Original Article

A Comparative Analysis on Surface Roughness of Plain Epoxy Composite with Reinforcement of 10 wt% of Pista Shell Particles Novel Composite using CNC Machining

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Abstract

Aim: The objective of this paper is to investigate the surface roughness of 10% of pista shell powder reinforced epoxy composite compared to plain epoxy resin composite.
Materials and Methods: Experiment was done by forming two groups namely Group 1 (Plain Epoxy Resin composites) and Group 2 (10% of Pista shell powder reinforced epoxy composite). The sample size calculation was done using a G power calculated and pre-test power is 95%. The mean value and standard deviation are 0.5 and 0.1 for without filler and with filler was 0.2 and 0.06 respectively and 16 samples per group were taken for study. Heavy calcium carbonate is contained in the pista shell. SPSS software tool was used for statistical analysis. G power is taken as 80%.
Results: It was obtained from the results that the surface roughness of the plain epoxy resin composite was 0.443µm and for 10% of pista shell powder reinforced epoxy composite it was 0.661µm. The significance value which was obtained from the statistical value analysis was P=0.029; p<0.05 and hence there is no significant variation observed between the groups.
Conclusion: Within the limitations of the studies, it was found that the surface roughness of novel polymer composite for 10% of pista shell reinforcement epoxy composite was better than the plain epoxy resin composite by approximately 35 percent.
Keyword: Pista shell powder reinforced, CNC machining, Epoxy hardener, Plain epoxy resin, Novel polymer composite, SPSS software, Surface roughness.

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INTRODUCTION

This study is mainly about analyzing the improving surface roughness of 10% of pista shell powder reinforced epoxy composite and plain epoxy resin composite to augment surface finish (Dave, Patel, and Raval 2012). It is done by testing surface roughness on drilled operation done on the samples of 10% of pista shell reinforcement epoxy composite compared to plain epoxy resin composite and comparing its results to find the lower surface roughness value. Drilling of 10% of pista shell powder reinforced epoxy composite is done to improve the surface finish for better quality (Priya, Infanta Mary Priya, and Vinayagam 2018). Pista shell powder reinforced composite can be used for aerospace, automotive parts, roofing in automobiles, boat interiors, office products, toys and building construction materials, machinery etc. Epoxy resin composite can be used to replace non-biodegradable Novel polymer composite for constructing or manufacturing components in automobiles. Among the different shell powders utilized as filler material in polymeric pitch, it has been discovered that pistachio shell has been a less investigated region (Masooth et al. 2020)(Väisänen et al. 2016)(Masooth et al. 2020).

The total number of related articles published in the previous years in google scholar citations is 32 and in sciencedirect is 160. Also, the accessibility of pistachio shells is exceptionally high as its creation rate is enormous. It likewise has high strength, epoxy hardener and modulus properties. With such properties, a pistachio nutshell molecule can possibly be utilized in polymeric composites with many designing applications. The characterization of green composites from biobased epoxy matrices and bio-fillers derived from seashell wastes (Parameswaranpillai et al. 2021). Little work is accounted for on pistachio shell particulates as filler material. Influence of reducing parameters on surface roughness in turning glass-fiber-strengthened plastics the usage of statistical analysis (Al- Kazemi and Ali 2002). When adding pista shell powder to a novel polymer, the surface roughness of the Epoxy hardener composite improves (Das, Sarmah, and Bhattacharyya 2015). Machinability of glass fiber strengthened plastic (GFRP) composite the use of alumina-based ceramic cutting gear (Uddin et al. 2017). The best study among the above paper is the characterization of green composites from biobased epoxy matrices and bio-fillers derived from seashell wastes (Parameswaranpillai et al. 2021).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)

No research has been carried out using this novel filler in fiber composites. These pista shell powder have high calcium carbon content which in turn reduces the surface roughness of pista shell powder filled with Epoxy hardener composite. Addition of pista shell powder reinforced composite will also improve surface roughness due to strong chemical bonding (Väisänen et al. 2016). In this research comparison of two groups, pista shell powder filled epoxy composite and plain epoxy composite were investigated for its surface roughness and analyzed using the SPSS software tool.

