Nano World Journal

https://doi.org/10.17756/nwj.2023-s3-100

Research Article

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Analyzing the Material Removal Rate of 15% Pineapple Fiber and 5% Novel Nano Carbon Particles Made of Custard Apple Seeds Reinforced Hybrid Epoxy Composites During Drilling Process

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Received: July 28, 2023
Accepted: October 19, 2023
Published: October 25, 2023

Citation: Reddy CVBP, Kumar DS. 2023. Analyzing the Material Removal Rate of 15% Pineapple Fiber and 5% Novel Nano Carbon Particles Made of Custard Apple Seeds Reinforced Hybrid Epoxy Composites During Drilling Process. *NanoWorld J* 9(S3): S556-S559.

Published by United Scientific Group

Abstract

Aim: This process's main objective is to evaluate the material removal rate (MRR) of cutting-edge hybrid epoxy composites reinforced with sustainable natural fiber (15%) and nanosized carbon particles (5%) to simple epoxy.

Methodology: For both groups, the samples were made using the hand lay-up method. According to the specifications, the samples were made, and drilling was carried out using a vertical CNC (computed numerical control) machine. With a pretest statistical power of 80%, a total of 20 trials were conducted to evaluate and compare the samples' material removal rates.

Results: The clearance rate was assessed using t-independent testing and SPSS statistical software. Compared to group 2 (plain epoxy), group 1's pineapple fiber mat's nano carbon particles removed material on average at a rate of 0.4051 mm^3/sec as opposed to 0.1283 mm^3/sec. The mean variance of MRR differs between group 1 and group 2 based on the results of the t-test statistical analysis (significant of $p = 0.001$, which is $p < 0.05$). The two research groups differ significantly from one another.

Conclusion: Within the confines of this study, it is obvious that using reinforcements like pineapple fiber and nano carbon particles has a big impact on increasing MRR.

Keywords

Novel hybrid epoxy composites, CNC drilling, Epoxy, Sustainable natural fiber, Sustainable pineapple fiber, Nano carbon particles, Material removal rate

Introduction

This investigation will look at the MRRs of epoxy (80%), sustainable pineapple fiber (15%), nanosized carbon particles (5%), and ordinary epoxy [1]. Because of their reliability and exceptional strength, reinforced composites made of synthetic or natural materials have a wide range of disciplines or fields. With respect to replacing the use of synthetic fibers, naturally extracted fibers are used [2]. Natural fiber composites offer reduced density and superior mechanical characteristics as compared to conventional fibers [3, 4]. In terms of weight to strength ratio, natural fiber reinforced FRPs perform better than traditional FRPs. These materials are used in various ways by the maritime, aerospace, automotive, building, and other industries.

Around 1,800 papers are observed in Google Scholar database and over 2,450 in Science Direct since there has been more than five years of study and writing on polymer composites. It has been studied how output variables like the rate at which composite material is removed are impacted by CNC drilling settings. These parameters include drill diameter in mm, feed rate in rev/sec,

and speed in rpm. This research investigates optimal drilling parameters, ideal conditions for getting a greater material removal rate. The influence of the epoxy-hardener ratio, and percentage of fiber on MRR have all been studied in sustainable pineapple fiber reinforced composites. The effects of feed rate and other influencing parameters on the MRR of sustainable pineapple fiber incorporated composite have been investigated by researchers. One of the best pieces of literature is the investigation on the influence of speed, fiber, and temperature on the MRR of epoxy related composites [5-9].

By the research since it is a naturally occurring fiber, pineapple fiber has been the subject of excellent research on composite materials. In this work, the impacts of drilling machining parameters on the MRR from epoxy reinforced with natural fiber and nano carbon particles as well as plain epoxy were investigated.

Materials and Method

Sample preparation and design-specific CNC drilling on the samples were performed in the Saveetha Engineering Industries, SIMATS, Chennai (Tamil Nadu, India). This study takes into account an experimental group under supervision. The control group utilizes standard epoxy, whereas the experimental group uses a novel hybrid epoxy composite made of epoxy (80), pineapple fiber (15%), and nanosized carbon particles (5%). With a pretest G-power of 80%, drilling was done using CNC with one repetition per group, yielding 20 experiments in each sample/group [10].

