Original Article

A Comparative Study on Surface Roughness of Novel Drumstick Gum Powder Filled Sisal/Glass Fiber Reinforced Epoxy Composite and Sisal/Glass Fiber Epoxy Composite

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Abstract

Aim: The main aim of this research is to evaluate the surface roughness of Sisal/Glass fiber reinforced epoxy composite filled with novel Drumstick Gum Powder and compare it with Sisal/Glass fiber epoxy composite. **Materials and Methods**: In this study, the Sisal/Glass fiber epoxy composite was taken as a control group which has 20 sample specimens. Also, Sisal/Glass fiber with 20% filled reinforced epoxy composites was considered as an experimental group which also has 20 sample specimens.The samples were calculated based upon G Power. G Power is taken as 80%. Composites plates were prepared by hand layup method with 20% drumstick gum powder novel bio-filler and without filler. **Results:** Surface roughness of Sisal/Glass fiber without filler reinforced epoxy composite is 4.00 µm. Sisal/Glass fiber with 20% filler epoxy composite is 3.03 µm. sisal/Glass fiber with 20% filler showed a significant value p= 0.000 ($p<0.05$) than Sisal/Glass fiber epoxy composite. **Conclusion:** Within the limitations of this study, the surface roughness of Sisal/Glass fiber with a 20% volume fraction of drumstick gum powder filler reinforced epoxy composite exhibited improvement in surface finish than the Sisal/Glass fiber epoxy composite.

Keywords: Natural fiber composite, Sisal fiber, Glass fiber, Novel Drumstick Gum Powder, Radial drilling , Surface Roughness, Epoxy.

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INTRODUCTION

Natural Fibers are the fibers that are obtained from plants,vegetables and mineral sources. Composite materials are the addition and mixing of two or more reinforcements like fibers, particles, flakes, or fillers that are present in the matrix is called as a composite material. The mechanical properties of the natural fibers mostly depend upon the fiber orientation and method of extraction. The mechanical properties of the natural fiber are not the same around the world, it always changes from place to place and time to time. It was noted that feed rate, speed of spindle, and point angle are mainly disturbed by the surface of the composite (Vinayagamoorthy et al. 2019)). Synthetic fiber composite has more strength, high stiffness, and also high density but these synthetic fibers are non-biodegradable & non-recyclable and the fiber cost is also very much high when compared to natural fibers such as sisal fiber.Due to these reasons, synthetic fibers have been mostly replaced by natural fibers (Sisal,Snake,Okra etc). Natural fibers are recyclable, biodegradable, renewable, non-poisonous, less abrasion, high thermal stability, and very less density (A. Kumar and Srivastava 2017; Teng et al. 2015). It was investigated that natural fibers are alternative materials for synthetic fibers and these fibers are used in a wide range of lightweight applications like military aircraft, defense, car interiors,automobiles and medical purposes (S. S. Kumar et al. 2021); (Gad, Rahoma, and Al-Thobity 2018).

From the past five years in Google Scholar around 220 articles, also in ScienceDirect around 52 articles were published related to this research. It was identified that Nano Khorasan powder natural bio filler with pineapple fiber showed more better surface roughness when compared to Pineapple fiber epoxy composite, properties like speed and feed are mostly influencing the surface roughness (Ra). Therefore these properties appeared to be significant machining parameters to achieve highest quality surface roughness in turning operation (Maroulakos et al. 2019). It was identified that minimum surface roughness was obtained, using high spindle speed with less feed rate and smaller drill diameter (Amran et al. 2014). It was investigated that using HSS drill bits in jute fiber reinforced polymer composites low surface roughness was attained (Ruschel et al. 2018). It was identified that a bigger drill bit diameter leads to reduction in thrust force and surface roughness at the highest cutting speed for glass fiber reinforced composites(Ray et al. 2020). It was identified that when the spindle speed increases, the surface roughness will be reduced because of more revolutions the MRR is high(Kiswanto, Zariatin, and Ko 2014)**.** From all the above findings (Ray et al. 2020) is the best study because it is the one which is very closely related to the study.

