EXPERIMENTAL INVESTIGATION ON FLEXURAL STRENGTH OF OKRA FIBER/ALUMINUM POWDER- BASED EPOXY COMPOSITE AGAINST OKRA FIBER COMPOSITE

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Abstract

Aim: The aim of present research work is to find the flexural strength of novel composites made of aluminum powder and woven Okra fiber.

Materials and Methods: The okra fiber acts as a control group, whereas the aluminum powder acts as an experimental group in this study. There were two groups involved, each with a sample size of 20 and a total of 40 samples. The G power for the independent sample tests utilized in this investigation was set to 80 %. The okra fibers were treated with 5 % KOH solution. To accomplish the above mentioned objective the following parameters were chosen like (i) aluminum powder (µm), (ii) okra fiber mate (gsm), and (iii) KOH treatment hours (hours), each at three distinct levels. The L_9 orthogonal array was chosen for the appropriate parameters, and the necessary composite materials were manufactured by hand lay-up procedures.

Results: Based on the experimental trials, the flexural properties of the hybrid novel composites were considerably improved. The composite provides the highest value of flexural strength (46.69 MPa) upto 4 hours of KOH treatment and it provides the significance values of $P = 0.041$ ($P<0.05$).

Conclusion: The research shows that the suggested levels of controlled process parameters for okra fiber and aluminum powder based hybrid novel composites are 15 µm of aluminum powder, 300 gsm of okra fiber and 4 hours of KOH treatment.

Keywords: Aluminum powder, Okra fiber, Flexural strength, Novel composite, KOH.

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1. Introduction

The aim of the present work is to identify natural fibers have recently the interest of scientists and academics due to the benefits they offer over man-made reinforcement materials, (Hodzic and Shanks 2014) Natural fiber composites (NFC) are made up of a variety of materials, including plant, animal, and mineral fibers, that are mixed in a polymer matrix (Natural or Synthetic). Natural fibers are low-cost and have a variety of unique qualities. Unlike traditional reinforcing fibers, they are biodegradable and provide excellent thermal and acoustic insulation (Schrottmaier et al. 2021). Okra fiber is extracted naturally by plants. In the realm of Indian fabrics, okra is the newest, most fascinating, and fashionable item to behold. For a fabric that resembles lignin in many aspects and is regarded as one of the most valuable natural fibers (Ganesan and Kaliyamoorthy 2020). Fabric made from cannabis okra fiber has been around for a long time and it was used to make paper, ropes, canvas, sailcloth, bags. These materials are entirely recyclable and have a lesser environmental flexural than traditional glass fiber reinforced composites. Natural fibers are used as reinforcement because of their lightweight and recyclability. Natural fibers contain cellulose, hemicellulose, and lignin as chemical components. Aluminum powder is created finely grinding aluminum (Cecchi and De Carolis 2021). It's possible to use aluminum powder as a polymer filler. It possesses cheap, renewable energy, low density, processability, biodegradability, and environmental friendliness advantages over mineral fillers (such as calcium carbonate, kaolin, mica, and talc) (Cecchi and De Carolis 2021; Yaghi et al. 2022). Composites prepared from aluminum powder filler particles and epoxy resin displayed improved flexural characteristics as a result of the greater filler particle content.

