Investigation on Material Removal Rate in CNC drilling operation on Hybrid epoxy Composite with and without the reinforcement of Natural Fibre (5%) and Aluminium Oxide Particle (5%)

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ABSTRACT

Aim: The motive of this research is to investigate MRR during CNC drilling of natural fibre (5%) and nano aluminium oxide particles (5%) reinforced novel hybrid epoxy composites and comparison with plain epoxy. **Materials and Methods:** The samples of both the groups were fabricated using a hand-layup technique. For Group 1, combinations of sisal fiber, nano aluminium oxide particles and plain epoxy were used, whereas in Group 2, only plain epoxy was used. The samples were prepared as per standards and drilling is performed using a vertical CNC machine. The MRR (material removal rate) of the samples were investigated and compared between the groups by performing 9 experiments (along with one repetition) per group, in total 18 per group. The number of samples were selected with g power of 80%.**Results:** T- independent tests were performed using SPSS statistical software tool to investigate the material removal rate. From the results of material removal rate, Group-1 comprising epoxy (75 wt. %)/Sisal fibre (5 wt. %)/ nano aluminium oxide particles (5 wt.%) exhibited an average of 0.4466 mm^3/sec, Group-2 comprising plain epoxy exhibited an average 0.1551 mm^3/sec. Based on T-test statistical analysis, it is found that there is a significant p=0.001 ($p<0.05$) difference in the mean variance of MRR between Group 1 and Group 2.**Conclusion:** Within the limitations of this study, it is clearly understood that the inclusion of reinforcements like Sisal fiber and nano aluminium oxide particles have significant influence on the improvement in MRR.

Keywords: Novel hybrid epoxy composites, CNC drilling, Epoxy, Natural fiber, Sisal fiber, Nano Aluminium oxide particles, Material Removal Rate.

INTRODUCTION

This research is to compare the MRR (Material removal rate) of epoxy (75% wt)/Sisal fiber (5% wt)/ nano aluminium oxide particles (5% wt) and plain epoxy . Because of their high strength and reliable characteristics, synthetic or natural reinforced composites have a huge range of applications in many fields. To minimise the use of synthetic fibres, natural fibres are used. Natural fibre composites possess good mechanical characteristics with lower density when compared to conventional fibres. Natural fiber reinforced outperforms conventional FRPs in terms of strength to weight ratio . The applications are vital in various fields like aerospace, marine, automotive and construction industries.

Based on the past 5 years of research and literature related to the polymer composites, it is found to be around 1800 papers in Google Scholar and around 2450 papers in ScienceDirect. The significant influence of CNC drilling parameters like speed (rpm), feed (rev/sec) and diameter of the drill (mm) on output parameters, that is material removal rate of composite, have been discussed . In a work, optimal conditions for achieving higher material removal rate followed by ideal parameters of drilling are discussed . The effect of epoxy to hardener ratio, temperature condition for curing and percentage of fiber over the MRR of epoxy with Sisal fiber reinforced composites has been investigated. The significant influence of feed rate, chisel edge width and point angle over the MRR of Sisal fiber reinforced composite has been studied . The work on investigation on the influence of speed, temperature and fibre over the material removal rate of epoxy based composite is considered one among the best literature .Previously our team has a rich experience in working on various research projects across multiple disciplines(Paramasivam and Vijayashree Priyadhar...; Rajesh et al. 2020; Gurusami et al. 2020; Prevalence of tooth loss among chroni...)

Sisal fiber is naturally available fiber and it is observed that very limited research has been carried out on composites using Sisal fiber. In this research, the effect of drilling parameters on material removal rate for epoxy reinforced with sisal fiber and nano aluminium oxide particles in comparison with plain epoxy were studied.

