Original Article

A Comparative analysis on Material Removal Rate of Plain Epoxy Composite with Reinforcement of 5 wt% of Egg Shell Powder particles Novel Composite using CNC Machining

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Abstract

Aim: The objective of this paper is to investigate the material removal rate of 5% egg shell powder reinforced epoxy composite compared with plain epoxy resin composite. **Materials and Methods:** Experiment was carried out for two groups namely Group 1 (Plain epoxy resin composite) and Group 2 (5% egg shell powder reinforced epoxy composite). The sample size calculation was done using a G power calculator, g-power was calculated, and pre-test power is 95%. Mean value and standard deviation are 0.3 and 0.04 respectively. 16 samples per group were taken for study. Egg shell contains calcium carbonate crystals. Eggshell contains 1% magnesium carbonate, 1% calcium phosphate, 4% organic matter, and 94% calcium carbonate. Statistical analysis was performed with the SPSS statistical tool. G power is taken as 80%. **Results:** It was inferred from the results that the material removal rate of the plain epoxy resin composite was 0.170 mm^3/min and 5% egg shell powder reinforced epoxy composite was 0.280 mm^3/min. The significance value obtained from statistical value analysis p=0.041 ($p<0.05$) and hence significant variation observed between the groups. **Conclusion:** Within the limitations of this study, it was found that the material removal rate of novel 5% egg shell powder laminated with epoxy composite was better than the plain epoxy resin composite. The analysis shows that speed and feed rate are the most important factors for material removal rate and point angle is the second most important factor.

Keywords: Plain Epoxy Resin, Egg Shell Powder Reinforced, CNC Machine, Epoxy Hardener, Novel Polymer Composite, Material Removal Rate, SPSS Software.

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INTRODUCTION

The research was about increasing material removal rate of an epoxy composite and egg shell powder reinforced epoxy novel polymer composite. Material removal rate is one of the main and important points of machine and cutter interaction when conducting the machining process. This work is mainly based on maximizing the material removal rate of egg shell powder novel polymer composite by drilling CNC machine processes ((Kamaraj, Santhanakrishnan, and Muthu 2018)). Composite materials have advantages over conventional metals and alloys due to their excellent mechanical properties, and as a result, they have wide applications in a variety of industries, like marine, aerospace and automobile industries, home applications and sports, utilities and many others ((Gupta and Kumar 2015)). Egg shell powder reinforced polymer is a composite material which has been mostly used in the automotive industry and aerospace industry due to its good performance and mechanical properties. Less weight, high specific strength, high corrosion resistance and superior fatigue strength are some of the mechanical properties of this material (Kiran et al. 2020)(Hassanien et al. 2021); (Kiran et al. 2020).

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 citation or research has been carried out using this novel filler in this composite. For the existing novel polymer composite material, the material removal rate is less, to overcome this limitation. The reinforcement of 5% egg shell powder with plain epoxy composite will help to increase the material removal rate. The major application of the composite material is fabrication of lightweight components or parts of aircrafts parts and sports car components, automobile ((C. Q. J. Singh et al. 2021).

MATERIALS AND METHODS

The fabrication was done in a central workshop and machining was done in Saveetha Industries, Department of Mechanical Engineering, Saveetha School of Engineering, Saveetha Institute of Medical and Technical 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 these composite materials. It was purchased from a private vendor in Poonamallee, Chennai. Egg shell powder and epoxy resin, epoxy hardener was purchased from Hayael aerospace India pvt. Ltd, Chennai, Tamil nadu. Two groups were taken for experimental investigation. Group 1 is Plain Epoxy Resin composites and Group 2 is 5% egg shell powder laminated epoxy composite. Sample size 32 (16 for each group) was calculated using g-power is 80% and pre-test power is 95% mean value and standard deviation are 0.3 and 0.04 for without laminated and 0.5 and 0.08 for laminated respectively. G-power is taken as 80%(Kamaraj, Santhanakrishnan, and Muthu 2018).