Similar work has been reported previously by many researchers, closely related articles published over the past 5 years in Google Scholar in 210 and in ScienceDirect 120. When compared to single fiber composites, hybrid composites have a longer fatigue life, better crack resistance, and lower sensitivity. The strength-to-weight ratio and ease of fabrication of the hybrid composite material make it popular in sophisticated engineering applications (Tilbe and Mahmutoglu 2019). Such hybrid composites offer more strength including stiffness, ductility, and strength when compared with single-fiber reinforced composites (Shan and Liao 2001). Aluminum powder is a type of composite material with desirable properties such as low density, high specific stiffness, high specific strength, controlled thermal expansion, increased fatigue resistance, and superior dimensional stability at high temperatures, among others. Aluminum powder has the potential to be used as a polymer filler. It has better properties than mineral fillers (such as calcium carbonate, kaolin, mica, and talc), such as cheap cost, renewable, low density, processable, biodegradable, and ecological (Li, Tabil, and Panigrahi 2007). Despite the fact that natural fiber-based composites are not without flaws, they are nevertheless a viable option. Natural fibers absorb a lot of water and have poor mechanical qualities due to their low moisture resistance (Fahim and Chand 2008). One of the most successful methods for increasing natural fiber adhesion between matrix materials by the chemical treatment process. Fibers were treated with potassium hydroxide (KOH) to improve the impact property in this investigation (Thomas, Pothan, and Cherian 2009). The chemical treatment has been used to eliminate certain fiber components from natural fibers. Improves the compatibility of the fiber and matrix, as well as the surface adhesion. Mercerization is an alkaline treatment in which potassium hydroxide (KOH) is administered to the fiber surface during treatment. This facilitates the elimination of contaminants and oil soluble in KOH solutions, reducing fiber diameter and aggregation levels, improving mechanical characteristics, and exposing the fiber surface, making it rougher (Eswara Prasad, Gokhale, and Wanhill 2013). Our team has extensive knowledge and research experience that has translated into high quality publications(Vickram et al. 2022; Bharathiraja et al. 2022; Kale et al. 2022; Sumathy et al. 2022; Thanigaivel et al. 2022; Ram et al. 2022; Jothi et al. 2022; Anupong et al. 2022; Yaashikaa, Keerthana Devi, and Senthil Kumar 2022; Palanisamy et al. 2022)

Pujan Sarkar (Sarkar, Modak, and Sahoo 2017), the research article can be denoted as the best paper, since it is mainly focused on the aluminum powder composite. Based on the above literature no one fabricates the natural hybrid composites by using the combinations of okra and aluminum powder. The main objective of the present research is to find the flexural properties of novel aluminum powder and okra fiber reinforced hybrid polyester composite and to determine the effectiveness of KOH treatment. The composites were made using a hand Lay-up process based on a L_9 orthogonal array to achieve the above goal. In Table 1 the physical and mechanical properties of matrix and reinforcements of novel composite are shown.

2. Materials and Methods

The present research was performed at Saveetha School of Engineering, Saveetha Institute of Medical and Technical Science, Chennai. The size gathering was calculated using previous concentrate on outcomes in an online sample calculator, with G power set of 80 %, edge set to 0.05 and certainty span set to 95 %. Number of groups involved was 2, in which each sample had a size of 20 and a total number of samples involved were 40. In this research, Okra composite acts as a control group and aluminum powder acts as an experimental group. Both were treated in 5 % KOH solutions with different time lengths Table 2 & 3 reveals the parameters and their levels used for the experiment and L_9 orthogonal arrays of hybrid composites (Velmurugan, Babu, and Flavia 2020). The aluminum powder and okra fiber were used in this present work and it was collected from Jute service center, Madurai, Tamilnadu, India. Unsaturated polyester (resin), methyl ethyl ketone peroxide (catalyst), and cobalt naphthenate (accelerator) were all collected from the GVR resin industry from Madurai, Tamil Nadu, India.

2.1 Fabrication of Composite

In group I to remove the impurities, okra fibers were washed with 1 to 2 % detergent solvents at 60º Cto 70º C for 1 hour, then rinsed with distilled water and dried in a vacuum oven at 70º C for 1 hour and 30 minutes. Untreated fibers were defined as dried fibers. After that, the okra fiber was chemically treated. The de-waxed yarns were then immersed in a 5 % KOH solution in a beaker. The period of KOH treatment was changed according to the experimental design: 2 hours, 4 hours, and 6 hours. After that, they were completely rinsed with distilled water.

In group II the okra fiber and aluminum powder were cleaned using the method described above. Fillers were made from dried aluminum powder. They were then thoroughly cleaned with distilled water and dried in atmospheric air for 24 hours (Velmurugan et al. 2022).

The stainless steel mold had dimensions of 150 x 150 x 3 mm. Unsaturated polyester resin was completely combined with 1 % wt of cobalt naphthenate and 1 % wt of methyl-ethyl ketone peroxide. The composite was built utilizing treated woven okra fibers and aluminum powder using a hand lay-up method. Constant stirring was used to disseminate the desired weight of aluminum powder in the prepared polyester resin. The prepared resin mixture was poured into the mold and smoothed out with a hand roller. A second layer of polyester resin was poured over the okra mate and spread out with a hand-roller. Composites were fabricated using the L_9 orthogonal array. The mold was then fastened in place and subjected to a consistent pressure of 50 kg/cm^2, which was then allowed to cure for 24 hours at room temperature. To prevent moisture absorption, the produced hybrid composite samples were placed in desiccators. The fabrication of hybrid novel composite is shown in Fig. 1.

