, the factorial design method is used to determine whether or not certain components are critical to the overall process. In certain cases, this can be done by narrowing down the list of elements to just a handful, or by describing how each factor interacts with the others [27]. Components in a mixture, like composite materials, can have different responses based on their respective quantities. Each run sums up to the same amount because all of the mixture components are inputted in the same units of measure. The response surface approach is a quantitative and empirical design technique that involves the examination of how selected dependent variables respond to changes across one or more unbiased or factor variables [28, 29]. These designs enable statistical models and improvement of empirical process factors/variables and response quality. The goal is to optimise the dependent variable's output (output/properties) by altering the implementation of targeted for one or more independent/factor variables (inputs/process parameters) [30].

Natural and agricultural waste materials such as rice husk, sugarcane bagasse, palm kernel shells, and coconut husk have been used to make aluminium alloy-based composites. According to several of these studies, peanut shell ash has the potential to be an effective hybrid reinforcement for composite materials [31–33]. The goal of this study is to construct an aluminium 8079-matrix composite with a single reinforcement of peanut shell ash (PSA). Processing peanut shell particles for use as reinforcement in an aluminium 8079 alloy matrix is the goal of this study. Compared to other synthetic fillers like SiC (3.18 g/cm^3) and Al_2O_3 (3.9 g/cm^3), PSA's low density (1.96 g/cm^3) makes it an ideal companion to hybrid aluminum-based composites, which is why it is being used in this study. In many parts of underdeveloped countries like India, peanut shell is also readily available in big quantities and is frequently distributed [34, 35]. Other impacts on particle-reinforced AA8079 composite physical and mechanical properties (denseness and apparent porosity, hardness and impact strength) were explored when the weight percent of peanut shell ash in the particulate composition was varied [36–38]. The research will also use the mixed design method to model and optimise the properties that have been tested experimentally. Thus the objective is to incorporate the agro-waste peanut shell ash as reinforcement in Metal Matrix Composites in varying percentages and to study the mechanical properties of the produced composites and alleviate some of the environmental concerns associated with this solid agricultural residue [39, 40].

2. Experimental Techniques

The following experimental techniques and procedures were adopted in carrying out this research.

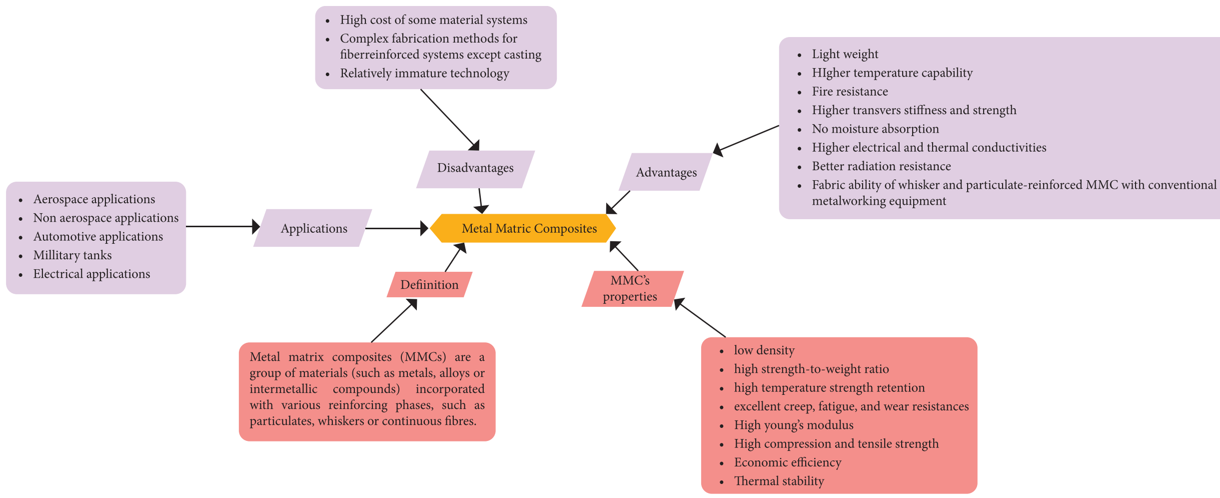

Figure 1: Schematic diagram of Metal matrix composites advantages and applications.

2.1. Materials Preparation

2.1.1. Matrix Material. Aluminum 8079 is a versatile, one-of-a-kind metal that may be brazed, welded, riveted. Most applications do not require a protective coating since aluminium is naturally corrosion resistant. Aluminium based alloy AA8079 with the elemental chemical composition specified in Table 1.

2.1.2. Processing of Reinforcing Material (Peanut Shell Ash). PSA is utilised to create panels, feedlot production, and manufacture activated carbon. Good chemical resistance, economy, improved workability, reduced bleeding and increased impermeability. There were enough dried peanut shells for this study. To ensure total combustion, the peanut shells were placed inside a vertical tube and ignited outdoors. To minimise the ash's volatile components, it was heated to 650°C in a muffle furnace for four hours. Table 2 shows the chemical make-up of peanut shell ash.

2.1.3. Fabrication of Composite. The AA8079 matrix composites were produced following double stir casting technique described elsewhere. To generate cast al-based results observed with peanut shell ash, the melted materials were injected into a readied sand mould and it is shown as a schematic diagram in Figure 2.