MATERIALS AND METHODS

The preparation of samples and CNC drilling of the samples as per design were carried out at Institute of Mechanical Engineering, Saveetha industries, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Thandalam, Chennai. In this investigation, 2 groups were considered, one is an experimental group and another control group. Novel hybrid epoxy composites comprising epoxy (75 wt%)/Sisal fiber (5 wt%)/nano aluminium oxide particles (5 wt%) is considered as an experimental group, whereas Plain epoxy is considered as a control group (Tang et al. 2018). Drilling were carried out based on Taguchi's L9 Orthogonal Array (OA) with one repetition per group and accordingly 18 experiments were carried out in each sample/group, and pretest power was calculated as 80% (Lihua, 2017; Singh et al. 2016).

Group 1 sample is prepared with the combination of sisal fibre mat is applied in two layers until the desired thickness is achieved, along the epoxy hardener and nano aluminium oxide particles. Similarly appropriate weights are placed on top setup and waited for 72 hours.

For preparing group 2 sample plain epoxy, apply the wax on 4 sides of the wooden box (mould). Traditional hand layup technique is used to prepare the sample with a mix of Epoxy (LY556) and the hardener (HY951) in a 10:1 ratio. Care should be taken to prevent bubble formation during the stirring process. This mixture is carefully poured into a mold box of 300×300 mm with a 5 mm depth.

Proper weights are placed over the setup and left undisturbed for nearly 72 hours to get composite with favourable characteristics.

VMC (Vertical machining centre), model name / number TCP- V- 500 axis, drilling capacity tool 40 mm, spindle speed range 15000 rpm over all dimensions (L×W×H) 2800 × 1900 × 2350 mm, controller siemens is used for drilling the composites. Testing procedure consists of drilling the samples with the drill bits to attain a circular cross-section holes as per the design of experiments.

The data from the VMC machine which shows in the FANUC is drilling time. Volume of the cut is found using the formula $3.14 \times r^2 \times h$, where 'r' is the radius of the hole and 'h' is the height of the hole, which in this case is the thickness of the plate. Material removal rate (MRR) is found using the ratio of volume with respect to time, after drilling.

Statistical Analysis

T-test is performed on the material removal rate (MRR) observations obtained for the samples under study using SPSS statistical tool. Accordingly the Material removal rate (MRR) is the dependent variable and the percentage of reinforcement, speed, feed rate and drill diameter are considered as independent variables.

RESULTS

CNC drilling on samples comprising group 1 (fiber reinforced epoxy) and group 2 (plain epoxy) are done with the consideration of speed (rpm), feed (rev/sec) and drill diameter (mm) at three levels as shown in Table 1. The corresponding MRR values are presented in Table 2. As per the independent t test analysis, Table 3 represents the group statistics, which comprises number of samples per group, mean MRR of the group, standard deviation and standard error. Whereas, Table 4 represents the independent t test results with equality of averages or means along with the Levene's test (i.e. in alliance with $P<0.001$).

CNC drilled samples for group 1 (fiber reinforced epoxy) is presented in Fig. 2 and group 2 (plain epoxy) is presented in Fig. 1, whereas the G graph for material removal rate (MRR) in mm^3/sec is shown in Fig. 3, which is plotted based on mean accuracy of detection with 95% CI.

DISCUSSION

A critical improvement in the MRR was found due to the addition of reinforcements in epoxy. From the group statistical results (Table 3), it is found that the mean MRR of fibre reinforced epoxy and plain Epoxy are0.4466 mm^3/sec and 0.1551 mm^3/sec respectively. Table 4 assists with comprehension of independent sample of T-test with equality of means. P value is found less than 0.05 which is 0.001 in Levene's test indicating the existence of significant and considerable difference in the variance of the MRR among the groups under investigation. Hence the alternate hypothesis of unequal variance is found appropriate. The negative t value indicates that the mean/average MRR of the composites of fiber reinforced epoxy (Group 1) is higher than that of plain epoxy (Group 2).

