

# A Comparative Analysis on Material Removal Rate of Plain Epoxy Composite with Reinforcement of 15 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 15% 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 (15% 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 and 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 0.180 mm<sup>3</sup>/min and 15% egg shell powder reinforced epoxy composite was 0.290 mm<sup>3</sup>/min. The significance value obtained from statistical value analysis p=0.010 (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 15% egg shell powder reinforced 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 drilling CNC machine process ((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 are widely used in a variety of industries, like marine, aerospace and automobile industries, home applications and sports, utilities and many others ((Gupta and Kumar 2015)). Eggshells contain mainly calcium and little amounts of other elements like magnesium, sodium, phosphorus, boron and carbon. 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 (Simpson, Aryee, and Toldrá 2019)(Hassanien et al. 2021); (Simpson, Aryee, and Toldrá 2019). 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; S. 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 composite material the metal removal rate is less, to overcome the limitation of the reinforcement of 15% egg shell powder reinforcement with plain epoxy composite. The major application of the composite material is fabrication of lightweight components or parts of aircrafts parts and sports car components, automobile.

## 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 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 selected for experimental investigation. Group 1 is Plain Epoxy Resin composites and Group 2 is 15% egg shell powder reinforced epoxy composite. 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 0.3 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 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 epoxy resin (LY556) and hardener (HY951) was mechanically stirred in a container for about 10 minutes in 10:1 ratio and then add 15 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 24-36 hrs. The method involved for the entire process was called the Hand lay-up method.

The drilling was carried out in a CNC machine by varying of input parameters i.e. speed, feed rate and depth of cut on different levels, data are collected of control group (Plain Epoxy Composites) for 16 samples and 15% 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 15% egg shell powder laminated epoxy composite varied from 0.290 mm<sup>3</sup>/min to 0.230 mm<sup>3</sup>/min and the values of Plain Epoxy Composites varied from 0.180 mm<sup>3</sup>/min to 0.140 mm<sup>3</sup>/min.

Data was obtained by the inhouse research facilities of radial drilling of type YCM – EV 1020A used. The Spindle Speed 45 ~ 1000 RPM, Spindle Nose Taper BT40, Spindle Motor (Std.) (cont./15min) 5.5 / 7.5 kW. CNC machined in specific contour milled specimens with both tools i.e plain epoxy and egg shell powder reinforced 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<sup>3</sup>/min. 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 1200rpm and weight is 2.5 kg, 10mm diameter (Stadelman, Newkirk, and Newby 2017).

### 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 15% 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 experiments 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 3. The comparison graph is also plotted using the SPSS tool and its significance is analyzed as on 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 0.140 mm<sup>3</sup>/min when machined with plain epoxy composites during the 15th trial at a speed of 1100m/min, 0.16mm depth of cut and

1.3mm/rev feed rate. In Table 3, The material removal values of 16 samples machined with the 15% 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 0.230 mm<sup>3</sup>/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  $p=0.010$  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 15% egg shell powder laminated epoxy composite. As expected the value of the material removal rate is less in the sample when drilled with the 15% 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 15% egg shell powder laminated epoxy composites gives a maximum material removal rate (Deo and Acharya 2010). Using egg shell powder laminated composites, the maximum material removal rate is found to be 0.290 mm<sup>3</sup>/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 0.230 mm<sup>3</sup>/min (Stadelman, Newkirk, and Newby 2017). Using plain epoxy composites, the maximum material removal rate was obtained as 0.180 mm<sup>3</sup>/min with the influence of 700 m/min of speed, 0.12 mm of depth of cut and 0.9mm/rev of feed rate. Minimum material removal rate was registered as 0.140 mm<sup>3</sup>/min (Tripathi et al. 2020). Test results show that 15% egg shell powder laminated epoxy composite gives more material removal rate when compared to plain epoxy composites (Stadelman, Newkirk, and Newby 2017; Jawaid, Thariq, and Saba 2018). The material removal rate of the composite was significantly maximized with the usage of laminated composites when it is compared to without laminated composites with a significance value of 0.010. Also, other parameters which were influencing material removal rate are depth of cut and feed rate which is similarly stated in (B. S. Kumar et al. 2016). If feed rate and depth of cut increases then material removal rate will decrease. Based on this it can be stated that material removal rate has improved by 44.15%. This is a newly laminated composite (15% 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. 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 (T. Rajasekaran et al. 2010).

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 this study, drilling studies on plain epoxy composite and 15% 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. Outcome of these experiments show that 15% 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.

