Innovative hybrid epoxy composites reinforced with natural fiber (5%) and nano carbon particles (5%) were experimentally examined for MRR during CNC drilling and contrasted with plain epoxy.

B. Revanth Kumar Reddy[1], D. Satish Kumar[2*]

[1]Research Scholar, Saveetha School of Engineering,Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamil Nadu, India. Pincode: 602105.

[2*]Associate Professor, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamil Nadu. India. Pincode: 602105.

ABSTRACT

Aim: To examine and find the material removal rate (MRR) of CNC drilled epoxy based novel mixture epoxy composite built up with sisal fiber, nano carbon particles. **Materials and Methods:**There are two groups of samples used considered in this research work. In group 1 (sisal in fiber form (5wt%), nano carbon particles (5wt%) reinforced novel hybrid epoxy composites) and in group 2 (plain epoxy).The samples of both the groups under investigation were fabricated using a hand-layup method. Samples were ready according to guidelines and drilling is performed using a CNC drilling machine. The material removal rate of the samples was investigated and analyzed between the groups by performing 9 examinations (along with one repetition) per group, in total 18 per group.The pre-test power for testing was 80%, Alpha=0.05% and CL was 95%, G power test was used to fix the number of samples for each group. **Results:** Independent tests were performed using SPSS statistical software tools to investigate the rate of material removal. From the rate of material removal results, Group-1 comprises sisal fiber (5%), Nano Carbon Particles (5%) and plain epoxy whereas Group-2 comprises plain epoxy. Based on T-test statistical analysis, it is discovered that there exist a significant ($P=0.0001$, $P<0.05$) difference in mean fluctuation of MRR between Group-1 and Group-2. **Conclusion:** Within the limitations of this study, it is clearly understood that the addition of reinforcements like sisal fiber and nano carbon particles have a critical impact on the improvement in MRR.

Keywords:CNC drilling, Epoxy, Sisal fiber, Nano Carbon particles, Material Removal Rate, Novel hybrid epoxy composite.

INTRODUCTION

This research paper is planned to compare the MRR (Material removal rate) of composite material consisting of sisal fiber (5%), nano carbon particles (5%) and novel hybrid epoxy composites with plain epoxy (Joshi et al. 2019). On account of their high strength and dependable characteristics, synthetic or natural fiber reinforced composite has a more scope of applications in many fields [Citation error]. To restrict the use of synthetic made fibers, natural fibers are used. Natural fiber composites possess good mechanical characteristics with lower thickness when compared to conventional fibers. Natural fiber reinforced outperforms conventional FRPs in terms of strength to weight ratio (Atmakuri et al. 2021). Applications are widened

indispensable in various fields like aerospace, marine, automotive and construction industries (Rajak et al. 2019).

By considering the last 5 year papers, research related to hybrid epoxy polymer composites is found to be around 1450 papers in Google Scholar and around 1780 papers in ScienceDirect. The agglomeration between the reinforcement fiber and matrix material in composite is given more attention to get enhanced properties (Rajaraman, Agasti, and Jenarthanan 2020). The making of holes in composite materials is unavoidable in many applications. The significant influence of parameters (speed, feed and drill point geometry) are considered as input process parameters (Paluvai, Mohanty, and Nayak 2017). In a work, optimal conditions for achieving higher material removal rate drilling parameters are discussed (Bukhari, Kandasamy, and Manzoor Hussain 2017). The impact of epoxy to hardener proportion, temperature condition for restoring and level of fiber over the MRR of epoxy with sisal fiber included epoxy composites has been studied (Paluvai, Mohanty, and Nayak 2017). The significant influence of feed rate, speed, drill diameter over the MRR of sisal in fiber and nano carbon particles included in hybrid epoxy composite have been studied (Meeuw et al. 2019). The work on investigation on the influence of speed, temperature and fiber over the material removal rate of epoxy based composite is considered one among the best literature [Citation error].Previously our team has a rich experience in working on various research projects across multiple disciplines(Sathish et al. 2020; Arivazhagan et al. 2020; Pandurangan, Veeraiyan, and Nesappan 2020; Saravanan et al. 2021)Our team has extensive knowledge and research experience that has translate into high quality publications(Venkat Jayanth et al. 2020; Sathish et al. 2021; Chandramohan et al. 2021; Muthu et al. 2021; Vijayakumar et al. 2021; Logendran, Chandramohan, and Sathish 2020; Krishna Priya, Jayakumar, and Suresh Kumar 2020; Mary Treasa Shinu and Needhidasan 2020; Rajkumar and Ganapathy undefined 2020)

Works identified with the impact of normal fiber on the Material removal rate alongside manufactured fiber are found less. 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 impact of drilling parameters on material removal rate for epoxy reinforced with sisal fiber and nano carbon particles and plain epoxy were studied.

