A novel hybrid composite made of glass and jute and reinforced with nanoparticles of copper slag, aluminum oxide, and glass underwent experimental analysis to determine its surface roughness.

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ABSTRACT

Aim:This research study is to investigate the surface roughness on the drilled hole surface of glass fibre/jute fibre reinforced polymer composite with and without filler particles Al_2O_3 +glass beads/copper slag. **Material and Methods**: The polymer composites are fabricated into two groups: Experimental and Control group. The fabrication process used is the hand layup method. The sample preparation and surface roughness measurements were done in accordance with the ASTM-D3039 standard using Mitutoyo make roughness tester.. The statistical analysis was performed using the SPSS v26 Statistical tool. The G-Power used for this process is 80%, $\alpha = 0.05$ per set for calculating sample size and total sample size is N=40. The surface roughness data was evaluated by using an independent sample t-test.**Results**: From the experimental results, the mean surface roughness value of 51.1097μm with standard deviation of 0.86734 is noticed in aluminium oxide+glass beads/copper slag filler added composite (Experimental Group) and mean surface roughness value of 55.4955μm with standard deviation of 1.7210 is reported for glass/jute fibre composite without novel aluminium oxide+glass beads/copper slag filler. Using the SPSS v26 software, the significance of the findings was estimated and found to be $p=0.002$ ($p<0.05$). **Conclusion:** Within the limitations of the study, the samples containing 4 wt.% of Aluminium oxide+glass beads/copper slag shows 9% reduction in surface roughness when compared to samples without filler materials which is significant improvement.

Keywords: Natural Fibre, Glass Fibre, Jute Fibre, Aluminium Oxide+Glass Beads, Copper Slag,Novel Hybrid Composite, Hand Layup

INTRODUCTION

To create a new material that combines Aluminium oxide+glass beads /copper slag, nano-particles as a filler in a novel hybrid composite with and without filler (Nobuaki, Keiichi, and Takashi 2015). They have a greater strength-to-weight ratio than many standard materials, making them appropriate for a wide range of applications. They're also corrosion-resistant, low-cost, and simple to make (Cardona et al. 2016). Natural fibres are growing in popularity due to their partially biodegradable properties and greater environmental concerns.They are also corrosion-resistant, inexpensive, and simple to make (Mehari et al. 2020). Natural

Fibre Reinforced Composites (NFRC) have grown in popularity as a result of its partially biodegradable properties and greater environmental awareness (Koronis, Silva, and Fontul 2013; Sanfona, Barroso, and Fontul 2019). They are employed in a variety of engineering fields, including electronics, marine aerospace, and automobiles .

Only a few studies from the previous five years of research stood out. To strengthen the interfacial interaction with the matrix, sisal fibres were exposed to different chemical and physical alterations such as mercerization, heating at 100°C, permanganate treatment, benzoylation, and silanization (McIlhagger, Archer, and McIlhagger 2015). Natural fibre is an excellent renewable resource for producing lightweight composite materials (Matuszak et al. 2021);(Skoczylas et al. 2021). Natural fibre's hydrophilic character, on the other hand, is a severe drawback when used as a composite reinforcement material (Koronis, Silva, and Fontul 2013). Drill analysis employing coir fibre reinforced polyester composite looked at drill bit diameter, spindle speed, and feed rate for the least value thrust force, torque, and drill wear. By investigating the optimum circumstances for drilling operation on jute fibre reinforced composites, such as feed rate (Paturkar et al. 2018). spindle speed, and drill diameter, chemical treatment of natural fibres and the use of customised drill bits could improve the composite's drilling performance. During drilling, heat builds up near the tool edge, disturbing matrix integrity and causing thermal damage (Queiroz et al. 2021).(Bhavikatti et al. 2021; Karobari et al. 2021; Shanmugam et al. 2021; Sawant et al. 2021; Muthukrishnan 2021; Preethi et al. 2021; Karthigadevi et al. 2021; Bhanu Teja et al. 2021; Veerasimman et al. 2021; Baskar et al. 2021)

. Due to the abrasive nature of composites, machining fibre reinforced composites presents additional challenges, such as splintering and delamination (Kalirasu et al. 2015). This study used aluminium oxide glass beads manufactured from rice husk as a filler material to address this disadvantage.

