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Surface Roughness Testing of a New Epoxy-banana-fiber Laminate with and without Stainless-steel Wire Mesh Reinforcement

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Abstract

The primary objective of this study is to measure the surface roughness of a laminate made of banana fiber epoxy reinforced with a stainless-steel (SS) wire mesh. Composite without SS reinforcement is made using 5 plies of bidirectional banana fiber fabric banana-banana-banana-banana-banana (B-B-B-B-B) and composite laminate with reinforcement is made using bidirectional sustainable banana fiber fabric and SS mesh stacked in sequence Bbanana-Stainless-steel-Banana-Stainless-steel-Banana (B-SS-B-SS-B). This research is aimed to achieve better low surface roughness with the addition of SS mesh reinforcement. A total of 20 tests were conducted. The number of samples was decided with a G-power of 80%. To analyze the surface roughness, T-independent tests were done using the SPSS statistical software tool. According to the experimental data, group 1, banana fiber-reinforced epoxy composite laminate had an average of 2.9530 (µm) while group 2, composite laminate of banana fiber reinforced with SS wire mesh had an average of 1.4249 (µm). The surface roughness testing is done with the Mitutoyo surface roughness test setup as per (the SJ-410) standard. The mean-variance of surface roughness between group 1 and group 2 is determined to be significantly different with "$p = 0.001$ ($p < 0.05$) based on T-test" statistical analysis. The samples from the experimental and control groups' mean surface roughness the samples from the "banana-fiber epoxy composite" laminate with "SS wire mesh" group have samples with an average surface roughness of 43% more compared to the banana fiber epoxy composite laminate without SS wire mesh group.

Keywords

Sustainable banana fiber, Surface roughness, Novel stainless-steel wire mesh, Epoxy, Hardener, Natural fiber

Introduction

Surface roughness of innovative banana-fiber epoxy composites is compared with SS wire mesh reinforcement which is the primary goal of this work (B-SS-B-SS-B) to that without reinforcement (B-B-B-B-B) [1]. Banana fiber is a sustainable and eco-friendly material, as it is derived from the waste products of the banana plant [2]. It does not require any additional resources to produce, and it is biodegradable. Despite its strength, banana fiber is also soft to the touch, making it comfortable to wear as clothing or use in other textiles [3]. Banana fiber has excellent moisture absorption properties, making it ideal for use in products such as towels, bathrobes, and other absorbent textiles [4]. Banana fiber has been found to have natural antibacterial properties, which makes it a good choice for use in products that require high levels of hygiene, such as medical textiles [5]. Banana fiber has a unique, natural appearance that can add visual interest to products [6]. Banana fiber is strong and durable, making it suitable for a variety of applications, including textiles, paper, and packaging.

According to Google Scholar there have been around 560 publications and 120 papers have been published in ScienceDirect, related to this study area over the past five years. The topic has received increasing interest and newer applications for natural fiber composite are being discovered every year. Some of the most cited articles on this topic are in this research drilling hybrid natural fiber composites is of interest because of the importance of demonstrating the impact of drill geometry configuration and drilling parameters on drilling-induced force and damages [7]. The impact of various fly ash filler contents for the different machining abilities of "hybrid fiber-reinforced composites" produced from pineapple, sisal were the focus of this investigation. Fly ash produced from biowaste comprising bagasse, bananas, and coir is employed for the investigation. The high hardness of the 3% banana and 3% coir reduces the rate of material removal and raises the surface roughness of the composites [8]. Although many machining environments have been developed to cut fiber-reinforced polymer, one that has proven to be particularly successful is one in which compressed air is used as a cooling medium [9]. The mechanical characteristics of glass fiber hybridized with both untreated and treated hemp fiber have been studied experimentally in this research article [10]. Upon analyzing various research papers, the best-suited research paper for the study provides evidence that sustainable banana fiber epoxy composites with SS reinforcement show good improvement in surface roughness [9]. The literature study has demonstrated that there is relatively little use of SS mesh as reinforcement in laminates made of natural-fibers.

Material and Methods

At Chennai's Saveetha Industries, SIMATS, the composites are created utilizing the hand lay-up technique. No ethical approval is required as this research is about composite making. Epoxy resin of grade LY556 and hardener of grade HY951 is bought from Herenba industries Pvt limited, Ambattur. It is a hot-curing epoxy resin possessing good mechanical properties and chemical resistance. Bidirectional banana fiber fabric is bought from Go Green Pvt Limited, Chennai. SS wire mesh of expanded type was bought from bokaria wire netting industries, Chennai. 20 surface roughness experiments were repeated once in each sample.