MATERIALS AND METHODS

The fabrication was done in a central workshop and machining was done in Saveetha Industries, Institute of Mechanical Engineering, Saveetha School of Engineering, Saveetha Institute of Medical and Sciences, Chennai. Ethical approval for this project is not applicable since we are not working on human samples. Epoxy resin (LY556) was the matrix material used for fabrication of composite materials (Thomas, Hosur, and Chirayil 2019). It was purchased from a private vendor in Poonamallee, Chennai. Pista shell powder contains a high concentration of calcium carbon (Yadav, Ram, and Negi 2019). Two groups were selected for experimental investigation. Group 1 is Plain Epoxy Resin composites and Group 2 is 10% of pista shell powder reinforced epoxy composites (Palaniappan et al. 2020). Sample size is 32 (16 for each group) was calculated using g-power calculated and pre-test power is 95% mean value and standard deviation are 0.5 and 0.1 for without filler and 0.2 and 0.06 for filler respectively G-power is taken as 80% (Dave, Patel, and Raval 2012).

Group 1: The epoxy resin (LY556) and hardener (HY951) was mechanically stirred in a container for about 10 minutes in 10:1 ratio and formed into plates on mica sheet (300x300x3mm) in Fig.1 and folding by using hand layup method. The curing time for composite is 24-36 hrs.

Group 2: The fabrication of coke particles was done by mixing epoxy resin (LY556) and hardener (HY951) and stirring in a container for about 10minutes in 10:1 ratio added with 10 wt% of pista shell powder and formed into plates on mica sheet (300 x 300 x 3 mm) in Fig. 2 by using the hand layup technique. The curing time for composite is about 24-36 hrs.

The drilling was carried out in a CNC machining by varying the input parameters i.e. speed, feed and depth of cut on different levels, datas are collected of control group (Plain Epoxy Composites) for 16 samples and Epoxy 10% reinforced pista shell powder composites for 16 samples in Fig.3.

Surface roughness (Ra) values for Epoxy hardener 10% reinforced pista shell powder composites varied from 0.316 µm to 0.494 µm as shown in Fig. 5 and the values of plain epoxy composites varied from 0.520 µm to 0.795µm. The surface mitutoyo profilometer was under the Standard ISO 4287 (1997) and model number SJ420. These standards are the international standards of surface roughness and are globally accepted. After placing the specimen and the surface profilometer the machined surface is tested. The sampling length is 5, measuring speed is 0.25 mm/sec and cut off length is 2.5 mm for the tests taken in the surface profilometer. The surface roughness of each specimen is noted and values are plotted in the graph shown in Fig. 3 and Fig. 4. For with filler and without filler novel polymer composite (Palaniappan et al. 2020).

Statistical Analysis

The SPSS software was used to compare the values of plain epoxy composites, the mean surface average was plotted in Y-axis and the epoxy hardener 10% reinforced pista shell powder composite was in X-axis shown in Fig. 6. The novel polymer composite had three independent variables namely depth of cut (mm), feed (mm/rev) and speed (m/min). The surface roughness was dependent variable (Ra) in microns, (i.e) any change in independent variable the values of surface roughness was affected. These statistics were used to identify the significant parameter and its analysis was done (Gupta and Kumar 2015).

RESULTS

The CNC machining based drilling experiments are performed on experimental and control groups based on the independent input parameters as shown in Fig. 1 and Fig. 3 and their values as shown in Table 1 and the determined surface roughness value of the drilled hole are shown in Fig. 2 and Fig. 4 their values as shown in Table 2 and 3. The surface roughness of the reinforced composite is shown in Fig. 5. The comparison graph is also plotted using the SPSS software tool and its significance is analyzed as shown in Fig. 6.

In Table.1, the specimens are machined under these input parameters with different levels. In Table 2, the roughness values of 16 samples drilled on plain epoxy composites are tabulated. The values of speed (m/min), depth of cut (mm) and feed (mm/rev) are given as the input parameters and the corresponding surface roughness values are obtained from the profilometer. The least value of surface roughness is 0.520 µm when machined with plain epoxy composites during the 3th trial at a speed of 500 m/min, 0.16 mm depth of cut and 1.3 mm/rev feed rate. In Table 3,The roughness values of 16 samples machined with the 10% reinforced pista shell powder composites. The values of speed (m/min), depth of cut (mm) and feed (mm/rev) are given as the input parameters while testing and the surface roughness values are calculated accordingly. The least value of surface roughness is 0.316 µm when machined with 10% reinforced pista shell powder composites during the 9th trial at a speed of 900 m/min, 0.08 mm depth of cut and 0.5 mm/rev feed rate.