MATERIALS AND METHODS

Hand lay-up composite fabrication was performed in the Central Workshop, Saveetha School of Engineering (SSE), Saveetha Institute of Medical and Technical Sciences (SIMATS), Chennai. Using ClinCalc software, the sample size is calculated using an 80 percent G-power, a mean of 0.5245, and a standard deviation of 0.5080, with a 95 % confidence interval by (Gardner and Simón 2017). The significance level was set at $p< 0.05$. For this research glass jute fibre sheets were combined with epoxy resin VBR8912 (density 1.16 g/cm^3) and hardener VRB1209 (density 0.98 g/cm^3) in the required proportions to create a hybrid polymer composite(Ganesan et al. 2021).

The epoxy resin and hardener was mechanically stirred in a container for about 10 minutes in 2:1 ratio and formed into plates on mica sheet (300 x 300 x 6mm). The curing time for composite is 24-36 hrs. The jute/glass and jute fibre mat was first cut into (300 x 300 mm) sheets, then a mould with dimensions of (300 x 300 x 6 mm) was prepared. The epoxy resin was mixed with hardener at a ratio of 2:1 ratio. 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 jute/glass and 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 4 layer of jute/glass fibre mat and 3 layer of glass fibre, once done a plastic sheet with wax was placed over it to cover the set up and dead weight was place over it and left to settle for 24-36 hours. After the 24-36 hour cycle has passed, plastic sheets are to be removed and a composite plate has been formed with dimensions of (300 x 300 x 3 mm).

Drilling operation was performed on the composite using a CNC Vertical Machining Centre (VMC) - YCM EV1020A, X-Axis Travel: 40.2", Y-Axis Travel: 20.5", Z-Axis Travel: 21.3", Max feed (X/Y/Z): 787 IPM, Rapid rate (X/Y/Z): 1,260 IPM, to form 20 drill holes. Each drill hole measured 8 mm in diameter. The drilling operation was carried out using an HSS drill bit at a speed of 900 rpm with feed rate of 0.5 mm/min. The experimental group sample specimen after drilling is shown in Fig. 2 and control group specimen in Fig. 3. The sample specimen removed after drilling operations were tested for surface roughness.

The surface roughness of all 20 drilled holes was tested using a Mitutoyo surface roughness tester, SJ-410 (Fig. 1). This surface roughness measuring instrument is equipped with 46 roughness parameters that conform to the latest ISO, DIN, ANSI and JIS standards. The unit's high-resolution detector and drive unit provide a wide range of highly accurate measurements and ultra-fine steps.Following the test, the readings from the multifunctional display are recorded. The surface roughness was determined by measuring the sample length of 10mm.

Statistical Analysis

The significance of the results was statistically evaluated using the Independent t-test with SPSS-V26 software application. To determine the statistical nature of the data, the relationship between the dependent variable (Surface roughness) and independent variable (Sample composition) variables is examined (George and Mallery 2019). The study was completed successfully, and the results were tabulated.

RESULTS

The surface roughness of the specimens with and without filler was tested and studied. The surface roughness of the specimens with filler and without filler was assessed according to ASTM-D3039 standards. Table 1 shows the surface roughness values for 20 samples of the above two groups. A comparison was also made between the specimens of the two groups with filler and without filler. From the test results shown in Table 2 the mean surface roughness value of 55.4955μm with standard deviation of 1.7210 is reported for the control group samples (glass/jute fibre composite without novel Aluminium oxide+glass beads/copper slag filler). The maximum and minimum surface roughness values measured are 59.12 µm and 52.20 µm, respectively. For the experimental group (glass/jute fibre composite with novel aluminium oxide+glass beads/copper slag filler) the mean surface roughness of 51.1097µm with standard deviation of 0.86734 is recorded. The maximum and minimum surface roughness values measured are 52.98 µm and 50.21 µm, respectively. Table 2 shows the mean and standard deviation of test results obtained using SPSS software. Table 3 shows independent t-test output with significance of the findings (surface roughness in drilled holes) obtained for both sample classes.

