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Experimental Study on Material Removal Rate of 5% Fiber and 5% Novel Nano Carbon Particles Made of Tamarind Seed Reinforced Epoxy Composites During Drilling Process

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Abstract

Primary goal of this work is to examine rate of material removal rate (MRR) during VMC (Vertical machining center) machining of inventive epoxy composites supported with sustainable natural fiber (areca) (5%) and nanocarbon particles made of tamarind seeds (5%) in comparison to plain epoxy. The samples for both groups were produced using the hand-layup method. The samples were prepared in accordance with the specifications, and a vertical machine was used to carry out the drilling operation. For a total of 20 experiments per group with a pretest of G-power 80%. The sample's MRR was assessed and compared. independent t-tests were performed on the MRR using the statistical software program. The average MRR for group 1 that is epoxy (90%)/fiber (5%)/nanocarbon particles (5%) was 0.37415 mm^3/sec, compared to 0.11860 mm^3/sec for group 2 (plain epoxy). Based on the outcomes of the independent t-test statistical analysis, it is determined that the mean variance of MRR between groups 1 and 2 is different (significant of $p = 0.00$, which is p less than 0.05). Hence identified a significant difference between the two groups considered. Within the constraints of this study, it is noticeable that the addition of reinforcements like sustainable areca fiber and nanocarbon particles has a significant effect on MRR improvement.

Keywords

Novel epoxy composite, Nano carbon particles, Tamarind seed, CNC drilling, Material removal rate, Sustainable areca fiber

Introduction

In this study, the MRR of epoxy (90 percent by weight), sustainable areca fiber (5% by weight), nanocarbon particles (5% by weight), and plain epoxy will be examined [1]. Due to its reliable characteristics and considerable strength, natural reinforced composites generally have a wide range of fields. In order to compensate for the use of synthetic fibers, novel natural fibers are used. Natural fiber composites have lower density and exceptional mechanical properties in comparison with traditional fibers [2]. In terms of strength/weight ratio, natural fiber reinforced outperforms conventional FRPs. These materials have numerous uses in the construction, automotive, aerospace, and marine industries among others [3].

Over 2000 papers on polymer composites are available in Google Scholar, and there are about 2660 papers in Science Direct, according to a review of more than five years of research and literature on the subject [4, 5]. The fundamental influence of CNC drilling parameters on output parameters, such as composite material removal rate, has been studied [6]. These parameters include speed in rpm, feed in rev/sec, and drill diameter in mm. In this paper, ideal drilling parameters are investigated, followed by ideal conditions for achieving a higher material removal rate [5]. The influence of the ratio of epoxy-to-hardener, and fiber percentage on the epoxy's MRR has been studied in fiber-reinforced composites [7].

Being a naturally occurring sustainable fiber, areca fiber has been the subject of excellent research on composite materials [8]. This study looked at the effects of drilling factors on the rate of material removal from epoxy reinforced with areca fiber and nanocarbon particles as well as plain epoxy [9].

Materials and Method

The sample preparation and CNC drilling of the samples were done at the facilities available at Saveetha Engineering Industries, SIMATS, Chennai (Tamil Nadu, India). In this study, a control group that underwent an experiment is considered. While the control group only uses regular epoxy, the experimental group uses a novel hybrid epoxy composite made of epoxy (85 weight percent), sustainable areca fiber (10 weight percent), and nanocarbon particles (5 weight percent) [10, 11]. Each sample/group underwent one repetition of 20 drilling experiments in each sample/group, with a pretest G-power of 80% [5].

Group 1 sample is composed of three layers of sustainable areca fiber mat, epoxy hardener, and nanocarbon particles prepared to required thickness. Weights are placed over the setup and left to cure for around 72 h. Wax should be applied to the box's four sides to prepare the group 2 sample of plain epoxy. The sample is made using the 10:1 mixture of epoxy (LY556) and the hardener (HY951) using the traditional hand-layup method. During the stirring process, caution should be taken to avoid the formation of bubbles. A mold box measuring 300 mm x 300 mm and 5 mm deep is carefully filled with this mixture [12, 13]. To create a composite with advantageous properties, the setup is weighted properly and left alone for nearly 72 h.

The composites are drilled using a VMC (TCP-V-500 axis), a Siemens controller. In accordance with the test design, round cross-section holes are made in the samples using drill bits as part of the testing technique [14]. Drilling time is shown in the FANUC data from the VMC machine. The volume of material removed is calculated using the formula ($\pi r^2 h$) where 'r' denotes the hole's radius and 'h' denotes the hole's height, in this case the plate's thickness. The volume-to-time ratio after drilling is used to calculate the MRR.