In order to achieve the required thickness, three layers of pineapple fiber mat, glass fiber mat, and nano carbon particles were used to create the sample for group 1. Required loads were placed over the material preparation setup and allowed it to cure for around 72 h.

Apply the wax to the four corners of the wooden box to prepare the group 2 sample of plain epoxy (mold). The work sample is prepared using the traditional lay-up method at 10:1 ratio of the hardener (HY951) and epoxy (LY556). Utmost care must be taken to avoid bubbles while stirring the mixture. This mixture is slowly poured into a mold box with dimensions of 300 mm in width by 300 mm in height. The setup is given the appropriate weights, which are then kept there unaltered for roughly 72 h to produce a composite with advantageous properties [11, 12].

The composites are drilled using a vertical machining center with a Siemens controller. The testing method entails using drill bits to make circular cross-section holes in the samples that correspond to the test design. Drilling time is seen in the FANUC data from the machine. The volume-to-time ratio after drilling is used to calculate the MRR.

Statistical analysis

The statistical software tool (SPSS) is used to investigate MRR and accordingly, independent t-test statistical analysis is performed. The speed, feed rate, and drill diameter of each sample are therefore taken as independent variables, while the MRR is considered as a dependent variable [13].

Results

Few methods for CNC machining (drilling) group 1 (fiber reinforced epoxy) and group 2 (plain epoxy) materials are shown in table 1. Drill diameter, feed rate, and speed are all taken into account (in rpm and rev/sec, respectively).

Table 1: Input parameters and their levels for CNC drilling.

Parameters	Levels		
	L1	L2	L3
Speed (rpm)	120	180	240
Feed (rev/min)	0.15	0.25	0.35
Drill diameter (mm)	4	5	6

The relevant MRR values are shown in table 2. As per the independent t-test analysis, the group data, including the number of samples per group, the mean MRR, standard deviation, and standard error, are displayed in table 3. The results of the independent t-test with correspondence of means and the Levene's test (in conjunction with $p < 0.05$) are shown in table 4.

Figure 1 and figure 2 show the CNC machined that is drilled samples for group 1 and group 2, which contain fiber reinforced epoxy, and figure 3 shows the MRR G-graph, based on mean accuracy of detection (with 95% CI).

Discussion

The MRR significantly increased as a result of the expansion of the epoxy reinforcements. The mean MRR of regular epoxy and fiber-reinforced epoxy are, respectively, 0.1283 mm^3/sec and 0.4426 mm^3/sec, according to the group statistical data (Table 3). Table 4 makes it simpler to understand a t-test with fairness of means for an independent sample. According to the results of Levene's test, the variance of the MRR differs significantly and tangibly across the study groups with a p-value less than 0.05 (achieved $p = 0.001$). It is proven that the alternative theory of unequal variance is true as a result. According to the negative t-test (Group 2) results, the composites with fiber reinforced epoxy (Group 1) have a mean/average MRR that is higher than that of plain epoxy.

Similar and outstanding works are found via this investigation. Analysts have advised research using a large number of samples, CNC drilling, and their weight% reinforcement variation as indicated to the procedure [4]. The critical process of the CNC machining (drilling) process had been discovered by another work. The final results demonstrate important disparities between fiber reinforced epoxy and conventional epoxy. According to the research, fiber reinforced epoxy seems to perform better than plain epoxy. Investigation is performed using reinforcing materials that include pineapple fiber mat and nano carbon particles, which significantly improved outcomes for various drilling situations [11]. Researchers have also suggested using carbon (nano) particles and pineapple fiber with good mechanical characteristics to improve the qualities, and it has been found that these proposals are generally in agreement with this study and don't include any major discrepancies.

Table 2: MRR of group 1 and group 2.