DISCUSSION

This investigation compared the surface roughness values of the drilled holes of the novel aluminium oxide+glass beads/copper slag filler reinforced glass/jute fibre hybrid composite with non filler added glass/jute fibre hybrid composite. The addition of novel Aluminium oxide+glass beads/copper slag filler to the epoxy polymer matrix showed effective drilling performance and better surface roughness value, when compared with composite without filler. However, the surface roughness of the composites was mainly dependent on the machining conditions. Variation in the machining could vary the surface roughness of the composites. These findings can be varied when the reinforcing percentage of the novel Aluminium Oxide+Glass Beads / copper slag is increased or decreased. To understand the effective performance a detailed optimization investigation is needed. Due to the addition of novel aluminium oxide+glass Beads/copper slag, this composite demonstrated good machining performance by addressing difficulties related to abrasive behaviour of composites, bonding issues such as delamination. However, more research is needed to limit water absorbability caused by natural fibre reinforcement.

The mean surface roughness value of 51.1097µm is noticed in aluminium oxide+glass beads/copper slag filler added composite (Experimental Group) which is 9% lesser than without filler composite (Control group). The maximum and minimum values measured for the filler group are 7.025 µm and 4.161 µm, respectively. The mean value of surface roughness for the without filler group is 7.514 µm. The maximum and minimum values measured for the without filler group are 9.765 µm and 6.234 µm, respectively.The results show that the presence of filler significantly reduced the surface roughness in drilled holes of hybrid composites. The addition of filler changes the surface and volume properties of the composite to some extent, according to the research work of (Singh et al. 2017); (Anggoro and Kristiana 2015). It was demonstrated that adding 4wt.% aluminium oxide glass beads/copper slag as a filler decreases the surface roughness which is similar to the findings of (Kumar and Anand 2019). The following findings support previous research, which found that adding natural fibre/filler to a composite improves its mechanical properties(Yang, Lue, and Zhang 2010);(Reis et al. 2015).

This research does have some limitations. The hand layup method of composite manufacturing produces gas pores between the layers of fibres, slower process, time consuming, lowering the composite's structural strength and also creates an uneven surface. This method of fabrication has been found to be inefficient and unsuitable for mass production (McIlhagger, Archer, and McIlhagger 2015).

The future scope of this research is to use various other approaches for composite fabrication like using compression moulding machines. The use of other fillers (Natural rubber, saw dust, clay, etc) can be experimented. Investigation of the mechanical properties of these composites with nano filler and various fibre orientations, as well as other fabrication techniques for aerospace applications and automobile fields are suggested for future research.

CONCLUSION

Within the limitations of this study, the surface roughness of the jute/glass fibre hybrid composite with 4 wt.% novel aluminium oxide+glass beads/copper slag filler was found to be reduced by 9% than that of the composite without any filler. The surface roughness of the drilled holes in the fabricated composites was investigated, and the experimental results were analysed using SPSS software.This study revealed differences in the drilling performance of two distinct epoxy based hybrid composites, and the suitability of the aluminium oxide+glass beads/copper slag as prominent filler materials in composite fabrication for various applications.

DECLARATIONS

Conflict of Interests

The authors declare that there is no conflict of interest in this manuscript.

Authors Contribution

Author YB was involved in data collection, data analysis, Manuscript writing. Author MT was involved in conceptualization, data validation, and critical review of the manuscript.

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Tables and Figures

Table 1. Surface roughness of control group samples (glass/jute fibre without filler) and experimental group samples (with 4 wt.% of Aluminium Oxide+Glass Beads, Copper Slag, filler) is presented.