No research has been done using this novel filler (Drumstick Gum Powder) in composites. However, our team has extensive knowledge and research experience that has translate into high quality publications(Bhansali et al. 2021; Jayanth et al. 2021; Sudhakar, Ravel, and Perumal 2021; Sathiyamoorthi et al. 2021; Deepanraj et al. 2021; Raju et al. 2021; Arun Prakash et al. 2020; Kamath et al. 2020; Shanmugam et al. 2021; Rajasekaran et al. 2020; Adhinarayanan et al. 2020; Rajesh et al. 2020; Aurtherson et al. 2021). In this work, a new filler was incorporated into the Sisal/Glass fiber namely drumstick gum powder. So,the surface roughness of 20 % volume fraction of novel drumstick gum powder filled Sisal/Glass fiber epoxy composite was compared with surface roughness of Sisal/Glass fiber epoxy composite.

MATERIALS AND METHODS

In this study, natural fiber composite plates were fabricated by using hand layup technique at Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Chennai**.** No ethical approval was needed for this present research. In this work, a control group and experimental group was taken for the study. Sisal/Glass fiber with 20 % volume fraction of novel drumstick gum powder filler was taken as an experimental group with a size of 20 sample specimens per group. Also, the Sisal/Glass fiber epoxy composite was taken as a control group with a size of 20 sample specimens. G Power calculator is the one which was used to calculate the sample size of the composites for which the mean and standard deviation values were 4.27 and 0.177. G Power is taken as 80%. (Vinayagamoorthy et al. 2019).

In this study, Sisal/Glass fiber bi-directional matte was used. Sisal fiber is a natural fiber that comes by scraping away the pulpy matter with a blunt knife. Sisal fiber has high cellulose content, high mechanical strength, high rigidity, and excellent thermal resistance. These types of Natural Fibers are biodegradable, very cost-effective, and less density as well as great chemical resistance. It was reported that the chemical properties of Sisal/Glass fiber are 67.5% cellulose, 15.6% hemicellulose, 11.9% lignin (Gad, Rahoma, and Al-Thobity 2018). Sisal/Glass fibers are used to increase the production of fiber composites and other industrial applications. Drumstick is the gum that is usually obtained from the drumstick tree which is a fragrant tree.The gum which is produced from the tree is taken and crushed into powder and was used as a filler and. The filler's size is 200 micrometers.

Composite plates were fabricated by using the hand layup technique. A mould was prepared in the size of 300×300×3 mm. In one container, the epoxy (LY556) and the hardener (HY951) were taken at a 10:1 ratio and continuously shaken for about 7-8 minutes and the resin mixture was prepared. Initially, wax was applied to the mould. The bi-directional Sisal/Glass fiber matte was placed with the size of 300 × 300 mm into the mould and the resin mixture was poured and spreaded, and the same process was carried out for three layers of fiber, using roller entrapped air was taken out from the mould. A heavy weight material was placed on the mould to increase the adhesion between matrix and fiber. Mould was allowed for 24 hours for curing and was left alone, after 24 hours the dried samples were taken away from the mould and cut the specimen with the size of 140×85×3 mm.

In an experimental group, epoxy (LY556) and hardener (HY951) with a 20% volume fraction of novel drumstick gum powder filler was taken. In one container, epoxy with hardener, and filler materials were taken and continuously stirred for about 15 minutes. Wax was applied on the mould so that the material comes out easily from the mould and a bi-directional Sisal/Glass fiber matte was placed on the mould and the resin mixture was poured and spreaded. This was the procedure that was repeated for three layers of fiber, using a roller excess mixture carried out from the mould. Mould was allowed for curing for 24 hours at room temperature. Dried samples were taken out from the mould so that the cutting should be done and cut the specimens with the size of 140×85×3 mm.