2.2. Measurement of Density and Apparent Porosity. Both experimental and theoretical densities of the composition of the unreinforced alloy and the composites formed were determined using the Archimedean principle and pycnometer method respectively. The experimental densities of the composites and the unreinforced AA8079 matrix were compared to the theoretical densities, and this data was used to determine the apparent porosity of the composites. The apparent porosity was calculated using the following relationship.

$$\text{apparent porosity} = \frac{\rho^T - \rho^{EX}}{\rho^T} \times 100, \tag{1}$$

where ρ^T is theoretical density and ρ^{EX} is experimental density.

2.3. Brinell Hardness Test. The Brinell hardness testing equipment is used to appraise the characteristics of toughness of the created metal matrix composite in accordance with the ASTM E10 standard. Each sample was subjected to three hardness tests, with the average value serving as a proxy for the specimen's hardness. The results of the Brinell hardness test was obtained for both the base AA8079 alloy and the composites.

2.4. Charpy Impact Test. Through cutting and grinding of the samples from the material, a test piece of dimension $55 \times 10 \times 10\,\text{mm}^3$ was produced. At half the length of the test piece, a 45-degree notch, 2 mm deep was produced. The specimen is supported as a beam on the pedestal impact testing machine base with the north centrally located and backing the hammer mass of the machine. The specification of the pendulum length of the machine is 0.7486 kg, hammer mass is 22.6 kg. The pendulum with the hammer lifted (swung up backwards) and locked, the nominal energy scale set to a maximum of 320 joules and the specimen north backing the hammer mass, the pendulum released at a velocity of $5.41\,\text{ms}^{-1}$ to load the specimen directly behind the notch. The impact energy of the specimen which reduced the swinging of the pendulum before the fracture is read off the energy scale deflected backwards in a clockwise movement. To compute the impact strength of the material the relation given in equation (2) is used.

$$\text{impact strength} = \frac{\text{impact energy}}{\text{cross sectional area of the material at the notch}}. \tag{2}$$

Table 1: AA8079 aluminum alloy matrix chemical composition.

Element	Al	Si	Mg	Fe	Cu	Mn	Zn	Cr
% Comp	98.61	0.5287	0.4741	0.2214	0.0009	0.0168	<0.0087	<0.0029
Element	Ni	Ti	Sn	Zr	V	Ca	Be	Pb
% Comp	<0.0034	0.0152	<0.0070	0.0028	<0.0056	>0.000	<0.0001	<0.0000

Table 2: Peanut shell ash chemical composition [39].

Compound	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O
wt%	66.34	7.48	4.44	11.57	2.06	1.07	0.41	4.92

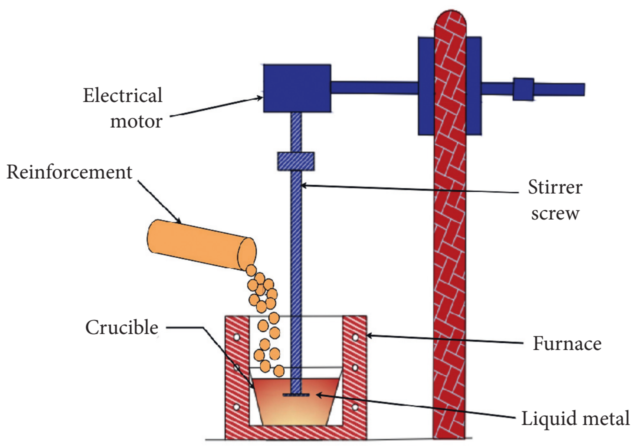

Figure 2: Schematic setup of stir casting.

2.5. Tensile Test. The tensile test was used to measure the material's capacity to developed composite material to withstand loads before elongation. The testing is conducted using digital JPL-100k tensile testing machine. The metal matrix composites were machined to the required dimension for the test. The ultimate tensile strength (UTS) of a material is determined because it is the highest stress that it can withstand when subjected to loading condition.

2.6. Wear Behaviour. The wear behaviour of the composite was determined utilising a Taber Abrasion Machine, a rotational platform abrasion tester. The composite samples were machined in accordance with the wear specification and then put on the wear machine's turntable platform, where they were grabbed continuously two grit rollers descended onto the specimen surface. The spinning platform circles at a constant pace of 1200 revolutions per minute for 15 minutes. The rub action created by the machine's rotational motion between the pattern's surface and the abrasion wheel results in the formation of abraded loose composite dirt on the surface of the sample. The starting and final weights of the sample were obtained using a digital scale, and the wear index was calculated using equation.

$$\text{impact strength} = \frac{\text{impact energy}}{\text{cross sectional area of the material at the notch}}, \tag{3}$$

where the starting and ending weights are in grams and the number of wear test cycles is expressed in revolutions per minute.

An attempt is here made by applying experimental design software packages and mixture design techniques in modelling and optimizing the composites fabrication process variables and predicting the responses of the composites' characteristics. The studied physical and mechanical composites' characteristics were optimized by mixture design tool. Simplex lattice design type, which requires the difference between low and high levels to be the same for all the mixture components, and a quadratic design model was employed in the investigation. Matrix and Reinforcement weight concentrations (%) were chosen to serve as independent variables. (Components 1 & 2), while density, apparent porosity, durometer, compressive strength, fracture toughness, and wear index were the factors that served as the dependent/response variables (Responses 1 to 6). Twelve rounds of investigations were carried out to ascertain the effect of the factor on the qualities tested as well as the dependent variables'/properties' responses.