Experiment No	**Surface Roughness Of Control group samples (Without novel filler) in µm**	**Surface Roughness Of Experimental group samples (With novel filler) in µm**
1	52.00	50.27
2	54.00	50.21
3	53.25	50.34
4	53.00	52.50
5	54.70	52.87
6	56.00	52.10
7	56.78	51.98
8	54.30	51.34
9	55.80	50.23
10	57.00	50.80
11	59.12	50.73
12	58.00	52.00
13	53.03	52.50
14	56.00	52.87
15	56.38	52.10
16	57.00	51.98
17	56.80	51.34
18	56.30	50.23
19	56.86	50.80
20	56.30	50.73

Table 2. Mean and standard deviation of surface roughness analysed using SPSS software shown below.

Group statistics					
	Group	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
Surface Roughness (µm)	Control Group	20	55.4955	1.72100	0.38483
	Experimental Group	20	51.1097	0.86734	0.19394

Table 3. Details of Independent sample test results are shown below. The significance of the independent sample test is found to be 0.042.

Levene's Test for Equality of Variances			**Independent samples test**						
			t-test for Equality of Means						
Surface Roughness	**F**	**Sig**	**t**	**df**	**Sig. 2 tailed**	**Mean Difference**	**Std. Error Difference**	**95% Confidence Interval of the Difference**	
								Lower	**Upper**
Equal variances assumed	11.476	0.042	-10.18	38	0.000	-4.3859	0.43094	-5.258	-3.503
Equal variances not assumed	-	-	-10.18	28.07	0.000	-4.3859	0.43094	-5.268	-3.503

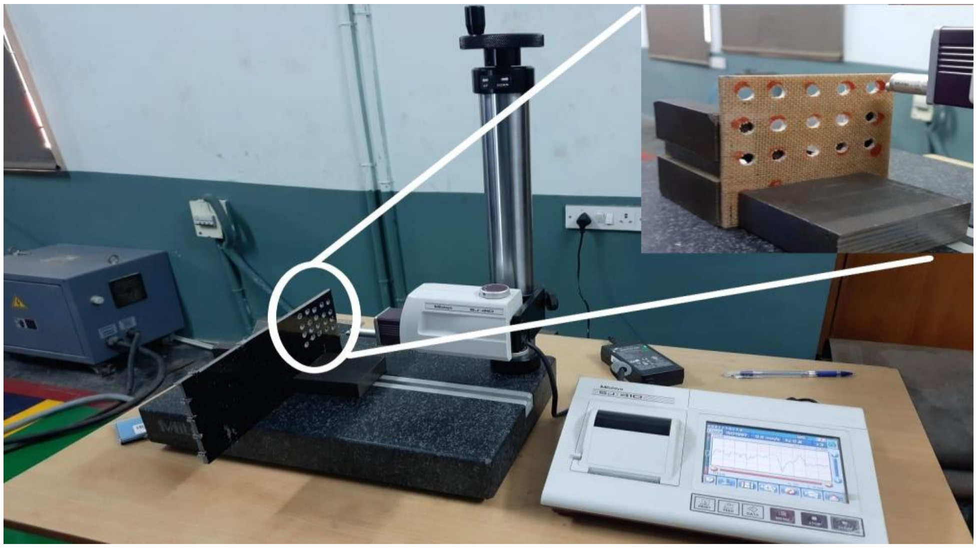

Fig. 1. Roughness Tester machine-Mitutoyo surface roughness tester (SJ-410).

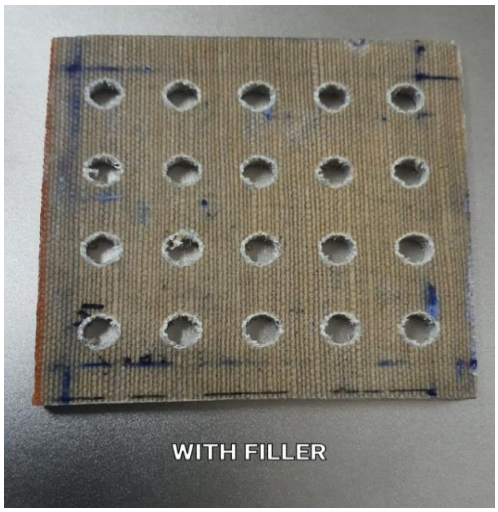

Fig. 2. Fabricated Sample with filler Aluminium oxide+glass beads/Copper Slag (Experimental Group).