Group 1: The epoxy resin (LY556) and epoxy hardener (HY951) was continuously stirred in a container for about 10-15 min in 10:1 ratio respectively as shown in Fig. 1 and formed into plates on mica sheet (300x300x3mm) and folded by using hand layup method. The curing time for composite is up to 24 hours.

Group 2: The epoxy resin (LY556) and epoxy hardener (HY951) was continuously stirred in a container for about 10-15 min in 10:1 ratio respectively and then add 5 wt % of egg shell powder in that mixture and start stirring it again for proper composition then form it into plates on mica sheet (300x300x3mm) in Fig. 2 and folding by using hand layup method. The curing time for composite is upto 24 hours. The method involved for the entire process was called the Hand lay-up method.

The drilling was done in a CNC machine by varying of input parameters i.e. speed, feed rate and depth of cut on various levels, datas are collected of control group (Plain Epoxy Composites) for 16 samples and 5% egg shell powder laminated epoxy composite for 16 samples by 8mm drill bit as shown in Fig. 3 and Fig. 4. Material removal rate (MRR) values for 5% egg shell powder laminated epoxy composite varied from 0.220 mm^3/min to 0.280 mm^3/min and the values of Plain Epoxy Composites varied from 0.170 mm^3/min to 0.120 mm^3/min. Data was collected in the inhouse research facilities of radial drilling of type YCM – EV 1020A.

The Spindle Speed of the machine was 45~1000 rpm, Spindle nose Taper BT40, Spindle Motor (Std.) (cont./15min) 5.5 / 7.5 kW. CNC machined in specific contour millied specimens with both tools i.e plain epoxy and egg shell powder laminated polymer are measured in terms of weight before and after machining and Material Removal Rate was evaluated for all specimens by dividing difference between before machining and after machining with density of the composite by time taken for machining that particular specimen in mm^3/min (Thakre, Singh, and Slipher 2018). Cutting of the plates was done with bosch GDC 120, marble cutter which has tungsten carbide tip and wood circular saw blade. The speed of the cutting machine is 1300rpm and weight is 2.5 kg, 10mm diameter. The next process is analysis of the material with SPSS software (Sonparote and Lakkad 1982).

Statistical Analysis

The SPSS software was used to compare the values of plain epoxy composites with epoxy hardener, the mean surface average was plotted in Y-axis and The 5% egg shell powder laminated epoxy composite was in X-axis. The composite had three independent variables namely depth of cut (mm), feed rate(mm/rev) and speed (m/min). The material removal rate was dependent variable (mrr) 4 of 13 in microns, (i.e) any change in independent variable the values of material removal rate was affected. These statistics were used to identify the significant parameter and its analysis was done (Landau 2017).

RESULTS

The CNC based drilling experiments are performed on an experiment as shown in Fig. 3 and Fig. 4. The drilling of control groups based on the independent input parameters and their values as shown in Table 1 and the determined material removal rate value of the drilled hole are shown in Table 2 and Table 3. The comparison graph is also plotted using the SPSS software and its significance is analyzed as shown in Fig. 5.

In Table.1, the specimens are machined under these input parameters with different levels. In Table 2, the material removal rate values of 16 samples drilled on plain epoxy composites are tabulated. The values of speed (m/min), depth of cut (mm) and feed rate (mm/rev) are given as the input parameters and the corresponding material removal rate values are obtained by dividing the difference between before machining and after machining with density of material multiplied by machining time. The least value of material removal rate is 0.130 mm^3/min when