3. Results and Discussion

3.1. Physical Characteristics. Table 3 summarizes the experimental results for physical parameters (density and porosity). Extracted from the table, it could be observed that both the theoretical and the experimental densities decreased progressively as the reinforcement concentration is increased, while the matrix component is reduced. This decrease in density possibly be attributed to the low density of the reinforcing particles. Reduction in the density of AMMCs reinforced with natural and agro-based fillers have been reported by several investigations. This is a desirable trend, as it motivates their employment in lightweight load-bearing applications.

The apparent porosity is used to estimate the percentage of voids in the fabricated composites. The porosity of the composite as shown in Table 3 increased from 2.218% at 3 wt % PSA to 2.122% at 18 wt% PSA. The maximum porosity of the lightest composite sample is 2.066%, corresponding to the lowest density of 3.428 g/cm^3. Thus, the porosity level of the fabricated composite is below the maximum limit of 4% reported as tolerable for cast AMMC It can further be noted that the composite fabrication route (stir-casting) was necessary and efficient in minimizing to the barest minimum the porosity level of the developed materials.

3.2. Mechanical Properties. AA8079 matrix composite reinforced with Peanut shell ash has lower impact strength

Table 3: Density and apparent porosity of the AA8079/PSA composites and the unreinforced AA8079.

Sample	Theoretical density (ρ^T)[g/cm^3]	Experimental density (ρ^{EX})[g/cm^3]	Apparent porosity (%)
Unreinforced Al	3.48	3.47	1.06
Al – 3 wt% PSA	3.726	3.71	1.91
Al – 6 wt% PSA	3.84	3.86	1.42
Al – 9 wt% PSA	3.76	3.79	1.06
Al – 12 wt% PSA	3.58	3.52	1.76
Al – 15 wt% PSA	3.42	3.41	1.18
Al – 18 wt% PSA	3.38	3.34	2.46

than the base aluminium alloy, the reason as the concentration of PSA increases, the number of hard oxides (SiO_2, CaO, Al_2O_3) and carbon content of the composite is increased [36], the hardness of the composites also increased progressively, thereby resulting in a corresponding impact strength of PSA reinforced composites decreases, as it becomes more brittle. Figures 3–6depicts the effect of reinforcement content on the hardness, abrasion resistance, impact strength, and tensile strength of AA8079-based reinforced materials with Peanut shell ash particles.

Very low impact and tensile strengths were obtained for the 15 and 18 wt% PSA reinforcement content because of the high volume of the dispersed phase (PSA) in the Al-Si-Mg matrix. The entrenching influence weight fraction on the reinforcement particles of the al alloy was determined to be positive. As the amount of peanut shell ash in the composite material rose, the composite material's ability to resist wear improved as well., this is indicated by the progressive decrease in wear index with the addition of the reinforcement particles (Figure 4). This may be explained to be as an outcome of the extraordinary bonding that exists between the aluminium alloy matrix and the reinforcements. There was an abysmal deterioration in the tensile strength, as the amount of PSA in AA8079 matrix increased gradually. This is expected as a trade-off between hardness and strength. Most hard materials are low in tensile and impact strengths. This was why the optimization of the experimental results was carried out to ascertain the optimal composition of the reinforcement and matrix mixture that will yield optimal physical and mechanical properties.

Unreinforced aluminium alloy 8079 is typically composed of an array of $Al1_2Mg_7$, $AlFe_2Mn$, Mg_2Si, and Al-Si-Mg plates in an alpha-aluminum matrix. The structures demonstrate how particle PSA disperses over grain boundaries. Between the peanut Particles of shell ash with the Al-Si-Mg matrix, there was excellent adhesive bonding. The better intermolecular adhesion could be explained by presence of magnesium in the matrix, which contributed to the reinforcement phase's increased wettability in the metal matrix.

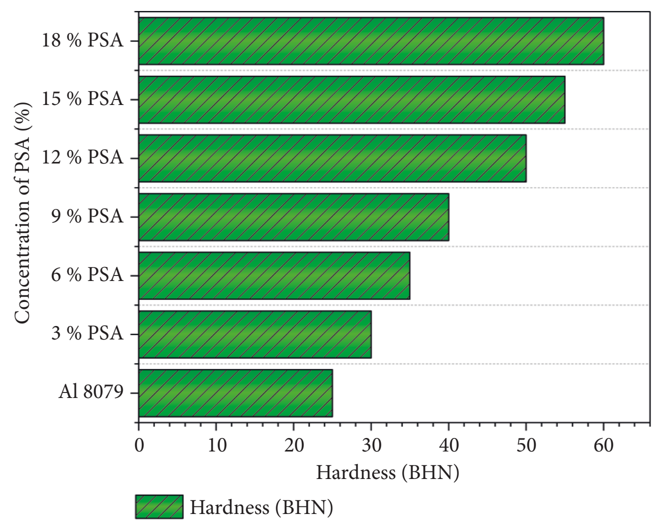

Figure 3: Hardness of the PSA reinforced composites and the unreinforced aluminium AA8079 alloy.

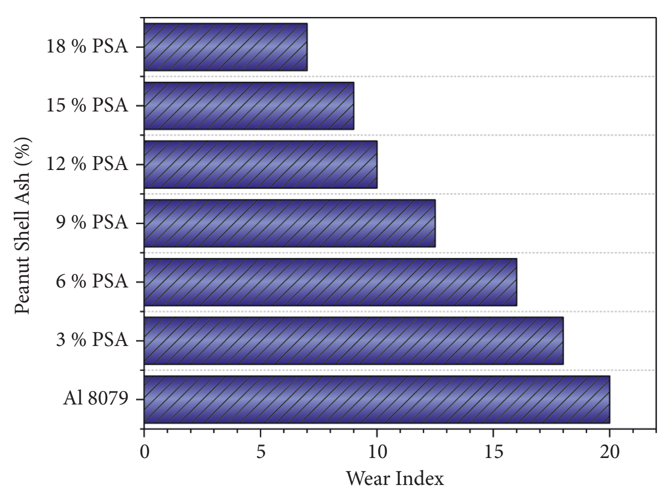

Figure 4: Wear index of the PSA composites with reinforcements and the unreinforced aluminium AA8079 alloy.