Comparative and unique works are identified with this investigation. Researchers have proposed a paper with different samples on which CNC drilling is performed and their weight % reinforcement variation according to the

process (Bajpai and Singh 2013; Thyer 2014). Another research has identified the unique mechanisms for the CNC drilling process (Rogoziński et al. 2015). The end results show significant differences between fibre reinforced epoxy and plain epoxy. Among the investigation, fiber reinforced epoxy is found to have better performance than plain epoxy. Works have been completed with the reinforcement materials like nano aluminium oxide particles and sisal fiber that show significant improvement in the results for different drilling conditions (Wang et al. 2013). Researchers have additionally proposed a work on nano aluminium oxide particles and sisal fiber with mechanical properties to augment the characteristics, which is found to be in fair agreement with this investigation with no significant contradictions.

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.

CONCLUSION

Within the limitations of this study, the experimental investigation on Material removal rate (MRR) during CNC drilling of epoxy based novel fiber reinforced epoxy comprising sisal fiber (5 wt.%) and nano aluminium oxide particles (5 wt.%) and plain epoxy. The mean MRR of fiber reinforced epoxy (0.4466 mm^3/sec) is 0.2915 mm^3/sec greater than that of the plain epoxy (0.1551 mm^3/sec). According to the T-test statistical analysis on the MRR of the plain epoxy and EGBC, significant difference in the mean/average MRR is observed between the material groups ($t_{23.00}$ = 5.447, P=0.001). This study concluded that epoxy based composites with natural fiber reinforcement that is sisal fiber mat and nano aluminium oxide particles exhibits better MRR when compared to plain epoxy.

DECLARATION

Conflict of interests

The authors of this research declare no conflict of interest.

Authors Contribution

Author ARVA was involved in data collection, data analysis and manuscript writing. Author DSK was involved in conceptualization, data validation and critical review of the manuscript.

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TABLES AND FIGURES

Table 1. Input parameters and their levels for CNC drilling

Parameters	Levels		
	L1	L2	L3
Speed (rpm)	100	160	220
Feed (rev/min)	0.10	0.15	0.20
Drill diameter (mm)	2	3	4

Table 2. Material removal rate of group 1 and group 2.

S. No.	Parameters			Group 1	Group 2
	Speed (rpm)	Feed (rev/min)	Drill dia (mm)	MRR (mm^3/ sec)	MRR, (mm^3/sec)
1	100	0.10	2	0.116	0.028
2	100	0.15	3	0.273	0.118
3	100	0.20	4	0.573	0.241
4	160	0.10	3	0.300	0.101
5	160	0.15	4	0.666	0.248
6	160	0.20	2	0.445	0.161
7	220	0.10	4	0.696	0.242
8	220	0.15	2	0.281	0.026
9	220	0,20	3	0.685	0.239
10	100	0.10	2	0.113	0.027
11	100	0.15	3	0.271	0.116
12	100	0.20	4	0.569	0.240
13	160	0,10	3	0.297	0.099
14	160	0.15	4	0.662	0.246

15	160	0.20	2	0.442	0.158
16	220	0.10	4	0.693	0.240
17	220	0.15	2	0.277	0.025
18	220	0.20	3	0.680	0.237

Table 3. Group statistics on MRR (mm^3/sec) values for the groups

GROUP		**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
MRR (mm^3/ sec)	Fibre Reinforced Epoxy (Group 1)	18	0.4466	0.20883	0.04922
	Plain Epoxy (Group-2)	18	0.1551	0.08917	0.02102

Table 4. Independent sample of t-test for equality of means of the MRR (mm^3/sec) values for the Group

		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**
MRR (mm^3/s)	Equal variances assumed	21.11	0.001	5.447	34	0.001	0.29150	0.05352	0.18273	0.40027
	Equal variances not assumed			5.447	23.00	0.001	0.29150	0.05352	0.18078	0.40222