MATERIALS AND METHODS

The preparation of samples and CNC drilling of the samples as per design were prepared at Saveetha Industries,Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Chennai. In this investigation, 2 groups were considered, one is a control group and another one is an experimental group. Sisal fiber (5 wt%), nano carbon particles (5 wt%) reinforced novel hybrid epoxy composites is considered as a control group, while plain epoxy is considered as experimental group [Citation error]. Drilling were performed based on Taguchi's (L9) Orthogonal Array (OA) with one repetition

per group and accordingly 18 experiments were carried out in each sample/group. According to a research article, the pretest power was calculated as 80% with mean - 83.06 and standard deviation - 6.3 [Citation error].

Group 1 sample is prepared in similar fashion as that of group 2 except that the sisal fiber mat is applied in several layers until the ideal thickness is accomplished, along the epoxy hardener and nano carbon particles. Similarly flat weights are placed on top to set up and wait for 24 hours.

For preparing plain epoxy (group 2), apply the wax on 4 sides of the wooden box (mould). Regular hand layup method is adopted to prepare the sample with a mix of Epoxy (grade-LY556) and the hardener (grade-HY951) in a 10:1 ratio. Precautions should be taken to prevent bubble formation during the stirring process. This mixture is carefully poured into a mold box of 30×30 cm with a 0.6 cm depth. Flat weights are placed over the setup and left undisturbed for nearly 24 hours to become hard for use in the CNC drilling process.

CNC (Computer Numerical Control), model name / number YCM-EV-1020A axis, drilling capacity tool 40 mm, spindle speed range 10000 rpm. Max tool (diameter, length, weight) 90mm, 300mm, 6kg 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 CNC 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 thehole 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 ([Citation error]. Accordingly the Material removal rate (MRR) is the dependent variable and the Feed rate, speed, drill diameter in each sample are considered as independent variables.

RESULTS

CNC drilling on samples comparing group 1 (sisal fibre (5%), nano carbon particles (5%), novel hybrid epoxy composites) and group 2 (plain epoxy) are done by considering the speed -feed rate-drill diameter at three levels as exhibited in Table 1. The corresponding MRR values are represented in Table 2. As per the independent t- test analysis, Table 3 represents the group statistics, which consists of the 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 and 2 are presented in Fig. 1 and Fig. 2 respectively, 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% SD.

DISCUSSION

A significant improvement in the MRR was found due to the addition of

reinforcements in epoxy. From the group statistical results as shown in Table 3, it is found that the mean MRR of polymer composite material and plain epoxy are1.25344 mm^3/sec and 0.52261 mm^3/sec respectively. Table 4 helps to understand the independent sample of T-test with equality of means. P value is found less than 0.0001 in Levene's test showing the existence of significant and considerable difference in the MRR among the groups under research work. Hence the alternate hypothesis of unequal variance is found appropriate. The t value indicates that the mean/average MRR of the polymer composites of (Group 1) is higher than that of plain epoxy (Group 2).

Similar and dissimilar works related to this investigation are discussed. Researchers [Citation error] have proposed a paper with different samples on which CNC drilling is performed and their weight % reinforcement variation according to the process [Citation error]. Another study has highlighted the different mechanisms for the CNC drilling process [Citation error]. The end results show significant differences between plain epoxy and epoxy with sisal fibre and nano carbon particles [Citation error]. Among the literature, epoxy with sisal fiber and nano carbon particles is found to have better performance than plain epoxy. Works have been carried out with the polymer composite materials like nano carbon particles, sisal fiber and hybrid epoxy composite that show significant improvement in the results for different drilling conditions [Citation error]. Researchers have also proposed a work on nano carbon 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 improve a method that could overcome the difficulties.

CONCLUSION

Within the limitations of this study, the experimental investigation carried on Material removal rate MRR during CNC drilling of plain epoxy and epoxy based novel hybrid composite comprising sisal fiber (5 wt.%) and nano carbon particles (5 wt.%). The mean MRR of polymer composite (1.25344 mm^3/sec) is 0.73083 mm^3/sec greater than that of the plain epoxy (0.52261 mm^3/sec). According to the T-test statistical analysis on the MRR of the plain epoxy and polymer composite, significant difference (p=0.0001) in the mean/average MRR is observed between the material groups. This study concluded that epoxy based composites with natural fiber reinforcement that is sisal fiber and nano carbon particles along with the novel hybrid epoxy composites exhibit better MRR when compared to plain epoxy.

DECLARATION

Conflict of interest

The authors of this paper hereby declare no conflict of interest.

Authors Contribution

Author BRKR 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	**Level**		
	L1	**L2**	**L3**
Speed(rpm)	100	170	230
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	0.228	0.120
2	100	0.10	2	0.236	0.110
3	100	0.15	3	0.785	0.350
4	100	0.15	3	0.689	0.320
5	100	0.20	4	1.660	0.786
6	100	0.20	4	1.701	0.765
7	170	0.10	3	0.852	0.432
8	170	0.10	3	0.880	0.412
9	170	0.15	4	2.267	0.867
10	170	0.15	4	2.241	0.834
11	170	0.20	2	0.653	0.265
12	170	0.20	2	0.732	0.224
13	230	0.10	4	1.783	0.763

Innovative hybrid epoxy composites reinforced with natural fiber (5%) and nano carbon particles (5%) were experimentally examined for MRR during CNC drilling and contrasted with plain epoxy.