In Table 4,the T-test table shows the standard deviation value for both plain epoxy composites and 10% reinforced pista shell powder composites. In Table 5**,** an independent sample test is tabulated to find the significance of the samples machined with both the composites by finding the T-test for equality of means with its significance in 2 tailed processes. The significance value is found to be $P = 0.029$ which is higher than $p<0.05$ and hence there is no significance among the considered groups. From Fig. 6**,** the bar chart shows the comparison of the mean roughness average value of the samples machined with both plain epoxy composites and 10% reinforced pista shell powder composites. As expected the value of the surface roughness is less in the sample when drilled with the 10% reinforced pista shell powder composites than the plain epoxy composites.

DISCUSSION

By this study we compare two different types of composites in which we found that 10% reinforced pista shell powder composites give a minimum of surface roughness. Using filler filled composites, the minimum surface roughness is found to be 0.316 µm using 900 m/min of speed, 0.08 mm of depth of cut and 0.5 mm/rev of feed rate. Maximum surface roughness is registered as 0.494 µm. Using without filler composites, the minimum surface roughness was obtained as 0.520 µm with the influence of 500 m/min of speed, 0.16 mm of depth of cut and 1.3 mm/rev of feed rate.

Maximum surface roughness was registered as 0.795 µm. Test results show that 10% reinforced pista shell powder composites give lesser surface roughness when compared to plain epoxy composites. The surface roughness of the composite was significantly minimized with the usage of filler composites when it is compared to without filler composites with a significance value of 0.029 (Liu et al. 2011). Also other parameters which were influencing surface roughness are depth of cut and feed rate which is similarly stated in (Masooth et al. 2020). If feed rate and depth of cut increases then surface roughness will also increase (Sathish and Karthick 2020). Based on this it can be stated that surface roughness is improved by 35%. This is a newly reinforced composite (10% reinforced pista shell powder composites) required to get improved surface finish and lower depth of cut for this composite (Bayraktar et al. 2018). There is no opposite research analysis observed in surface roughness findings.

This study considered only 10% reinforced pista shell powder composites. In future, research work can be expanded to the volume fractions of 5wt%, 15wt%, 25wt% and 30wt% to improve surface properties of composites. The CNC machining based drilling experiments are performed on experimental and control groups based on the independent input parameters and their values.

CONCLUSION

Within the limitations of this study, the drilling studies on plain epoxy composite and 10% reinforced pista shell powder composite using HSS drill bit and the performance of these materials were evaluated based on the measured surface roughness. Outcome of these experiments show that 10% reinforced pista shell powder exhibits better surface roughness than plain epoxy composites. The results of conducted experiments show the depth of cut, feed and feed rate are the most significant factors of surface roughness.

DECLARATION

Conflict of interests

The authors declare that there is no conflict of interest.

Authors contribution

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

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TABLES AND FIGURES

Table 1. Input parameters (speed, feed, depth of cut)

Index	Factor description	Level 1	Level 2	Level 3	Level 4
A	Speed (m/min)	500	700	900	1100
B	Depth of Cut (mm)	0.08	0.12	0.16	0.2
C	Feed (mm/rev)	0.5	0.9	1.3	1.7

Table 2. shows the surface roughness values for the specimens drilled in plain epoxy composite.

Trail	Factor A	Factor B	Factor C	Speed (m/min) A	Depth of Cut (mm) B	Feed (mm/rev) C	Surface Roughness (μm)
1	1	1	1	500	0.08	0.5	0.620
2	1	2	2	500	0.12	0.9	0.684
3	1	3	3	500	0.16	1.3	0.520
4	1	4	4	500	0.2	1.7	0.710
5	2	1	2	700	0.08	0.5	0.764
6	2	2	1	700	0.12	0.9	0.554
7	2	3	4	700	0.16	1.3	0.628
8	2	4	3	700	0.2	1.7	0.746
9	3	1	3	900	0.08	0.5	0.652
10	3	2	4	900	0.12	0.9	0.795
11	3	3	1	900	0.16	1.3	0.625
12	3	4	2	900	0.2	1.7	0.525
13	4	1	4	1100	0.08	0.5	0.625
14	4	2	3	1100	0.12	0.9	0.710
15	4	3	2	1100	0.16	1.3	0.630
16	4	4	1	1100	0.2	1.7	0.790

Table 3. shows the surface roughness of the specimens drilled with pista shell powder reinforced composite.