The Radial drilling machine was used to drill holes in the fabricated composite plates. Totally 20 operations were conducted for each composite. The drilling on the sample was performed with a 5 mm diameter HSS tool to make holes with a constant speed of 1000 rpm and a feed rate of 200 mm/min. The specimen was completed on the work holding device in the drilling machine. The hole was made with the help of an HSS drill tool as shown in Fig. 1. After the radial drilling operation was done, the sample was taken for the surface roughness test in the Mitutoyo surface roughness tester as shown in Fig. 2. The drilled specimen which was obtained after fabricating and radial drilling was mounted on the holding device on the Mitutoyo surface roughness tester SJ-410. The thickness of the sample specimen was manually kept in the tester.

Statistical analysis

Statistical software SPSS v.26 is the software which was used to determine the independent samples t-test and Group statistics, and the GGraph. The independent t-test analysis was performed by taking Sisal/Glass fiber, drumstick gum powder was taken as independent variables. Surface roughness was taken as the dependent variable in this test (Babu et al. 2020).

RESULTS

The surface roughness of the Natural Fiber Sisal/Glass fiber epoxy composite and Sisal/Glass fiber with 20% drumstick gum powder filler reinforced epoxy composite was determined using Mitutoyo surface roughness tester SJ-410.The test results were tabulated as shown in Table 1.

An independent sample t-test was carried out among control and experimental group results using statistical software SPSS v.26, and the results were obtained as shown in Table 2, where the mean and standard deviation of Sisal/Glass fiber epoxy composite is 4.27 µm and 0.177. The Sisal/Glass fiber with 20% filler reinforced epoxy composite, the mean and standard deviation is 3.88 µm and 0.346 µm. Table 3 of the independent t-test presents the results of Levene's test carried out to establish the equality of the means of the hypothesis formulated between the control and experimental groups.

Based on the results, it was found that significant differences between the groups were considered, as the level of significance $p = 0.010$ ($p<0.05$). From a simple bar mean graph, 20% filler reinforced epoxy composite exhibited less surface roughness than without filler epoxy composite as shown in Fig.3.

DISCUSSION

The Surface roughness of the Sisal/Glass fiber epoxy composite was exhibited in the mean value of 4.27 µm and the standard deviation of 0.177 for 20 sample specimens. Sisal/Glass fiber with 20% filler reinforced epoxy composite exhibited the average mean value of 3.88 µm, and a standard deviation of 0.346. From the independent t-test, Sisal/Glass fiber with 20% filler reinforced epoxy composites shows better significance than Sisal/Glass fiber epoxy composite $p = 0.010$ ($p<0.05$).

The surface roughness of the Sisal/Glass fiber with 20% filler reinforced composite was reduced/decreased due to the bond present between the Sisal/Glass fiber and the epoxy composite, resulting in very good surface roughness. It was observed that the type of drill bit which was used and the speed at which it is used have a physical effect on the surface roughness.

Similar work was done regarding this work by adding clam shell filler with sisal/glass fiber. 10 % volume fraction of clam shell filler incorporated in glass fiber composite showed less surface roughness (Jena and Kumar 2019). No findings were there which was contrary to this study. Speed of spindle, feed rate, diameter of drill bit, fiber nature, size of filler are the parameters that affect the mechanical properties of the natural fiber and drumstick gum powder filler reinforced composite. It was reported that mechanical properties such as tensile,flexural and impact of natural fiber reinforced polymer composites always depend on the hand layup technique which takes more time for fabrication when compared to other processes, and production efficiency is less when compared to others (Khan, Srivastava, and Gupta 2018). Therefore, hand layup technique is not suitable for bulk production. In another study, composites size is important for determining the size of delamination. If the spindle speed is increased, the surface finish of the composite will also increase, because more rotations of the spindle produce high heat and it causes the deformation of material (Zariatin 2017; Romanszki, Klébert, and Héberger 2020). The feed rate is the most important parameter that evaluates the surface roughness of a material. For a higher feed rate the spindle produces higher surface roughness, and for a lower feed rate the spindle produces lower surface roughness of the composite (Palola et al. 2021) ; (Khan, Srivastava, and Gupta 2018) is the best study among all the above mentioned studies.