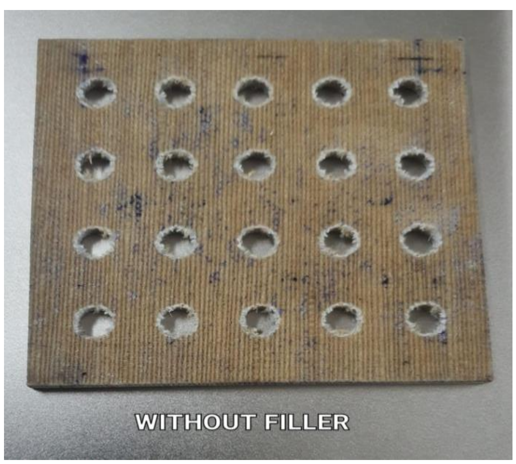

Fig. 3. Fabricated Sample without filler Aluminium oxide+glass beads/Copper Slag (Control Group).

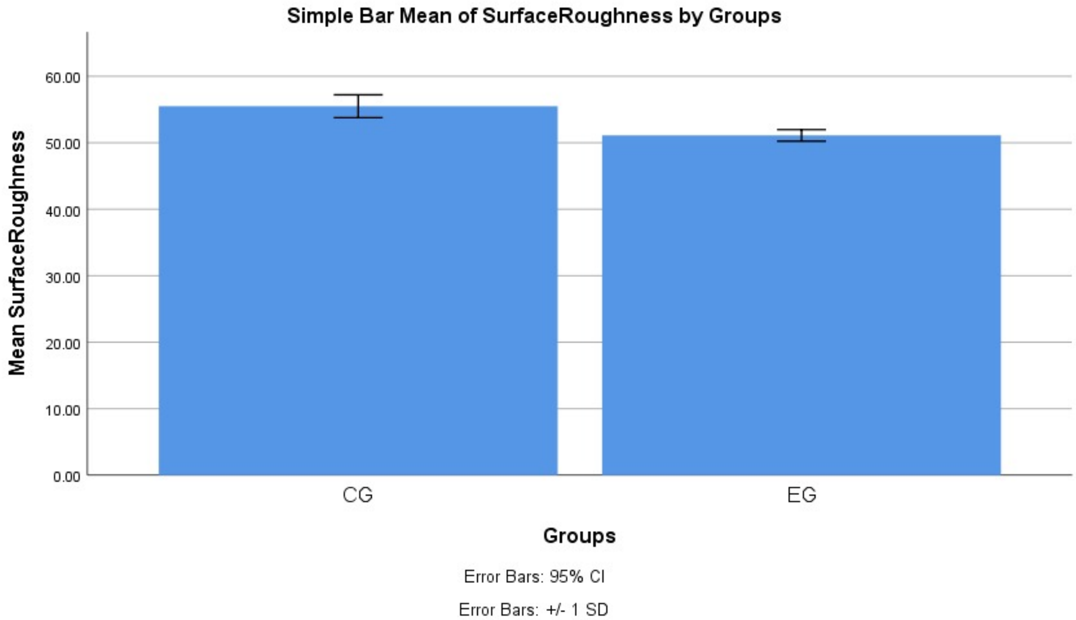

Fig. 4. The surface roughness of hybrid composites fabricated with and without filler are compared and represented in the bar graph. With a standard deviation of ±1, the mean accuracy of readings obtained. The surface roughness of the samples in the experimental group with novel Aluminium Oxide+Glass Beads / copper slag filler (51.25µm) are found to be high compared to the other samples in the control group without novel Aluminium Oxide+Glass Beads / copper slag filler (55.11µm). EG-Experimental group with filler, CG-Control group without filler