Trail	Factor A	Factor B	Factor C	Speed (m/min) A	Depth of Cut (mm) B	Feed (mm/rev) C	surface roughness (μm)
1	1	1	1	500	0.08	0.5	0.481
2	1	2	2	500	0.12	0.9	0.470
3	1	3	3	500	0.16	1.3	0.430
4	1	4	4	500	0.2	1.7	0.474
5	2	1	2	700	0.08	0.5	0.420
6	2	2	1	700	0.12	0.9	0.417
7	2	3	4	700	0.16	1.3	0.390
8	2	4	3	700	0.2	1.7	0.480
9	3	1	3	900	0.08	0.5	0.316

10	3	2	4	900	0.12	0.9	0.464
11	3	3	1	900	0.16	1.3	0.490
12	3	4	2	900	0.2	1.7	0.376
13	4	1	4	1100	0.08	0.5	0.430
14	4	2	3	1100	0.12	0.9	0.494
15	4	3	2	1100	0.16	1.3	0.468
16	4	4	1	1100	0.2	1.7	0.490

Table 4. the mean value,standard deviation and standard error mean value.

Group Statistics					
	COMPOSITE	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
RA	WITH FILLER	16	.44313	.050038	.012510
	WITHOUT FILLER	16	.66113	.087175	.021794

Table 5. significance level of plain epoxy composite with filler and without filler particles and mean difference and standard error difference.

Independent samples test										
		Levene' Test For equality of Variances		**T-test For Equality of Means**						
		F	**sig**	**t**	**df**	**Sig 2**	**Mean difference**	**Std error difference**	**95% confidence interval of the difference**	
									lower	**upper**
RA	**Equal variances assumed**	5.259	0.29	-8.675	30	.000	-.218000	.025129	-.26932	-.166680

	Equal Variances Not assumed			-8.675	23.916	.000	-.218000	.025129	-.26987	-.166127

Fig. 1. Epoxy resin (LY556) and Hardener (HY951) mixture.

Fig. 2. Epoxy + 10wt% pista shell powder reinforcement.

Fig. 3. CNC machined Plain epoxy 16 samples drilled by 8mm drill bit.

Fig. 4. CNC machined Plain epoxy + 10% pista shell powder 16 samples drilled by 8mm drill bit.

Fig. 5. The surface roughness of plain epoxy reinforced with 10 wt% of pista shell powder particles.

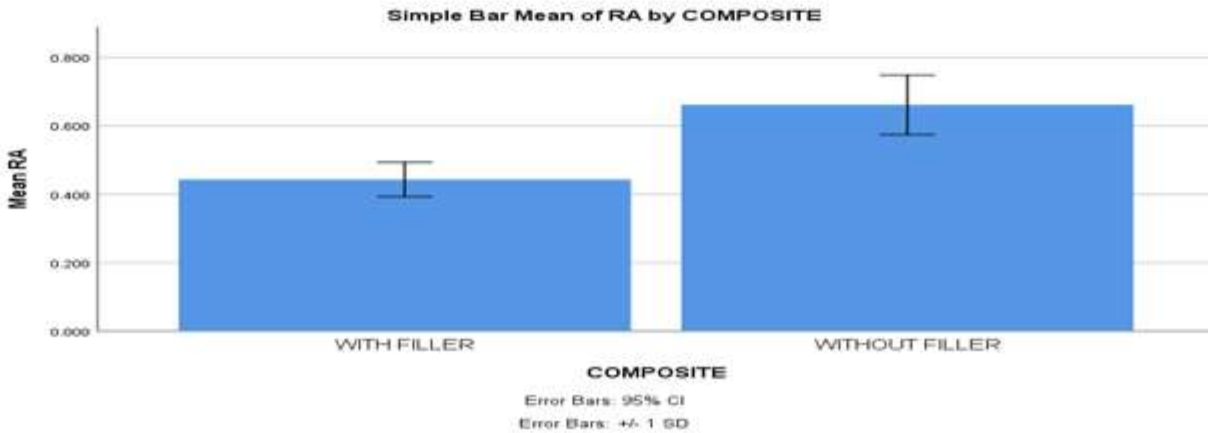

Fig. 6. Comparison of reinforced pista shell powder composites (With filler) or Plain Epoxy composites (Without filler) in terms of mean accuracy. The Mean accuracy of reinforced pista shell powder composites (With filler) better than Plain Epoxy composites (Without filler). The standard deviation of reinforced pista shell powder composite is slightly better than Plain Epoxy composites. X Axis: With VS without filler, Y Axis: Mean accuracy of detection ± 1SD.