3.3. Results of Predictive Modelling and Optimization Using Mixture Design. The results from the mixture design study show that the density, apparent porosity, abrasion resistance, compressive strength, fracture toughness, and wear index are functions of the mixture composition (reinforcement and matrix concentrations). The design summary for the mixture components (matrix and reinforcement) and the responses are given in Tables 4 and 5 respectively. The tables indicate the analysis type, minimum and maximum values for the mixture components and the responses, mean, standard deviation, factor coding and the models, etc.

3.3.1. Analysis of Variance (ANOVA), Fit Statistics, and Model Equations. The detailed results of the polynomial

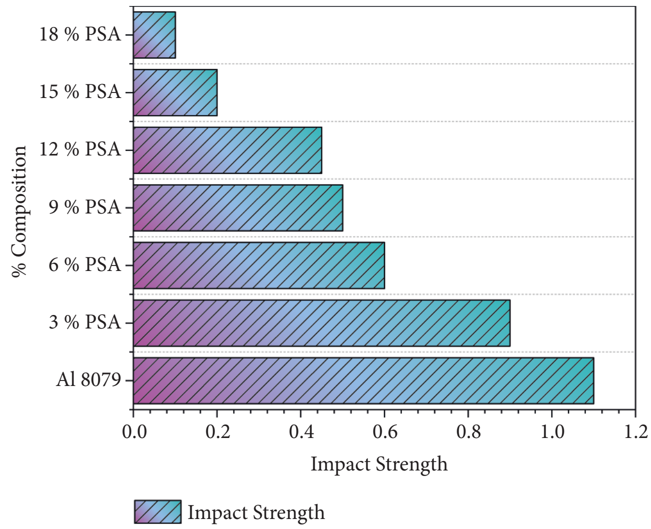

FIGURE 5: Impact strength of the PSA reinforced composites and the unreinforced aluminium AA8079 alloy.

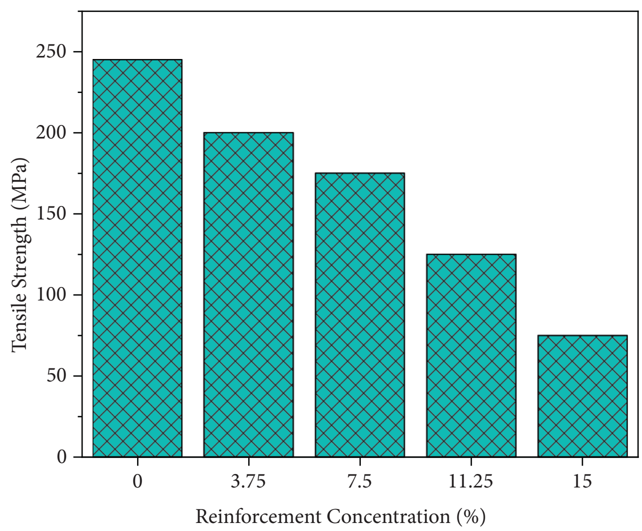

FIGURE 6: Tensile strength of PSA reinforced composites and the unreinforced aluminium AA8079 alloy.

TABLE 4: Design summary for mixture components.

Name	Min (%)	Max (%)	Low coded (%)	High coded (%)	% of mean	Std. dev.
Matrix	82	100	+0 ↔ 82	+1 ↔ 100	91	6.21
Reinforcement	0	18	+0 ↔ 0	+1 ↔ 18	9	6.21

TABLE 5: Design summary for responses.

Response	1	2	3	4	5	6
Name	Density (g/cm^3)	Porosity (%)	Impact strength (J/mm^2)	Hardness (BHN)	Tensile strength (MPa)	Wear index
Minimum	3.18	1.12	0.27	28	67.6	8.2
Maximum	3.89	2.34	1.76	62.4	258.16	24
Mean	3.53	1.73	1.015	45.2	162.88	16.1
Std. dev.	0.0961	0.514	0.501	14.56	74.6	6.28
Ratio	1.12	2.9	10.6	2.45	4.18	2.78

analysis of the various factors are discussed in terms of the ANOVA, computational refinement and forecasting. The ANOVA and the displayed on a monitor of fit for the composites response properties are presented in Tables 6–11. The descriptive statistics are used as a check on the models' utility. All responses had probability values (p values) < 0.05,

Table 6: ANOVA and fit statistics for the density of AA8079/PSA composites.

Source	Sum of squares	df	Mean square	F value	p value
Model	0.0921	2	0.0921	1356.4	<0.0001
Linear mixture	0.0921	2	0.0921	1356.4	<0.0001
Residual	0.00061	11	0.0001		
Lack of fit	0.00061	6	0.0001		
Pure error	0	6	0		
Cor total	0.0921	12			
Std. dev.	0.0091		R^2	1.0146	
Mean	2.72		Adjusted R^2	1.1218	
C.V.%	0.4281		Predicted R^2	1.1416	
			Adeq precision	69.82	

Table 7: ANOVA and fit statistics for apparent porosity of AA8079/PSA composites.