2.2 Testing

To accomplish the flexural testing, the specimens were cut into ASTM D-790 dimensions (10 mm width, 125 mm length, 3 mm thickness). Specimens were tested in a universal testing machine. The following equation (1) is used to calculate the flexural strength of the hybrid composites (Ganesan et al. 2021).

$$\text{Flexural strength } (\sigma) = 3\,PL/2\,bd^2 \quad (1)$$

Where P= Applied load, L= Length of the specimen, b= Width of the specimen and d= Thickness of the specimen.

2.3 Statistical Analysis

The statistical analysis was conducted by using IBM SPSS version 28 software, which included an independent sample t-test. The independent variables in this analysis are particle size, grms of mate, and KOH treatment hours. The outcome flexural strength of the hybrid composites are dependent variables (Velmurugan, Babu, and Flavia 2020).

3. Results

Flexural test determines the amount of energy absorbed by a material during the flexural load conditions. This test was conducted to find the ability of a material to withstand flexural load, used by engineers to predict its behavior under actual conditions the flexural strength of okra fiber composite and okra fiber and aluminum powder based hybrid novel composite were compared. The flexural strength of hybrid composite for the proposed combinations of the parameters and comparison of okra fiber and hybrid composite are given in Table 4 and Table 5. Table 6 shows the Group statistics and independent sample t-test results. The flexural strength mean values obtained for okra based composite and hybrid composite are 43.8070 and 46.0610 respectively. The standard deviation of okra fiber 0.55344 and hybrid composite 0.36117 are obtained. The standard error mean for okra composites and hybrid composites were 0.12375 and 0.08076 obtained. Results reveal that the significant value between the two groups is observed to be $P= 0.041$ ($P< 0.05$). Fig. 2 shows the bar graph represents the flexural strength of okra fiber based composite and hybrid novel composite. The bar graphs are comparing the mean of (+/-1SD) natural composite.

Natural fiber composites' flexural strength was improved by using novel hybrid compositions of okra fiber and aluminum powder reinforcement.

4. Discussion

The independent sample t-test is used in this study, with significance of P = 0.041 for hybrid composite. According to the results, the suggested hybrid novel composite has a flexural strength of (46.91 MPa), which is higher than the okra fiber based composite (44.49 MPa). The hybrid composites were found to be improved at the following levels of input parameters: A3, B3, and C2.

According to Table 3, the optimal values for the hybrid composites were 15 µm aluminum powder, 300 gsm okra fiber mate, and 4 hours of KOH chemical treatment. As the gsm of composite fiber grows, the flexural strength value progressively rises. This demonstrates that using a thicker okra fiber mate increases the hybrid composite's strength. This is because the presence of thicker, greater density in fiber materials compensates for the effects of voids, which is consistent with the author's claims (G, Velmurugan et al. 2022). The hybrid composites reveal high strength for 15 µm of aluminum powder. The increases in flexural strength with high µm size of filler addition may be due to the chemical bond strength between filler particles and the matrix is too strong to transfer the flexural load. The improvement in the flexural strength of the composites with filler size of 15 µm is probably caused by good compatibility of the particulates and the epoxy matrix, leading to increase in interfacial bonding (Hodzic and Shanks 2014; Ramasubbu and Madasamy 2022). When the fiber was treated with KOH solution, all natural and artificial impurities were removed, resulting in a rough topography on the surface. It aids in the compatibility and adherence of natural fibers to the polymer matrix. The degree of crystallinity and polymerization increased when the porosity content was reduced (Velmurugan, Babu, and Flavia 2020; Taj, Munawar, and Khan 2007). As a result of these traits, the hybrid composite's mechanical and morphological attributes were considerably improved. After being treated for more than 4 hours, the concentration of KOH in the fiber rises, reducing the crystalline index of the fiber (Neto et al. 2022). The above findings researchers are not in line with this work, because in the current research work the fibers were treated only upto 4 hrs of NaOH.