machined with plain epoxy composites during the 13th trial at a speed of 1100 m/min, 0.16 mm depth of cut and 1.3 mm/rev feed rate. In Table 3, The material removal values of 16 samples machined with the 5% egg shell powder laminated epoxy composite. The values of speed(m/min), depth of cut(mm) and feed rate (mm/rev) are given as the input parameters while testing and the material removal rate values are calculated accordingly. The least value of material removal rate is 0.220 mm^3/min when machined with egg shell powder laminated epoxy composite during the 6th trial at a speed of 700 m/min, 0.12 mm depth of cut and 0.9 mm/rev feed rate.
In Table 4, the T-test table shows the standard deviation value for both plain epoxy composites and glass fiber laminated epoxy composite. 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 $p=0.041$ which is lower than $p<0.05$ and hence there is significance among the considered groups. From Fig. 5**,** the bar chart shows the comparison of the mean material removal average value of the samples machined with both plain epoxy composites and 5% egg shell powder laminated epoxy composite. As expected the value of the material removal rate is less in the sample when drilled with the 5% egg shell powder laminated epoxy composite than the plain epoxy composites.

DISCUSSION

By this study we compare two different types of composites in which we found that 5% egg shell powder laminated epoxy composites gives a maximum material removal rate. Using egg shell powder laminated composites, the maximum material removal rate is found to be 0.280 mm^3/min using 700 m/min of speed, 0.16 mm of depth of cut and 1.3 mm/rev of feed rate.
Minimum material removal rate is registered as 0.220 mm^3/min (Jawaid, Thariq, and Saba 2018). Using plain epoxy composites, the maximum material removal rate was obtained as 0.170 mm^3/min with the influence of 700 m/min of speed, 0.12 mm of depth of cut and 0.9 mm/rev of feed rate. Minimum material removal rate was registered as 0.130 mm^3/min. Test results show that 5% egg shell powder laminated epoxy composite gives more material removal rate when compared to plain epoxy composites(Simpson, Aryee, and Toldrá 2019). The material removal rate of the composite was significantly increased with the usage of reinforced composites when it is compared to without reinforced composites with a significance value of $p=0.041$. Also, other parameters which were influencing material removal rate 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 material removal rate will automatically decrease(Tripathi et al. 2020). Based on this it can be stated that material removal rate has improved by 44.5%. This is a newly reinforced composite (5% egg shell powder laminated epoxy composite) required to get improved material removal and lower depth of cut for this composite. There is no opposite research analysis observed in material removal rate findings (Simpson, Aryee, and Toldrá 2019).
During the sample preparation, the development of air bubbles and lumps are observed as the drawbacks which inturn hinders the proper machining of the composite, which is considered as the limitations in this work. This arises the need for developing new or improvising the existing technique. Thus the future scope of this investigation is to develop or improvise a method that could overcome the hurdles and this material will be useful to manufacture ceiling fan blades and research work can be expanded to the volume fractions of 10 wt%, 20 wt%, 25 wt% and 30 wt% to improve surface properties of composites.

CONCLUSION

Within the limitations of old novel polymer composite study, drilling studies on plain epoxy composite and 5% egg shell powder laminated epoxy composite using HSS drill bit and the performance of these materials were evaluated based on the measured material removal rate. The application of these composite materials are to aerospace industries, aircrafts and sports vehicles. Outcome of these experiments show that 5% egg shell powder laminated epoxy composite exhibit better material removal rate than plain epoxy composites. The results of conducted experiments show the depth of cut, speed and feed rate are the most significant factors of material removal rate. The respective analysis report from the SPSS software.

DECLARATION

Conflict of Interest
The authors declare that there is no conflict of interest.

Authors contribution
Author MS was involved in data collection, data analysis, and 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. Material removal rate 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	Material removal rate(mm^3/min)
1	1	1	1	500	0.08	0.5	0.160
2	1	2	2	500	0.12	0.9	0.150
3	1	3	3	500	0.16	1.3	0.160
4	1	4	4	500	0.2	1.7	0.150
5	2	1	2	700	0.08	0.5	0.160
6	2	2	1	700	0.12	0.9	0.170
7	2	3	4	700	0.16	1.3	0.160
8	2	4	3	700	0.2	1.7	0.160
9	3	1	3	900	0.08	0.5	0.150
10	3	2	4	900	0.12	0.9	0.150
11	3	3	1	900	0.16	1.3	0.140
12	3	4	2	900	0.2	1.7	0.150
13	4	1	4	1100	0.08	0.5	0.170
14	4	2	3	1100	0.12	0.9	0.160
15	4	3	2	1100	0.16	1.3	0.130
16	4	4	1	1100	0.2	1.7	0.140

Table 3. Material removal rate of the specimens drilled with egg shell powder laminated composite.