Banana fiber that is bidirectional is chopped into pieces that are 300 × 300 mm in size for the manufacture of the control group. The ratio of epoxy to hardener is 10:1. Stacking sequence is B-B-B-B-B. Epoxy resin is evenly applied over the layers throughout the putting up process, and any air bubble that forms is eliminated with a roller. After stacking is done, a uniform weight is kept upon during the entirety of the curing period for proper adhesion.

For the fabrication of the experimental group, expanded SS wire mesh is cut into the size 300 × 300 mm. The stacking sequence is B-SS-B-SS-B. The SS wire mesh is rubbed with 400-grit paper for good adhesion. For 48 hours, the composite is allowed to cure at room temperature. The composite is subsequently cut by water-cut machining into the necessary specimen size.

Specimens of both groups of size 100 × 100 mm composite plates had holes drilled into them using a radial drilling machine. 20 operations in total were performed on each composite. The sample was pierced with holes drilled using a 5 mm diameter HSS tool at a constant speed of 1000 rpm and a feed rate of 200 mm/min. As can be seen in figure 1, an HSS drill bit was used to create the hole and is evaluated using the Mitutoyo surface roughness test equipment in accordance with the (SJ-410) surface roughness standard. In Microlabs, Chennai, the surface roughness is measured using the Mitutoyo surface roughness test system in accordance with the (SJ-410) standard. The test was conducted with the specimen properly maintained in the Mitutoyo surface roughness test setup in accordance with the (SJ-410) standard.

Figure 1 and figure 2 shows the samples of "banana fiber epoxy composite laminate" with and without "SS wire mesh" and the testing setup for surface roughness testing with the Mitutoyo test setup as per the (SJ-410) standard. Table 1 displays the surface roughness of banana fiber composite samples that were tested with and without SS wire mesh. Table 2 displays the "mean standard deviation and standard error". According to table 3, there is a 0.001 statistical difference between the two groups. Figure 3 depicts a SPSS bar graph of the mean surface roughness of two groups. The tests were carried out for 20 specimens of both groups and the results of the same were obtained.

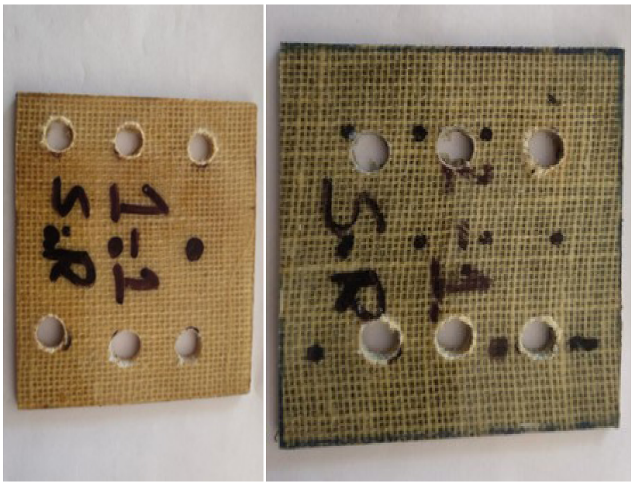

Figure 1: Composites samples: **(a)** Without reinforcement of SS wire mesh, and **(b)** with reinforcement of SS wire mesh.

Statistics analysis

The standard deviation, standard error, and mean values were determined using SPSS V.26's statistical analysis. The independent variables are banana fiber, SS wire mesh, and the properties of epoxy material, and the dependent variable is surface roughness. Significance, Anova, descriptives tables, and mean surface roughness graph is obtained from the software [11].

Figure 2: Surface testing loading of the specimen.

Table 1: Surface roughness (µm) for two groups.

	Surface roughness in (µm)	
S. No.	**With SS mesh reinforcement**	**Without SS mesh reinforcement**
1	1.584	2.401
2	0.401	1.657
3	1.584	4.386
4	1.164	2.081
5	2.010	4.100
6	1.123	2.133
7	0.234	2.234
8	1.123	3.345
9	2.567	2.123
10	1.567	2.786
11	1.789	3.124
12	2.574	4.355
13	1.899	4.144
14	0.256	2.133
15	1.345	3.145
16	1.566	2.789
17	1.324	3.436
18	0.564	2.111
19	2.234	3.899
20	1.589	2.678

Table 2: Surface roughness of two classes, tabulated descriptively.