S. No.	Parameters			Group 1	Group 2
	Speed (rpm)	Feed (rev/min)	Drill diameter (mm)	MRR (mm^3/sec)	MRR (mm^3/sec)
1	120	0.15	4	0.185	0.028
2	240	0.15	4	0.256	0.118
3	120	0.35	4	0.271	0.199
4	240	0.35	4	0.355	0.101
5	120	0.15	6	0.362	0.090
6	240	0.15	6	0.459	0.161
7	120	0.35	6	0.595	0.242
8	240	0.35	6	0.665	0.126
9	120	0.25	5	0.284	0.219
10	240	0.25	5	0.294	0.027
11	180	0.15	5	0.359	0.116
12	180	0.35	5	0.219	0.050
13	180	0.25	4	0.538	0.199
14	180	0.25	6	0.395	0.080
15	180	0.25	5	0.481	0.158
16	180	0.25	5	0.489	0.140
17	180	0.25	5	0.421	0.105
18	180	0.25	5	0.492	0.137
19	180	0.25	5	0.489	0.133
20	180	0.25	5	0.492	0.136

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)	Fiber reinforced epoxy (Group 1)	20	0.4051	0.12902	0.02885
	Plain epoxy (Group 2)	20	0.1283	0.05858	0.01310

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

MRR (mm^3/sec)	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% CI of the difference	
								Lower	Upper
Equal variance assumed	13.271	0.02	8.736	38	0.001	0.3	0.03	0.212	0.340
Equal variance not assumed	-	-	8.736	26.5	0.001	0.3	0.03	0.211	0.341

Figure 1: CNC drilling on plain epoxy (Group 2).

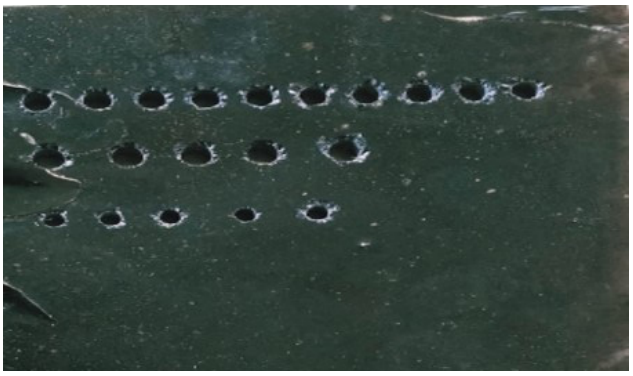

Figure 2: CNC drilling on novel hybrid reinforced epoxy (Group 1).

The production of air bubbles and lumps during sample preparation, which prevents adequate composite machining, is recognized as the fundamental shortcoming of this study. As a result, either new procedures need to be created or current ones

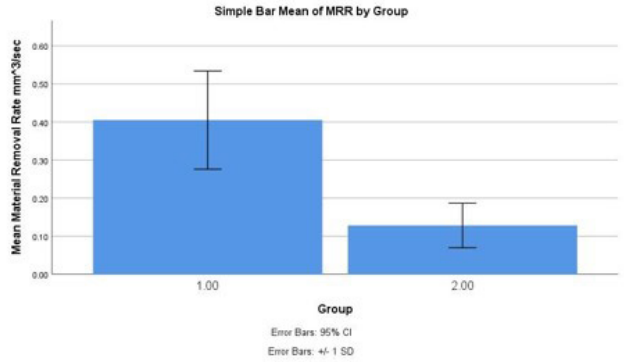

Figure 3: Graphical representation of MRR (mm^3/sec) for group-1 (Epoxy (80%), sustainable pineapple fiber (15%), nano carbon particles (5%) and group-2 (Plain epoxy), X-axis: Material groups, Y-axis: MRR (mm^3/sec) with mean accuracy of detection 95% CI and +/-1 standard deviation.

need to be improved. The target of this investigative research is to develop or improve a method to get over these challenges and use this material to make ceiling fan blades [12].

Conclusion

The rate of MRR of epoxy-based innovative fiber reinforced epoxy, which contains pineapple fiber (15%) and nano carbon particles (5%), as well as plain epoxy, was investigated during CNC drilling. The revolutionary hybrid reinforced epoxy has a mean MRR (0.4051 mm^3/sec) that is 0.28 mm^3/sec higher than normal epoxy. In terms of the t-test statistical analysis of the MRR of fiber incorporated epoxy cum plain epoxy ($t_{26.514}$ = 8.736, p = 0.001), the mean or average MRR differs considerably between the sample groups. There exists a significant difference among two groups under study. In this study/work, it was discovered that epoxy-based composites strengthened with sisal fiber mat and nano carbon particles outperformed epoxy alone in MRR tests.

Acknowledgements

None.

Conflict of Interest

None.

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