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Measurement of surface roughness in drilling on epoxy matrix composite reinforced with E-Glass fibre and calophyllum inophyllum powder in comparison with plain GFRP epoxy composite.

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ABSTRACT

Aim: This research work deals with measure of surface roughness on E-glass fibre reinforced with epoxy matrix addition of Calophyllum inophyllum filler in comparison with plain GFRP epoxy composites. **Materials and Methods:** In this project Calophyllum inophyllum filler was added with volume fraction of 10% along with an epoxy matrix reinforced by E-glass fibre. The laminates were made using a hand lay-up method. The sample size per group was 20. The pre test power for testing was 80%, Alpha was 0.05% and CL was 95%, G power 80% used to fix the number of samples for every group. By using previous literature, mean and standard deviation values were taken for the sample calculator. During the calculation, the mean value and standard deviation for without filler composite 2.31 and 1.99. For 10% filler composite exhibited 0.186 and 0.240. **Results:** Surface roughness test result showed that 10% volume fraction of Calophyllum inophyllum filler added composite exhibited notable values of surface roughness compared to plain GFRP laminate. The Significance value obtained was 0.000 ($p < 0.05$). **Conclusion:** Within the limitations of this work, the addition of Calophyllum inophyllum filler exhibits enhanced surface roughness properties in 10% Volume fraction when compared to plain GFRP composite.

Keywords: Epoxy, E-glass fibre, Hybrid Composite, Novel Calophyllum inophyllum filler, GFRP, Hand layup.

INTRODUCTION

This research work was about investigating surface roughness of E-glass fiber epoxy composites added with Novel Calophyllum inophyllum, comparing the surface roughness of plain glass fiber reinforced epoxy composites without fillers. Surface roughness was observed with necessary values and plotting graphs for better understanding(Lau et al. 2018). Synthetic fiber composite has high strength, stiffness, and density when compared to natural fibers because of these reasons, synthetic fibers have been considered for this test(Gholampour and Ozbakkaloglu 2020). E glass fiber is used as a reinforcement in the preparation of bullet proof vests, bicycle frames, race car components etc. Synthetic fibers, commonly known as man-made fibers were prepared using petrochemicals(Miner 1977) : (Thakur, Thakur, and Pappu 2017).

The most citations in google scholar was 2100 articles and science direct was 523 articles. It was found that the addition of Al2O3 and fly ash to composite leads to decrease in surface roughness strength according to the study undertaken(Devendra and Rangaswamy 2013). The surface roughness of sisal fiber polyethylene (LDPE) composites were sensitive to fiber length, fiber content and fiber orientation(Orue et al. 2016). Cutting speed and flow rate of abrasive are used as variables for the process in abrasive water jet machining on glass fibre reinforced polymer (GFRP) composites to calculate the material removal rate (MRR)(Tripathi et al. 2020). Due to the lower consolidation pressure, the fibre fractions available from vacuum impregnation are slightly lower, which has an impact on the laminate's mechanical and thermal properties(Nguyen et al. 2018). By working as an abrasive medium between the shaft and the surface, the broken pieces have increased wear(Nagaraju, Venkatesu, and Ujwala 2018). Polymer composites enhance surface roughness due to hybridization(Xanthos 2010). From the above survey it is highlighted that (Tripathi et al. 2020) is best and closely related to this research.On gaining knowledge from these literatures this work was proposed (Samuel et al. 2019; Johnson et al. 2020; Venu, Subramani, and Raju 2019; Keerthana and Thenmozhi 2016; Thejeswar and Thenmozhi 2015; Krishna and Babu 2016; Subashri and Thenmozhi 2016; Sriram, Thenmozhi, and Yuvaraj 2015; Jain, Kumar, and Manjula 2014; Menon and Thenmozhi 2016)

Based on the literature survey it was noticed that no work has been done on addition of Calophyllum inophyllum filler with epoxy resin reinforced by E-glass fibre. The aim of the study was to fabricate and test Calophyllum inophyllum filler added with an epoxy matrix reinforced by E-glass fibre composite laminate.