Group		N	Avg.	SD	SE
Surface roughness (µm)	**With SS mesh reinforcement**	20	1.4249	0.68587	0.15336
	without SS mesh reinforcement	20	2.9530	0.86560	0.1

Results

Figure 1 shows the samples of "banana fiber epoxy composite" laminate with and without SS wire mesh. Figure 2 shows the testing setup for surface roughness testing with the Mitutoyo test setup as per the (SJ-410) standard. Comparing samples of composites with and without reinforcement, the ones with reinforcement exhibit less surface roughness. The composite with SS mesh reinforcement showed a mean surface roughness of 1.4249 µm with standard deviation of 0.68587. Composite without SS mesh reinforcement showed a mean surface roughness of 2.9530 µm and a "standard deviation" of 0.86560. Figure 3 depicts a simple bar graph of the mean surface roughness of two groups.

Discussion

The surface roughness of the samples was tested using a Mitutoyo surface roughness test setup as per the (SJ-410) standard as seen in figure 2. The composite with and without SS mesh Reinforcement showed a mean surface roughness of 1.4249 µm and 2.9530 µm respectively with the standard deviation being 0.68587 and 0.86560 respectively as seen in table 1 and table 2. The surface roughness is 30% better with the use of SS. Plies of bidirectional banana fiber were replaced in the experimental group with SS, which did not significantly increase weight but significantly reduced surface roughness.

A similar study conducted there were extensive inventories of mechanical qualities and preparation methods [12, 13]. This study provides a summary of the existing understanding of banana fiber-reinforced composites along with any open research gaps [5]. Another study found that the strength and modulus of the material are the key factors influencing material choice in any mechanical design. A characteristic of natural fiber composites is always influenced by the proportions of the

Table 3: Independent sample of t-test for surface roughness (µm) of with and without reinforcement SS wire mesh.

		Levene's test		t-test							
		F	Sig.	t	df	Significance		Mean difference	Std. Error difference	95% CID	
						One-sided p	Two-sided p			Low	High
Surface roughness (µm)	Equal variances	2.405	0.001	-6.188	38	0.001	0.00	-1.528	0.2469	-2.0280	-1.028
	No equal variances	-	-	-6.188	36.112	0.001	0.00	-1.528	0.2469	-2.0289	-1.027

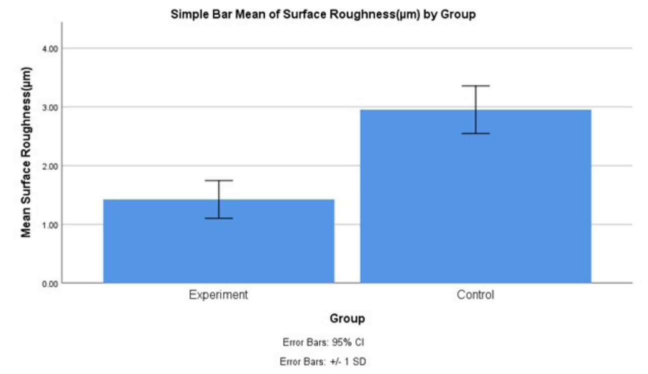

Figure 3: Surface roughness (µm) is represented graphically for group 1 and 2.

ingredients (cellulose, hemicellulose, and lignin). The current work aims on many characterisation investigations of natural fiber composites. Therefore, it provides insight into the factors that affect natural fiber composite's strength, stiffness, and stability [14].

This study examines banana fibers, including their usage, applications, mechanical characteristics, and potential improvements to mechanical properties (ICB-Inter consult Bulgaria Ltd 2022). In this experimental effort, palm and coir fibers have been used as fillers, and banana fiber has been used as a basis material due to its high tensile strength [15]. All studies conclude that banana fiber improves mechanical properties. The process of fabrication used in this study is the hand lay-up method which acts as a limitation by being a very time-consuming process. The possibility of irregularities and improper bonding within the composite is high in this process. The required characteristics can be obtained by adjusting the orientation, mesh size, and number of layers of SS wire mesh reinforcement.

Conclusion

The purpose of this study is to compare the surface roughness of "banana-fiber epoxy composite" laminate samples reinforced with "SS wire mesh" to those without such reinforcement. The composite with and without SS mesh reinforcement showed a mean surface roughness of 1.4249 µm and 2.9530 µm respectively with the standard deviation being 0.68587 and 0.86560 respectively. The samples of novel banana fiber with reinforcement of SS wire mesh showed lower surface roughness compared to samples of the group without SS wire mesh reinforcement.

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None.

Conflict of Interest

None.

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