Higher speed and higher feed rate affect the surface finish of the composite material.These are the few disadvantages in this study. In future, this work can be extended with the addition of various volume fractions of fiber and epoxy reinforcement.

CONCLUSION

Within the limitations of this study, it is concluded that Sisal/Glass fiber with 20% volume fraction of new novel drumstick gum powder filler reinforced epoxy composite exhibited the less surface roughness value of 3.03µm. This surface roughness value is lesser than without adding filler in Sisal/Glass fiber composite.

DECLARATIONS

Conflicts of interests

The authors of this paper declare no conflict of interest

Authors Contribution

Author MRH was involved in data collection, data analysis, manuscript writing. Author GB was involved in conceptualization, guidance, and critical review of the manuscript.

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TABLES AND FIGURES

Table 1. Surface roughness data for 20 samples (Without filler and 20% filler) in µm

Specimen No	Surface roughness of Sisal/Glass fiber without filler (µm)	Surface roughness of Sisal/Glass fiber with 20% filler (µm)
1	4.35	3.03
2	4.42	4.09
3	4.46	4.12
4	4.25	3.31
5	4.29	4.22
6	4.02	3.89
7	4.58	3.55
8	4.59	3.96
9	4.42	4.05
10	4.26	4.29
11	4.00	3.69
12	4.16	3.71
13	4.19	3.44
14	4.02	4.13
15	4.21	3.72

16	4.10	3.99
17	4.33	3.86
18	4.48	4.18
19	4.16	4.22
20	4.22	4.26

Table 2. Group statistics table represents the lowest mean value of surface roughness is 3.8855 µm found at 20% filler with a standard deviation of 0.34

Group Statistics					
	Groups	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
Surface Roughness	**Sisal/Glass fiber without filler**	20	4.2755	0.17733	0.03965
	Sisal/Glass fiber with 20% filler	20	3.8855	0.34684	0.07756

Table 3. Levene's Test for Equality of Variances and t-test for Equality of Means for contact temperature with significance value p = 0.010 (p<0.05) achieved among the considered groups

Independent Samples Test										
		Levene's Test for Equality of Variances		**t-test for Equality of Means**						
		F	**Sig.**	**t**	**df**	**Sig. (2-tailed)**	**Mean Difference**	**Std. Error Difference**	**95% Confidence Interval of the Difference**	
									Lower	**Upper**
Surface Roughness	**Equal variances assumed**	7.272	.010	4.4	38	0.000	.3900	0.08711	0.2136	0.5663
	Equal variances not assumed			4.4	28.2	0.000	.3900	0.08711	0.2116	0.5683

Fig. 1. Drilled composite Specimen

Fig. 2. Mitutoyo surface roughness test setup (SJ-410)

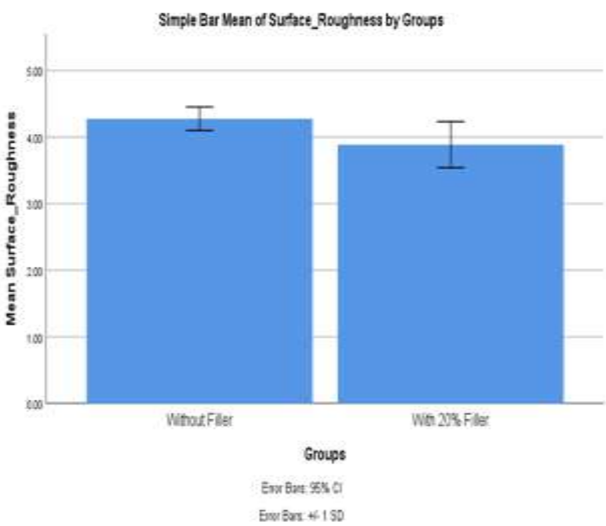

Fig. 3. Comparison of mean surface roughness of Sisal/Glass fiber without filler and Sisal/Glass fiber with 20% filler with error bars and accuracy of ±1 SD. Surface roughness of Sisal/Glass fiber with 20% filler reinforced composite shows lower surface roughness than Sisal/Glass fiber epoxy composite.