Sources	Sum of squares	df	Mean square	F-value	p value
Model	1.28	2	1.28	11.62	0.0091
Linear mixtures	1.28	2	1.28	11.62	0.0091
Residuals	1.42	11	1.42		
Lack of fit	1.42	6	1.58		
Error	0	6	0		
Cor total	2.65	12			
Standard deviation	0.42		R^2	0.61	
Mean	1.56		Adjusted R^2	0.512	
C.V.%	22.8		Predicted R^2	0.4368	
			Adeq precision	6.82	

Table 8: ANOVA and fit statistics for impact strength of AA8079/PSA composites.

Source	Sum of squares	df	Mean square	F value	p value	
Model	1.88	3	0.912	282	<0.0002	Significant
Linear mixture	1.82	2	1.92	541	<0.0002	
AB	0.0312	2	0.0316	8.62	0.0326	
Residual	0.0334	10	0.0034			
Lack of fit	0.0334	5	0.0076			
Pure error	0	6	0			
Cor total	2.1	12				
Std. dev.	0.062		R^2	1.128		
Mean	0.5942	Adjusted R^2	1.21			
C.V.%	10.61	Predicted R^2	1.28			
		Adeq precision	36.53			

Table 9: ANOVA and fit statistics for the hardness of AA8079/PSA composites.

Source	Sum of squares	df	Mean square	F value	p value
Model	2046.5	2	2046.5	401.5	<0.0002
Linear mixture	2.46.5	2	2046.5	401.5	<0.0002
Residual	61.4	11	6.28		
Lack of fit	61.4	6	13.4		
Pure error	0	6	0		
Cor total	85.8	12			
Std. dev.	3.56		R^2	1.46	
Mean	48.4		Adjusted R^2	1.472	
C.V.%	6.21		Predicted R^2	1.52	
			Adeq precision	40.12	

that is a strong indicator that the predictors are genuine. (matrix and reinforcements) had a substantial effect on those response variables. In other words, all replies are meaningful in terms of the model's terms. Additionally, all six replies have a high model F-value. In comparison, all of the models' F-values for lack of fit are non-significant when compared to the pure error, and because the model should fit, a non-significant lack of fit is ideal. Because the difference between R^2 values anticipated and adjusted is less than 0.2, the predicted and adjusted R^2 values for all responses examined

Table 10: ANOVA and fit statistics for tensile strength of AA8079/PSA composites.

Source	Sum of squares	df	Mean square	F value	p value
Model	55281	5	14678	1242.3	<0.0002
Linear mixture	54768	2	55734	4653.74	<0.0002
AB	130.8	2	131.24	11.24	0.0162
AB (A-B)	7.64	2	7.12	0.5807	0.584
Residual	85.18	8	13.2		
Lack of fit	85.18	3	43.4		
Pure error	0	6	0		
Cor total	56467.34	12			
Std. dev.	3.85		R^2	1.212	
Mean	162.86		Adjusted R^2	1.228	
C.V.%	2.37		Predicted R^2	1.12	
		Adeq precision			

Table 11: ANOVA and fit statistics for wear index of AA8079/PSA composites.

Source	Sum of squares	df	Mean square	F value	p value
Model	307.4	5	77.3	7140.61	<0.0002
Linear mixture	301.2	2	301.2	28763.8	<0.0002
AB	3.81	2	3.81	302.6	<0.0002
AB (A-B)	3.06	2	3.06	240.2	<0.0002
Residual	0.0742	8	0.0212		
Lack of fit	0.0791	3	0.0421		
Pure error	0	6	0		
Cor total	311.1	12			
		R^2	1.086		
Std. dev.	0.1176		Adjusted R^2	1.042	
Mean	14.6		Predicted R^2	1.026	
C.V.%	0.821		Adeq precision	197.6	

are in reasonably good agreement. Adeq Precision (adequate precision) is a metric for determining the SNR. A accuracy value > 4 implies that the signals in the model are sufficiently strong and appropriate for optimization. All response ratios are more than four, demonstrating that the signals are appropriate and the models are capable of navigating the entire design area.

Figure 7 shows Model graphs of predicted response values against observed response values of (a) density, (b) apparent porosity, (c) impact strength, (d) hardness, (e) UTS, and (f) wear index. ANOVA for mixture design normally generates three model equations for each response. One for the pseudo model (factor coding) taken from the model coefficient table, one in the real coding scale, and the third one in the actual coding scale. The default analysis computes and tests the pseudo model which is then converted to the real model and finally to the actual model. Density, apparent porosity, hardness, impact strength, tensile strength, and wear index prediction equations for composites as a function of mixture components are supplied in coded form and outlined in equations. The model equations written can be utilised in terms of coding to forecast the composite characteristics' reactions at specified weight concentrations (wt%) of the mixture components (A&B). By default, the combination components' high levels are coded as +1 and their low values as 0. By comparing the factor coefficients, the coded equations May be used to determine the factors' relative importance (mixing components).

3.3.2. Design Numerical Optimization. The DOE's mixed design enables the response values to be optimized by altering the mixture components. The independent variable (mixing components) was optimized to decrease the density, porosity, and wear index of the composites and to enhance their hardness, impact, and tensile strength responses. Target criteria were established for both the constituent materials and the responses during mathematical programming. The matrix and reinforcement concentrations have been set to be within a certain range. Density, apparent porosity, and wear index responses were set to zero, whereas hardness, impact, and tensile strengths were set to their optimum amount. Even though the main objective is not to maximise possibility, The most desired factor settings are those that produce the highest desirability value. suggest that the numerical optimization produced an acceptable result. Table 12 illustrates one numerical optimization approach for the mixture components and responses of PSA reinforced aluminium alloy AA8079 composites with a degree of desire.