Trail	Factor A	Factor B	Factor C	Speed (m/min) A	Depth of Cut (mm) B	Feed (mm/rev) C	Material removal rate (mm^3/min)

1	1	1	1	500	0.08	0.5	0.250
2	1	2	2	500	0.12	0.9	0.270
3	1	3	3	500	0.16	1.3	0.240
4	1	4	4	500	0.2	1.7	0.240
5	2	1	2	700	0.08	0.5	0.230
6	2	2	1	700	0.12	0.9	0.220
7	2	3	4	700	0.16	1.3	0.280
8	2	4	3	700	0.2	1.7	0.230
9	3	1	3	900	0.08	0.5	0.240
10	3	2	4	900	0.12	0.9	0.250
11	3	3	1	900	0.16	1.3	0.230
12	3	4	2	900	0.2	1.7	0.240
13	4	1	4	1100	0.08	0.5	0.220
14	4	2	3	1100	0.12	0.9	0.270
15	4	3	2	1100	0.16	1.3	0.250
16	4	4	1	1100	0.2	1.7	0.270

Table 4. The Mean, Standard deviation and Standard error mean values for both plain epoxy composites (without filler) and egg shell powder laminated epoxy composite (with filler) are obtained for 16 sample data sets. Egg shell powder laminated epoxy composite (with filler) has better performance than plain epoxy composites (without filler).

Group Statistic					
	Polymer	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
MRR	Without filler	16	.24563	.018608	.004652
	With filler	16	.15375	.010878	.002720

Table 5. Independent sample T-test t is performed for the two groups for significance and standard error determination. P value is less than 0.05 and it is considered to be statistically significant.

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**

MRR	**Equal variances assumed**	4.563	0.04	17.05	30	.000	.091875	.005389	.080870	.102880
	Equal Variances Not assumed			17.05	24.18	.000	.091875	.005389	.080758	.102992

Fig. 1. Plain epoxy & hardener(10:1) mixture formed into plates on mica sheet (300x300x3mm) and folded by hand layup method.

Fig. 2. Plain epoxy & hardener(10:1) with 5% egg shell powder mixture formed into plates on mica sheet (300x300x3mm) and folded by hand layup method.

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

Fig. 4. CNC machined Plain epoxy + 5% egg shell powder 16 samples drilled by 8mm drill bit.

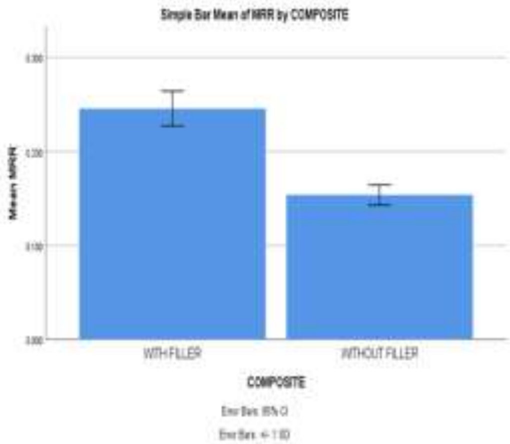

Fig. 5. Comparison of reinforced egg shell powder composites (With filler) or Plain Epoxy composites (Without filler) in terms of mean accuracy. The Mean accuracy of reinforced egg shell powder composites (With filler) better than Plain Epoxy composites (Without filler). The standard deviation of reinforced egg shell powder composite is slightly better than Plain Epoxy composites. X Axis: With VS without filler, Y Axis: Mean accuracy of detection ± 1 SD.