MATERIALS AND METHODS

This research work was done in the central workshop, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences Chennai. Two groups were selected for this research work. There were control and experimental group. The experimental group consists of a glass fibre, Novel Butea monosperma filler added with epoxy reinforced by glass fibre. The control group comprises a GFRP epoxy composite. The sample size per group was 20. The pre test power for testing was 80%, Alpha was 0.05% and CL was 95%, G power test was used to fix the number of samples for each group. By using previous literature, mean and standard deviation values were taken for the sample calculator. For the calculation of experimental work, mean and standard deviation was considered to be 85 and 11(Devendra and Rangaswamy 2013)

A bidirectional woven mat of 400 GSM grade was purchased with a cost of Rs. 200 per metre and Calophyllum inophyllum filler of weight 200gm with a cost of Rs. 250. The E-Glass fibre mat was first cut into 300 × 300mm sheets, then a mould with dimensions of 300x300x3mm was prepared. The epoxy resin was mixed with hardener at a ratio of 10:1 for volume fraction of 10% of Calophyllum inophyllum natural filler. Here we used about 600 ml and 60 ml for epoxy and hardener respectively.

In the experimental group, E-glass fibre was purchased from Hayael aerospace India pvt. Ltd, Chennai, Tamil Nadu. Calophyllum inophyllum natural filler was mixed with matrix with no lumps, in 10% volume fraction of natural filler. After the mixture has been prepared, a plastic sheet was placed and wax was added to the sheet, as this aids in the easy removal of the prepared composite plate, a layer of epoxy mixture was uniformly spread over the plastic sheet, and a cut E Glass fibre mat was placed on the epoxy, another layer of epoxy mixture was poured over the placed fibre mat and evenly applied, and the process was repeated along for a total of 3 layers of E Glass fibre mat, once done a plastic sheet with wax was placed over it to cover the set up and weight was place over it and left to settle for 24 hours. After the 24-hour cycle has passed, plastic sheets are to be removed and a composite plate has been formed, the excess epoxy can be cut away to create a Natural filler reinforced epoxy composite plate with dimensions of 300 × 300 × 3mm. The sample shown in Fig. 1.

The glass fiber was first cut into required dimensions of 300 × 300mm, then similar to that of the experimental group, The control group followed the same procedure similar to that of the experimental group without addition of natural filler into the matrix mixture. The sample shown in Fig. 2.The method involved for the entire process was called the Hand lay-up method(Sonparote and Lakkad 1982).

Radial drilling machine was used to drill the holes in the specimen. The drilling on the sample was performed with a 10 mm diameter HSS tool. The radial drilling machine was performed to make a 10 mm diameter hole with a constant speed of 1000 rpm and a feed rate of 200 mm/min. The drilling process shown in Fig. 3. The specimen was mounted on the work holding device in the drilling machine. The hole was made with an HSS drill tool as shown in Fig. 4. After the drilling operation, the sample was taken for the surface roughness test in the Mitutoyo surface roughness tester as shown in Fig. 5. The drilled specimen was mounted on the holding device on the Mitutoyo surface roughness tester SJ-410. The thickness of the sample specimen was manually fed in the tester and the deep hole stylus is authorized to touch the hole surface and the machine measured the surface roughness of the drilled hole surface.The comparison of surface roughness was made between these groups.

Statistical analysis

It was evaluated under Independent T- test, group statistics and G graph using the statistical program SPSS version 21. E- glass fibre, Calophyllum inophyllum filler were independent variables, whereas surface roughness was the dependent variable.

RESULTS

The composites consisting of Kevlar fiber, reinforced with epoxy matrix addition of Calophyllum inophyllum filler with volume fraction of 10% were fabricated. The tests were conducted on all test specimens. The surface roughness values of experimental group and control group samples were tabulated in Table 1. Table 2 describes the mean value, standard deviation, Minimum and maximum values for the entire sample. Table 3 Shows the T-table describes the significant value of surface roughness between the groups as $p=0.000$ ($p<0.05$) and significance values of experimental and control groups.