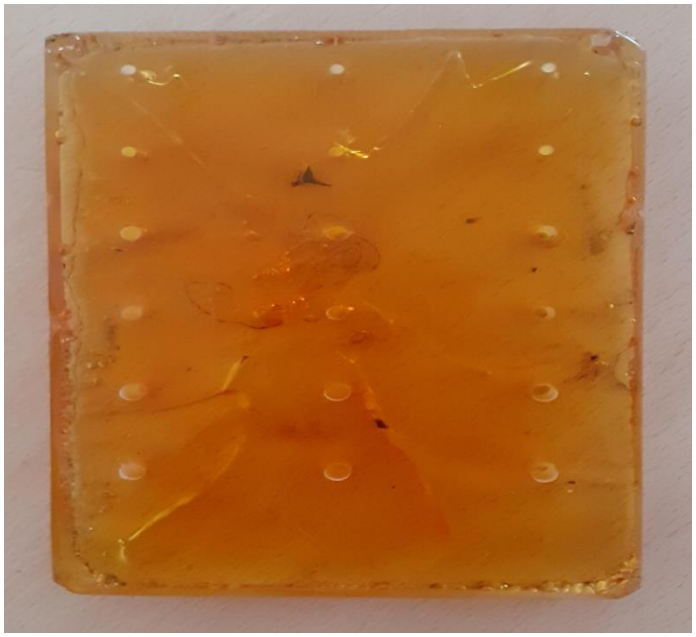

Fig. 1.CNC drilling onplain epoxy (Group 2)

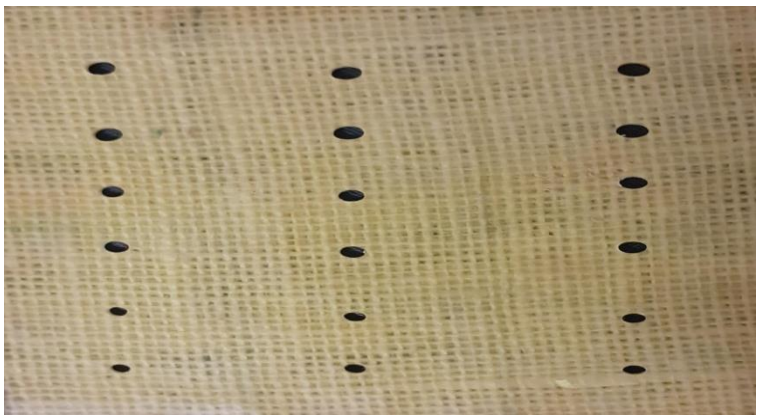

Fig. 2.CNC drilling on fiber reinforced epoxy (Group 1)

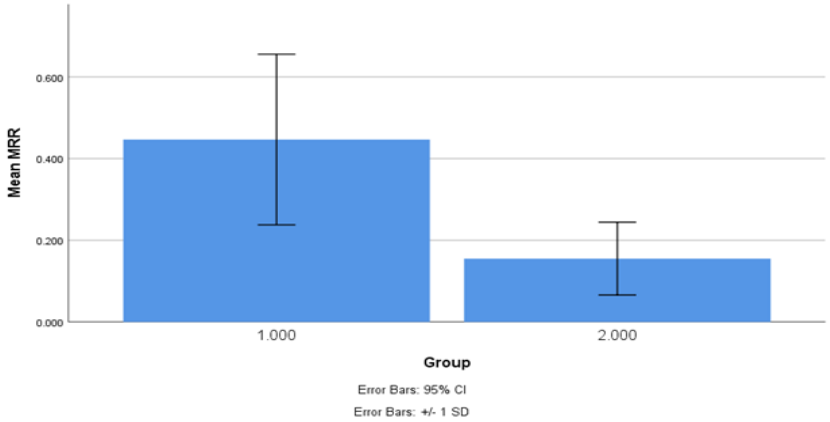

Fig. 3. Graphical representation of MRR (mm^3/sec) for Group-1 (Epoxy (75%), Sisal fiber (5%), nano aluminium oxide particles (5%)) and Group-2 (Plain Epoxy), X axis: Material groups, Y axis: MRR (mm^3/sec) with Mean accuracy of detection 95% CI and +/-1 SD.