The flexural strength of the okra fiber mate with 100 gsm, aluminum powder with a particle size of 5 µm, and KOH treatment at 2 hours is where it reaches its lowest point, and this may be considered as the research's limitations. On the basis of using different chemical and chemical concentration levels, there is scope to increase flexural strength in the future (Velmurugan and Babu 2020).

5. Conclusion

In this research, the flexural strength of okra fiber and okra fiber & aluminum powder based polyester hybrid novel composites was examined. The 15 µm of aluminum powder, 300 gsm of okra fiber, and 4 hours of KOH treatment are the suggested levels of controlled process parameters produced by hybrid novel composites. Hybrid novel composites with improved flexural strength qualities come from the combination of numerous factors. By enhancing the coupling and miscibility of natural fibers to the polymer background, the flexural strength of natural fibers was enhanced by up to 4 hours of KOH treatment.

Declarations

Conflict of interests

No conflict of interests in this manuscript

Authors Contribution

Author KT was involved in data collection, data analysis, and manuscript writing. Author GV was involved in conceptualization, data validation, and critical review of manuscript.

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Tables and Figures

Table 1. Physical and mechanical properties of Matrix and Reinforcements of novel composite.

Sl.No	Properties	Aluminum powder	Okra fiber	Polyester resin
1	Lignin (%)	32-43	2.5	-
2	Hemicellulose (%)	0.15-0.25	17-22	-
3	Lignin (%)	40-45	3.7-5.7	-
4	Density (g/cm^3)	0.63	1.68	2.16
5	Tensile strength (MPa)	17-48.5	760	7-9
6	Young’s modulus (GPa)	0.64-1.92	65	0.98

Table 2. Parameters and their levels used for the experiment of novel composite

SI. No.	Parameters	Symbol	Levels		
			L_1	L_2	L_3
1	Aluminum powder (µm)	A	5	10	15
2	Okra fiber mate (gsm)	B	100	200	300
3	KOH Treatment Hours (hours)	C	2	4	6

Table 3. L_9 Orthogonal array for the experiment of novel composites in aluminum powder (µm), okra fiber mate (gsm) and KOH treatment hours (hours).

SI.No	Aluminum Powder A (µm)	Okra Fiber Mate B (gsm)	KOH Treatment Hours C (hours)
1	5	100	2
2	5	200	4
3	5	300	6
4	10	100	4
5	10	200	6
6	10	300	2
7	15	100	6

8	15	200	2
9	15	300	4

Table 4. Result of Okra composite and hybrid composite of 20 samples.

Okra Composite	**Hybrid composite**
Flexural strength (MPa)	**Flexural strength (MPa)**
46.69	44.49
46.15	43.76
46.83	43.34
45.59	43.45
45.88	44.87
45.82	43.44
46.61	44.49
45.54	43.22
45.96	44.11
46.01	43.88
45.54	43.66
45.96	44.12
46.01	44.33
45.98	44.22
45.65	42.94
46.12	43.56
45.72	43.34
46.32	42.78
46.18	43.92
45.86	44.21

Table 5. Group Statistics of sample mean, standard deviation and standard error mean of the okra composite and hybrid novel composite is obtained.

	Groups	N	Mean	Std. Deviation	Std. Error Mean
Flexural Strength (MPa)	Okra composite	20	43.8070	0.55344	0.12375
	Hybrid composite	20	46.0610	0.36117	0.08076

Table 6. Independent sample t-test showing that both the groups are statistically significant with P value (<0.05) for the flexural strength. The study was conducted with 95 % confidence interval of the difference.

Flexural strength (MPa)		**Levene's Test for Equality of Variances**		
		F	**Significance**	**t**
	Equal variances assumed	4.491	.041	-15.253
	Equal variances assumed			-15.253