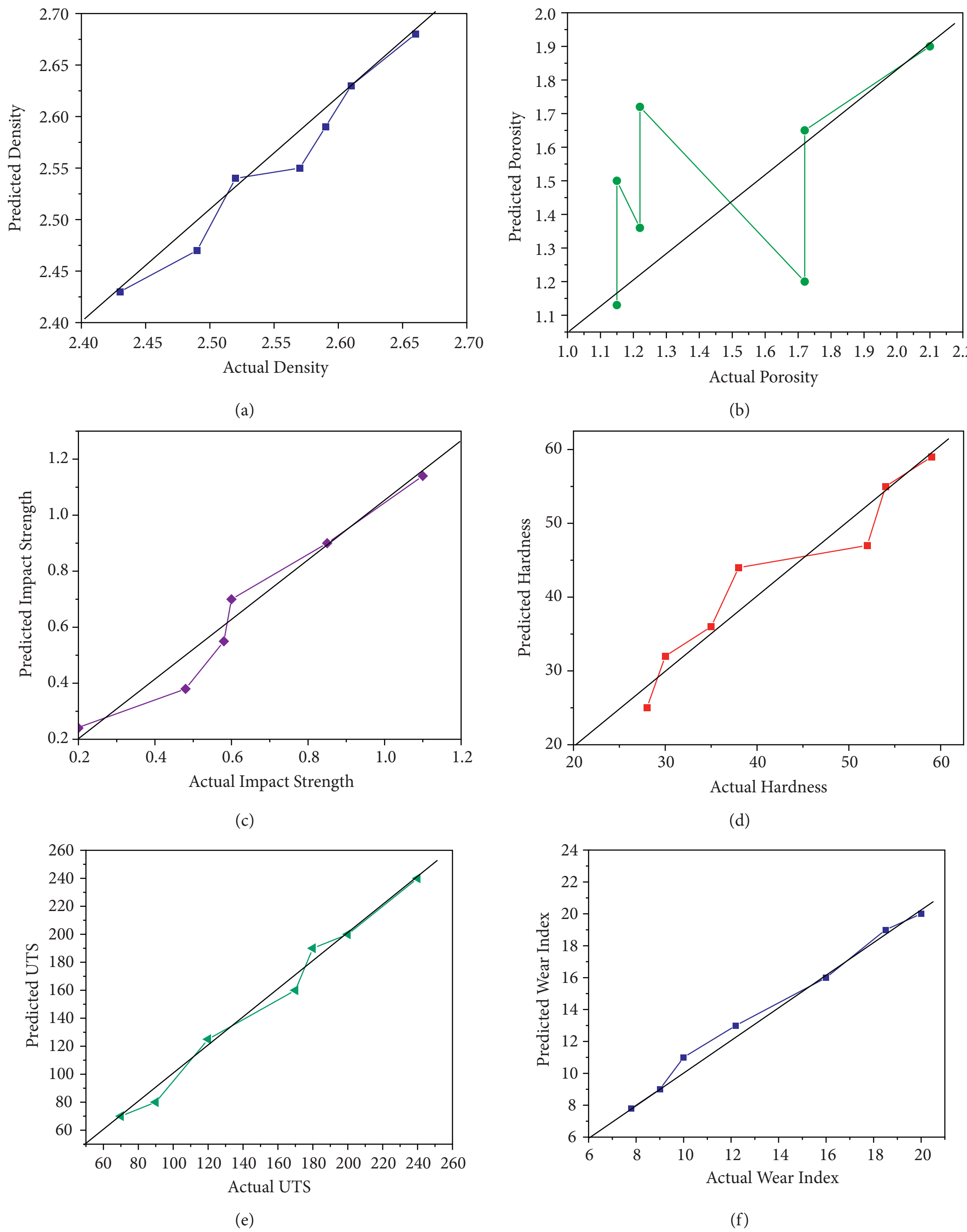

Figure 7: Model graphs of predicted response values against observed response values of (a) Density, (b) Apparent porosity, (c) Impact strength, (d) Hardness, (e) UTS, and (f) Wear index.

Table 12: Optimization solutions.

Matrix	93.48
Reinforcement	6.52
Density	2.64
Porosity	1.520
Impact strength	0.452
Hardness	47.46
Tensile strength	168.05
Wear index	13.18
Desirability	0.608

The results of numerical optimization show that optimal responses for the proposed composite will be attained at matrix and reinforcement concentrations of 93.48 and 6.52 percent, respectively.

4. Conclusion

Stir casting was used to manufacture AA8079/PSA composites successfully.

(i) The composite is more challenging than the pure AA8079 alloy, and its hardness rises as the reinforcing weight percentage rises.

(ii) The porosity of the composite is low and within an acceptable level of 0–4% due to filler matrix compatibility and stir casting process.

(iii) In addition to Peanut, shell ash increases the tendency of the material to resist wear.

(iv) The density of the AA8079/PSA composites formed is lower than that of the AA8079 base alloy. This indicates that peanut shell ash can reinforce lightweight load-bearing Composites.

(v) Mixture design modelling revealed the optimal reinforcement and matrix composition that yield optimal responses of composite mechanical properties.

Data Availability

The data used to support the findings of this study are included within the article. Further data or information are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflicts of interest.