14	230	0.10	4	1.923	0.732
15	230	0.15	2	0.775	0.312
16	230	0.15	2	0.663	0.302
17	230	0.20	3	1.955	0.916
18	230	0.20	3	2.539	0.897

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)	Polymer composite (Group 1)	18	1.25344	0.742693	0.175054
	Plain epoxy (Group 2)	18	0.52261	0.288244	0.67940

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

		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/sec)	Equal variances assumed	35.66	0.0001	3.89	34	0	0.73083	0.187776	0.34923	1.11244
	Equal variances not assumed			3.89	22.01	0.001	0.73083	0.187776	0.34142	1.12025

Fig. 1.CNC drilling onpolymer composite

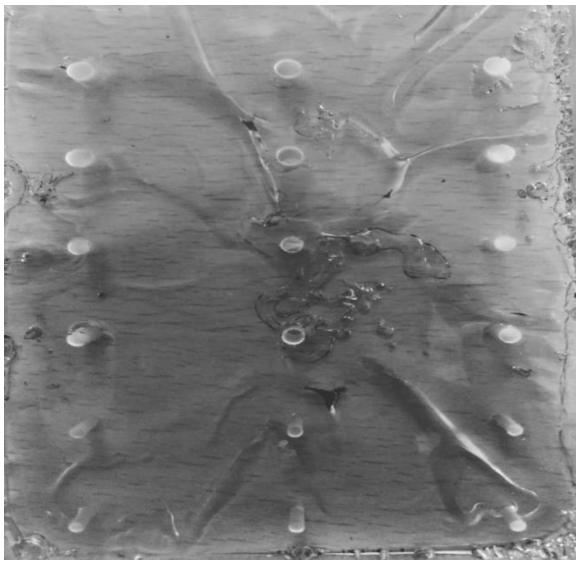

Fig. 2.CNC drilling on plain epoxy

Innovative hybrid epoxy composites reinforced with natural fiber (5%) and nano carbon particles (5%) were experimentally examined for MRR during CNC drilling and contrasted with plain epoxy.

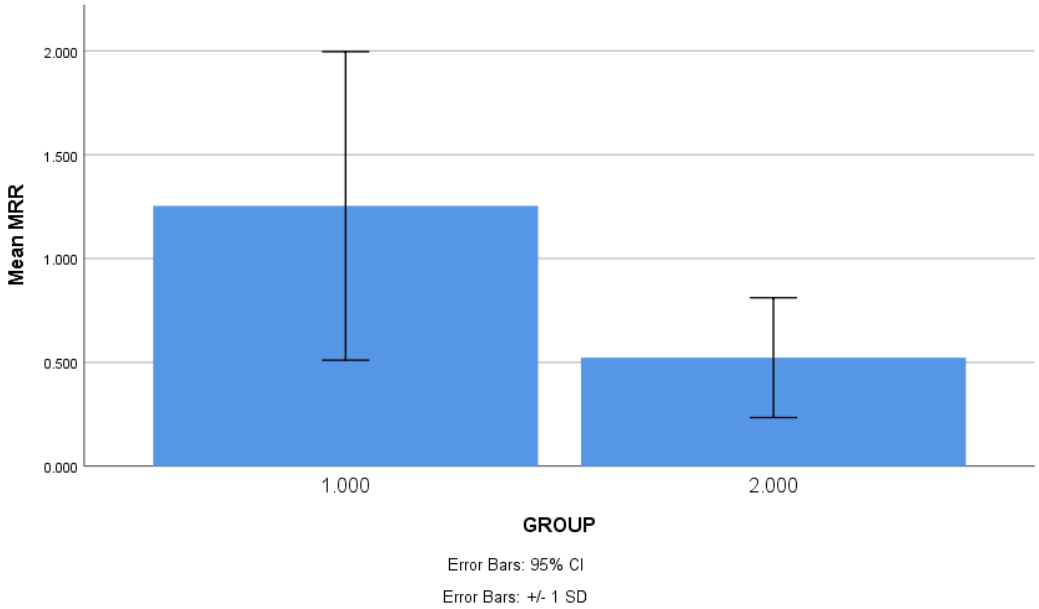

Fig. 3. Graphical representation of MRR (mm^3/sec) for Group-1 (sisal fiber(5wt%), nano carbon particles(5wt%),reinforced novel hybrid epoxy composites) and Group-2 (plain epoxy), X axis: Material groups, Y axis: MRR (mm^3/sec) with Mean accuracy of detection 95% CI and +/-1 SD.