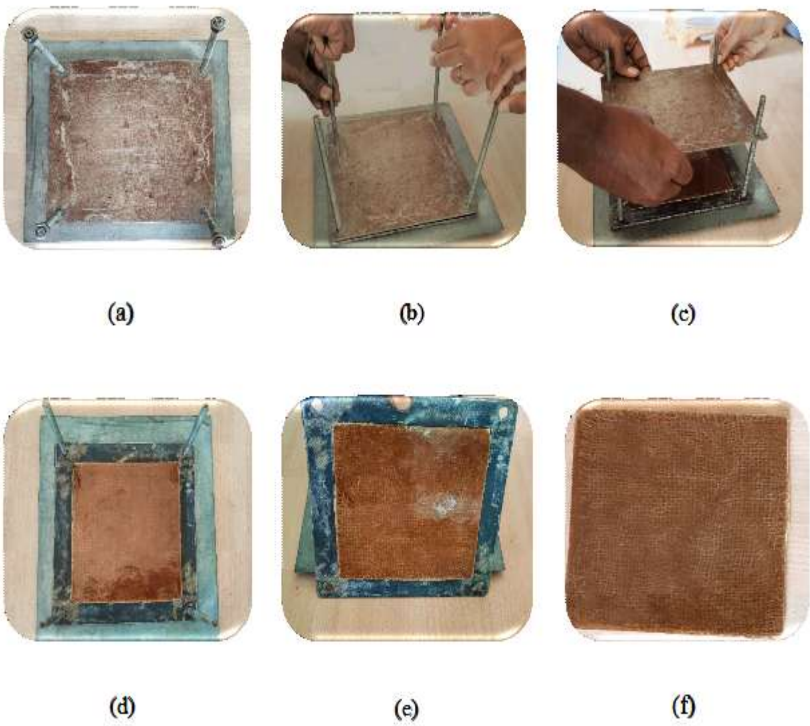

Fig. 1. Fabrication of the hybrid novel composite by using hand lay-up technique.

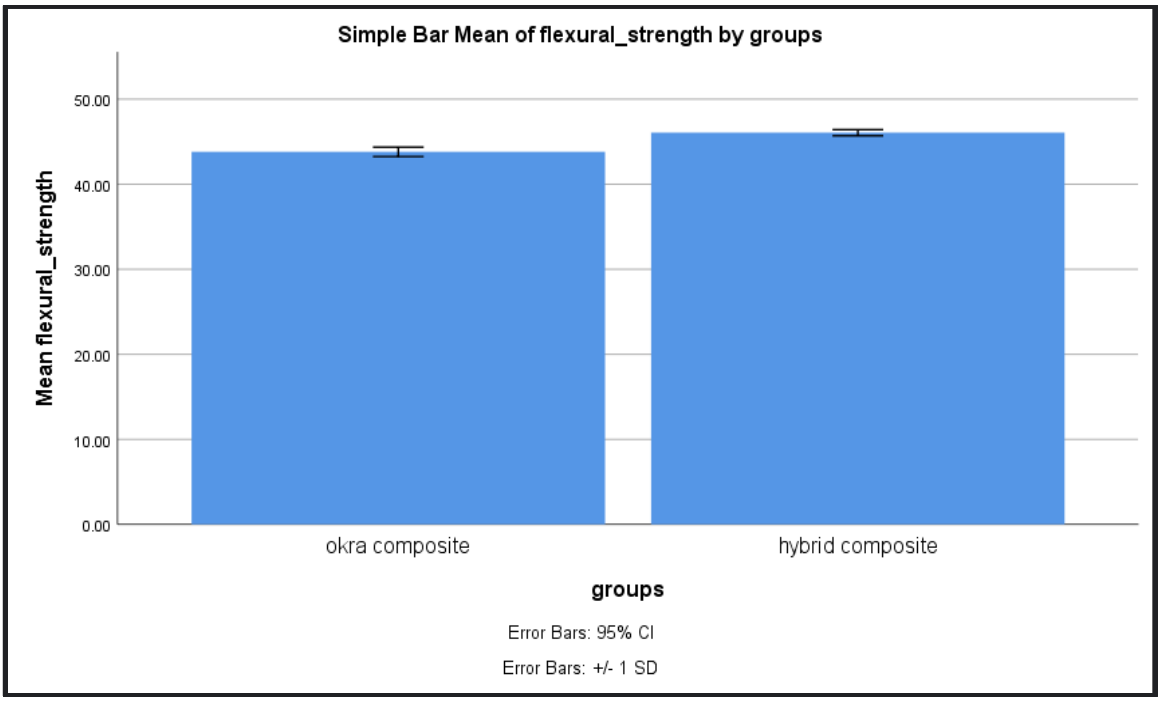

Fig. 2. The bar chart compares the mean of the flexural strength of okra composite and hybrid composite. X-axis: okra composite and hybrid composite, Y-axis: values of mean flexural strength with +/-1SD.