A bar chart shown in Fig. 5 describes the surface roughness values of both control group and experimental group with error bar. From the bar chart it was noticed that glass fiber reinforced with epoxy addition of Calophyllum inophyllum filler with 0% volume fraction was not clumped and 10% volume fraction composite values were clumped around the mean showing the property improvement in 10% volume fraction with mean accuracy of detection ± 1SD

The surface roughness of glass fiber epoxy composite was observed with the mean value of 2.3012 and standard deviation of 0.18511 for 20 test samples. For 10% volume fraction of Calophyllum inophyllum filler reinforced epoxy composite value exhibited the mean values 0f 1.9522 and a standard deviation of 0.15429 as shown in Table 2. Significant value between without filler and with 10% filler composite in terms of surface roughness was ($p = 0.000$) i e., $p < 0.05$ as shown in Table 3.

DISCUSSIONS

The surface roughness of glass fiber, with a 10% volume fraction of Calophyllum inophyllum natural filler added with epoxy has improved property when compared to that of 0% volume fraction of filler added with epoxy. For a 0% volume fraction of natural filler the surface roughness ranges from 1.881 μm to 2.618 μm. For the 10% volume fraction of natural filler the surface roughness ranges from 1.618 μm to 2.471 μm.

The surface roughness of the composite was significantly improved with the usage of laminated composites when compared to without filler composites with a significance value of 0.000. Important parameters for surface roughness are depth of cut and feed rate which is similarly stated in(Kumar et al. 2016). If feed rate and depth of cut increases then roughness will decrease(Tripathi et al. 2020). Based on this it can be stated that the roughness has improved by 44.5%. There is no opposite research analysis observed in material removal rate findings. The factors which affect the surface roughness were filler size, Distribution of filler in the matrix material, Nature of bonding between fibre material with epoxy, Formation voids in intermediate layers.

The Limitations were improper distribution of Calophyllum inophyllum filler and formation of air bubbles in the specimen due to hand layup method. It was inferred that composites made by varying volume fraction result in better improvements in mechanical properties in the near future. Hybrid particles may be used as filler materials.

CONCLUSION

Within the limitations of this study, E-glass fiber and Calophyllum inophyllum filler as reinforcement and epoxy as matrix hybrid composite was fabricated. Drilling was done on the laminated plates. It was noticed that the surface roughness of 10% filler composite showed higher values, when compared to plain GFRP composite. Drilling on plain GFRP composite was easy and gave a smooth surface on the specimen.

DECLARATIONS:

Conflict of Interest

The authors declare that there was no conflict of interest.

Author Contribution

Author SA was involved in Fabrication of Composite Materials, Testing Author NK was involved in conceptualization, data validation, and critical review of manuscript.

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TABLES AND FIGURES

Table 1. Surface roughness values of Experimental group and control group specimens.The maximum value of glass fiber without filler is 2.652 µm and the maximum value of Glass fiber composite with 10% filler is 2.471 µm

Sample Number	Surface roughness of Glass Fibre without filler (µm)	Surface roughness of Glass Fibre with 10% filler (µm)
1	2.112	1.862
2	2.413	1.971
3	2.618	2.082
4	2.421	1.712
5	2.361	1.941
6	2.472	1.856
7	2.348	1.712
8	2.352	1.618
9	2.414	1.819
10	2.291	1.921
11	2.262	1.682
12	1.992	1.961
13	1.881	2.072

14	2.121	2.162
15	2.261	2.451
16	2.311	2.262
17	2.218	2.471
18	2.409	2.151
19	2.652	2.225
20	2.361	2.019

Table 2. Mean value, Standard deviation and error of composite laminates of experimental and control group

Group Statistics					
	Group	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
Ra	GF without filler	20	2.31350	.186858	.041783
	GF with 10% filler	20	1.99750	.240970	.05882

Table 3. T- test values of mean square and significance

Independent Sample Test										
		Levene's Test for Equality of Variances		**T-test for Equality of Mean**						
		F	**Sig.**	**t**	**df**	**sig.**	**Mean Diff**	**Std Error Dff**	**95% Confidence Interval of the Difference**	
									Lower	**Upper**
Surface roughness	Equal variances assumed	2.00	.165	11.27	38	.000	1.059	.09	.8695	1.250
	Equal Variances not assumed			11.27	35.41	.000	1.059	.09	.86910	1.250