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References

[1] V. Mohanavel, M. Ravichandran, S. Suresh Kumar, M. Melwin Jagadeesh Sridhar, S. Dineshkumar, and M. M. Pavithra, "Microstructural and tribological characterization of Al/EGG shell ash composites prepared by liquid metallurgy process," *Journal of the Balkan Tribological Association*, vol. 26, no. 2, pp. 319–326, 2020.

[2] S. N. Monteiro, K. G. Satyanarayana, and F. P. D. Lopes, "High strength natural fibers for improved polymer matrix composites," *Materials Science Forum*, vol. 638-642, pp. 961–966, 2010.

[3] U. Shehu, O. Aponbiede, T. Ause, and E. F. Obiodunukwe, "Effect of particle size on the properties of polyester/palm kernel shell (PKS) particulate composites," *Journal of Materials and Environmental Science*, vol. 5, no. 2, pp. 366–373, 2014.

[4] V. R. Rao, J. R. Chowdary, A. Balaji et al., "A review on properties of aluminium based metal matrix composites via stir casting," *International Journal of Scientific Engineering and Research*, vol. 7, no. 2, pp. 742–749, 2016.

[5] R. Dasgupta, "Aluminium alloy-based metal matrix composites: a potential material for wear resistant applications," *International Scholarly Research Notices*, vol. 2012, Article ID 594573, 14 pages, 2012.

[6] P. O. Babalola, C. Bolu, A. O. Inegbenebor, and K. M. Odunfa, "Development of aluminium matrix composites: a review," *International Journal of Engineering Sciences & Research Technology*, vol. 2, pp. 1–11, 2014.

[7] A. V. Muley, S. Aravindan, and I. P. Singh, "Nano and hybrid aluminum based metal matrix composites: an overview," *Manufacturing Review*, vol. 2, no. 15, 2015.

[8] M. Dinesh, D. R. Ravindran, and A. A. Aluminium, "7075 properties enhanced by Zirconium and Chromium nano particle," *International Journal of ChemTech Research*, vol. 9, no. 1, pp. 296–301, 2016.

[9] B. V. Ramnath, C. Elanchezian, R. M. Annamalai et al., "Aluminium metal matrix composites–a review," *Reviews on Advanced Materials Science*, vol. 38, no. 5, pp. 55–60, 2014.

[10] R. O. Akaluzia, F. O. Edoziuno, A. A. Adediran, B. U. Odoni, S. Edibo, and T. M. A. Olayanju, "Evaluation of the effect of reinforcement particle sizes on the impact and hardness properties of hardwood charcoal particulate-polyester resin composites," *Materials Today Proceedings*, vol. 38, pp. 570–577, 2021.

[11] B.-H. Yan and C.-C. Wang, "Machinability of SiC particle reinforced aluminum alloy composite material," *Journal of Japan Institute of Light Metals*, vol. 43, no. 4, pp. 187–192, 1993.

[12] M. Ravichandran, V. Mohanavel, T Sathish, P. Ganeshan, S. Suresh Kumar, and S. Ram, "Mechanical properties of AlN and molybdenum disulfide reinforced aluminium alloy matrix composites," *Journal of Physics: Conference Series*, vol. 2027, Article ID 012010, 2021.

[13] R. Umunakwe, O. C. Okoye, C. I. Madueke, D. O. Komolafe, and I. J. Umunakwe, "Effects of carburization with palm kernel shell/coconut shell mixture on the tensile properties and case hardness of low carbon steel," *FUOYE Journal of Engineering and Technology*, vol. 2, no. 1, p. 83, 2017.

[14] D. Srinivasan, R. S. Kadadeveramath, S. Rajendran, and E. N. Ganesh, "State-of-art review of ceramic reinforced aluminum metal matrix composite and it's machining characteristics," *Journal of Chemical and Pharmaceutical Sciences*, vol. 11, pp. 154–164, 2017.

[15] V. Mohanavel, S. Prasath, K. Yoganandam, T. B. Girma, and S. Suresh Kumar, "Optimization of wear parameters of aluminium composites (AA7150/10 wt% WC) employing Taguchi approach," *Materials Today Proceedings*, vol. 33, no. 7, pp. 4742–4745, 2020.

[16] F. O. Edoziuno, A. A. Adediran, B. U. Odoni, A. D. Akinwekomi, O. S. Adesina, and M. Oki, "Optimization and development of predictive models for the corrosion inhibition of mild steel in sulphuric acid by methyl-5-benzoyl-2-benzimidazole carbamate (mebendazole)," *Cogent Engineering*, vol. 7, no. 1, Article ID 1714100, 2020.

[17] A. James, "The study of wear behaviour of glass/epoxy composites reinforced with titanium dioxide and graphite filler materials," *AIP Conference Proceedings*, vol. 2080, no. 1, Article ID 20011, 2019.

[18] M. I. M. Kandar and H. M. Akil, "Application of design of experiment (DoE) for parameters optimization in compression moulding for flax reinforced biocomposites," *Procedia Chemistry*, vol. 19, pp. 433–440, 2016.

[19] C. Homkhiew, T. Ratanawilai, and W. Thongruang, "The optimal formulation of recycled polypropylene/rubberwood flour composites from experiments with mixture design," *Composites Part B: Engineering*, vol. 56, pp. 350–357, 2014.

[20] C. Homkhiew, T. Ratanawilai, and W. Thongruang, "Optimizing the formulation of polypropylene and rubberwood flour composites for moisture resistance by mixture design," *Journal of Reinforced Plastics and Composites*, vol. 33, no. 9, pp. 810–823, 2014.