### 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 <sup>3</sup> /min)
1	1	1	1	500	0.08	0.5	0.170
2	1	2	2	500	0.12	0.9	0.160
3	1	3	3	500	0.16	1.3	0.170
4	1	4	4	500	0.2	1.7	0.160
5	2	1	2	700	0.08	0.5	0.170
6	2	2	1	700	0.12	0.9	0.180
7	2	3	4	700	0.16	1.3	0.170
8	2	4	3	700	0.2	1.7	0.170
9	3	1	3	900	0.08	0.5	0.160
10	3	2	4	900	0.12	0.9	0.160
11	3	3	1	900	0.16	1.3	0.150
12	3	4	2	900	0.2	1.7	0.160
13	4	1	4	1100	0.08	0.5	0.180
14	4	2	3	1100	0.12	0.9	0.170
15	4	3	2	1100	0.16	1.3	0.140
16	4	4	1	1100	0.2	1.7	0.150

**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 <sup>3</sup> /min)
1	1	1	1	500	0.08	0.5	0.270
2	1	2	2	500	0.12	0.9	0.280
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	0.240
6	2	2	1	700	0.12	0.9	0.230
7	2	3	4	700	0.16	1.3	0.290
8	2	4	3	700	0.2	1.7	0.250
9	3	1	3	900	0.08	0.5	0.260
10	3	2	4	900	0.12	0.9	0.270
11	3	3	1	900	0.16	1.3	0.250
12	3	4	2	900	0.2	1.7	0.250
13	4	1	4	1100	0.08	0.5	0.240
14	4	2	3	1100	0.12	0.9	0.280
15	4	3	2	1100	0.16	1.3	0.270
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	.25813	.017970	.004492
	With filler	16	.16375	.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

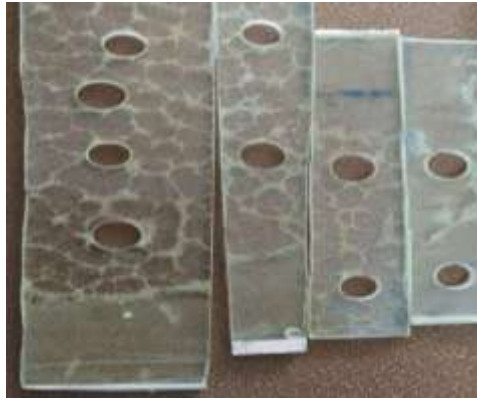
MRR	Equal variances assumed	7.626	0.01	17.97	30	.000	.094375	.005251	.083650	.105100
	Equal Variances Not assumed			17.97	24.69	.000	.094375	.005251	.083553	.105197



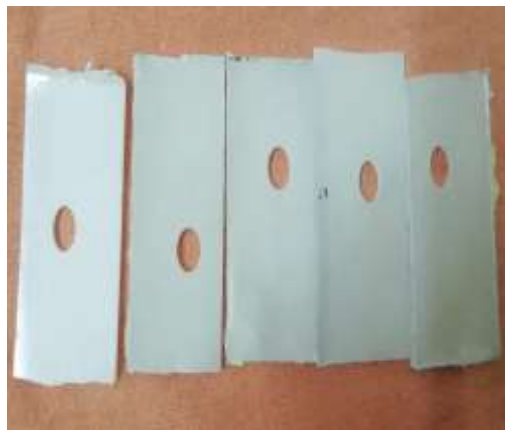
**Fig. 1.** Plain epoxy & epoxy hardener(10:1) mixture formed into plates on mica sheet (300x300x3mm) and folded by hand layup method.



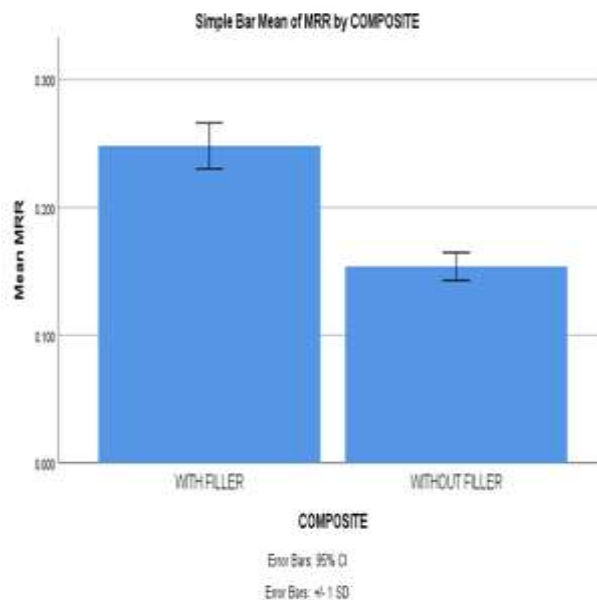
**Fig. 2.** Plain epoxy & hardener(10:1) 15% egg shell powder preparation mixture formed into plates on mica sheet (300x300x3mm) and folded by hand layup method.



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



**Fig. 4.** CNC machined Plain epoxy + 15% 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  $\pm 1$  SD.