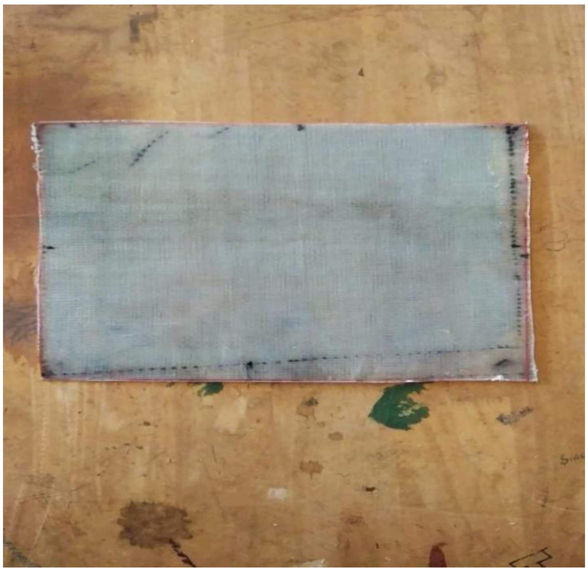

Fig. 1. Plain GFRP Laminate

Fig. 2. Surface roughness sample before testing

Fig. 3. Radial drilling undergone on glass fiber specimen

Fig. 4. Mitutoyo surface roughness tester SJ-410

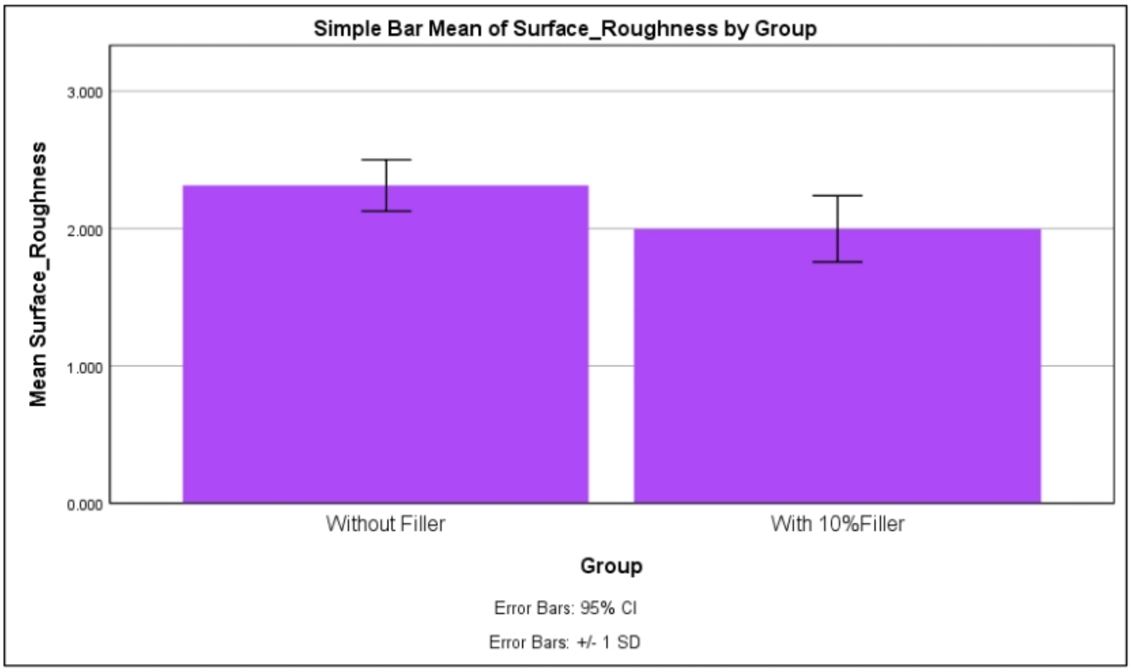

Fig. 5. Mean surface roughness values of glass fiber reinforced with epoxy addition of Calophyllum inophyllum filler 0% and 10% volume fraction composite suggest that the values are clumped around the mean. X-axis shows glass fiber with and without filler and Y-axis mean surface roughness with accuracy of ±1 SD.