[21] P. S. Kumar, S. P. Reddy, and G. Kartheek, "Study of hardness and optimization of wear properties of AL 7075 hybrid composite," *International Journal of Engineering Research and Technology*, vol. 6, no. 6, 2017.

[22] G. Agarwal, A. Patnaik, and R. K. Sharma, "Parametric optimization and three-body abrasive wear behavior of sic filled chopped glass fiber reinforced epoxy composites," *International Journal of Composite Materials*, vol. 3, no. 2, pp. 32–38, 2013.

[23] A. Vedrtnam and A. Kumar, "Fabrication and wear characterization of silicon carbide and copper reinforced aluminium matrix composite," *Materials Discovery*, vol. 9, pp. 16–22, 2017.

[24] Z. Xin-gang, Z. Yuan-feng, and L. Yan-bin, "The spillovers of foreign direct investment and the convergence of energy intensity," *Journal of Cleaner Production*, vol. 206, pp. 611–621, 2019.

[25] C. R. Kothari, *Research Methodology: Methods and Techniques*, New Age International, New Delhi, India, 2004.

[26] R. Umunakwe, D. J. Olaleye, A. Oyetunji, O. C. Okoye, and I. J. Umunakwe, "Assessment of some mechanical properties and microstructure of particulate periwinkle shell-aluminium 6063 metal matrix composite (PPS-ALMMC) produced by two-step casting," *Nigerian Journal of Technology*, vol. 36, no. 2, pp. 421–427, 2017.

[27] A. Yekinni, M. Durowoju, J. Agunsoye, L. Mudashiru, L. Animashaun, and O. Sogunro, "Automotive application of hybrid composites of aluminium alloy matrix: a review of rice husk as based reinforcements," *International Journal of Composite Materials*, vol. 9, pp. 44–52, 2019.

[28] J. E. Hernández-Ruiz, L. Pino-Rivero, and E. Villar-Cociña, "Aluminum matrix composite with sugarcane bagasse ash as reinforcement material," *Revista Cubana de Fisica*, vol. 36, no. 1, pp. 55–59, 2019.

[29] N. Srivastava and S. P. Dwivedi, "Development of green hybrid metal matrix composite using agricultural waste bagasse as reinforcement-A review," *IOP Conference Series: Materials Science and Engineering*, vol. 691, no. 1, Article ID 12051, 2019.

[30] F. O. Edoziuno, B. U. Odoni, F. I. Alo, and C. C. Nwaeju, "Dry sliding wear and surface morphological examination of an aluminium matrix composite reinforced with palm kernel shell," *Acta Metallurgica Slovaca*, vol. 26, no. 2, pp. 54–62, 2020.

[31] F. O. Edoziuno, A. A. Adediran, B. U. Odoni, O. G. Utu, and A. Olayanju, "Physico-chemical and morphological evaluation of palm kernel shell particulate reinforced aluminium matrix composites," *Materials Today Proceedings*, vol. 38, pp. 652–657, 2021.

[32] I. O. Oladele and A. M. Okoro, "The effect of palm kernel shell ash on the mechanical properties of as-cast aluminium alloy matrix composites," *Leonardo Journal of Sciences*, vol. 15, pp. 15–30, 2016.

[33] A. Apasi, D. S. Yawas, S. Abdulkareem, and M. Y. Kolawole, "Improving mechanical properties of aluminium alloy through addition of coconut shell-ash," *Journal of Science and Technology*, vol. 36, no. 3, pp. 34–43, 2016.

[34] O. O. Daramola, A. A. Adediran, and A. T. Fadumiye, "Evaluation of the mechanical properties and corrosion behaviour of coconut shell ash reinforced aluminium (6063) alloy composites," *Leonardo Electronic Journal of Practices and Technologies*, vol. 27, pp. 107–119, 2015.

[35] O. B. Fatile, J. I. Akinruli, and A. A. Amori, "Microstructure and mechanical behaviour of stir-cast Al-Mg-Sl alloy matrix hybrid composite reinforced with corn cob ash and silicon carbide," *International Journal of Engineering and Technology Innovation*, vol. 4, no. 4, p. 251, 2014.

[36] O. O. Joseph and K. O. Babaremu, "Agricultural waste as a reinforcement particulate for aluminum metal matrix composite (AMMCs): a review," *Fibers*, vol. 7, no. 4, p. 33, 2019.

[37] M. N. Nwabufoh, *Development and Characterization of Al-3.7% Cu-1.4% Mg alloy/periwinkle ASH (Turritella Communis) Particulate Composites*, Thesis. Ahmadu Bello University, Zaria, Nigeria, 2015.

[38] K. R. Garadimani, G. Raju, and K. Kodancha, "Study on mechanical properties of corn cob particle and e-glass fiber reinforced hybrid polymer composites," *American Journal of Materials Science*, vol. 5, no. 3C, pp. 86–91, 2015.

[39] F. O. Edoziuno, R. O. Akaluzia, B. U. Odoni, and S. Edibo, "Experimental study on tribological (dry sliding wear) behaviour of polyester matrix hybrid composite reinforced with particulate wood charcoal and periwinkle shell," *Journal of King Saud University-Engineering Sciences*, vol. 33, no. 5, pp. 318–331, 2021.

[40] M. R. Sanjay, G. R. Arpitha, L. L. Naik, K. Gopalakrishna, and B. Yogesha, "Applications of natural fibers and its composites: an overview," *Natural Resources*, vol. 7, no. 3, pp. 108–114, 2016.