Statistical analysis

The observed MRR values were subjected to independent statistical t-test with the help of Statistical Package for the Social Sciences statistical tool. Accordingly, the percentage, speed, feed rate, and drill diameter are regarded as independent variables, and the MRR is considered as the dependent variable [4].

Results

As shown in table 1, CNC machining (drilling) on group 1 (fiber-reinforced epoxy) and group 2 (plain epoxy) materials is performed in three steps while accounting for speed (rpm), feed (rev/sec), and drill diameter (mm). Table 2 displays the pertinent MRR values. The group statistics are shown in table 3. The results of the t-test with correspondence of averages/means and Levene's test (in conjunction with P less than 0.05) are displayed in table 4. The CNC-drilled samples for groups 1 (fiber-reinforced epoxy) and 2 (plain epoxy) are shown in figure 1 and figure 2, respectively, while figure 3 displays the G graph for MRR in mm^3/sec, which is plotted based on 95% CI (Confidence interval).

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

Parameters	Levels		
	L1	L2	L3
Speed (rpm)	220	300	400
Feed (rev/min)	0.10	0.20	0.30
Drill diameter (mm)	4	5	6

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	220	0.10	4	0.155	0.027
2	400	0.10	4	0.208	0.056
3	220	0.30	4	0.248	0.071
4	400	0.30	4	0.312	0.079
5	220	0.10	6	0.359	0.082
6	400	0.10	6	0.471	0.112
7	220	0.30	6	0.561	0.147
8	400	0.30	6	0.701	0.269
9	220	0.20	5	0.245	0.067
10	300	0.20	5	0.261	0.088
11	300	0.10	5	0.282	0.098
12	300	0.30	5	0.306	0.103
13	300	0.20	4	0.196	0.039
14	300	0.20	6	0.504	0.171
15	300	0.20	5	0.377	0.131
16	300	0.20	5	0.408	0.151
17	300	0.20	5	0.446	0.159
18	300	0.20	5	0.467	0.161
19	300	0.20	5	0.491	0.172
20	300	0.20	5	0.485	0.189

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	0.37415	0.141209	0.031575
	Plain epoxy (Group-2)	20	0.11860	0.059569	0.013253

Discussion

The inclusion of reinforcements in epoxy led to a fundamental improvement in the MRR. According to statistical findings (Table 3), the mean MRR of fiber-reinforced epoxy and plain epoxy are, respectively, 0.37415 mm^3/sec and 0.11860 mm^3/sec. Understanding an independent sample of the independent t-test can be understood from table 4. Lev-

Table 4: Independent 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% CI of the difference Lower	95% CI of the difference Upper
MRR (mm^3/sec)	Equal variance assumed	14.289	0.001	7.463	38.00	0.00	0.26	0.03	0.19	0.32
	Equal variance not assumed			7.463	25.49	0.00	0.26	0.03	0.19	0.33

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

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

ene's test results reveal the existence of significant and substantial differences in the variance of the MRR among the study groups, with a p value less than 0.05 (achieved p = 0.00). So, it is found that, alternative hypothesis of unequal variance is noticeable. The composites of fiber-reinforced epoxy (Group 1) have a mean/average MRR that is wiser than plain epoxy, according to the negative t value (Group 2).

With this investigation, similar and extraordinary works are identified. Analysts have proposed a paper with various samples on which CNC drilling is carried out and their weight% reinforcement variation as indicated by the process [15]. The exceptional mechanisms involved in cutting through the CNC drilling process have been investigated by another study [8]. In-depth comparisons between fiber-reinforced epoxy and plain epoxy are presented in the final results. According to the research, fiber-reinforced epoxy performs better than plain epoxy [15]. Work has been completed using reinforcement materials like areca fiber mats and nanocarbon particles, which significantly improved results for various drilling conditions [8]. Researchers have proposed more research on nanocarbon particles and areca fiber with mechanical characteristics to improve the qualities, which has been shown to be in reasonable accord with this study with no serious discrepancies.

Limitations in this work are caused by the formation of air pockets and lumps during test planning, which is acknowledged as a drawback and prevents the composite from being machined properly. Therefore, it is necessary to develop new methodologies or enhance those that already exist. As a result, the goal of this investigation is to create or improvise a solution to the problems, and the information obtained will be useful when creating sharp edges for roof fans.

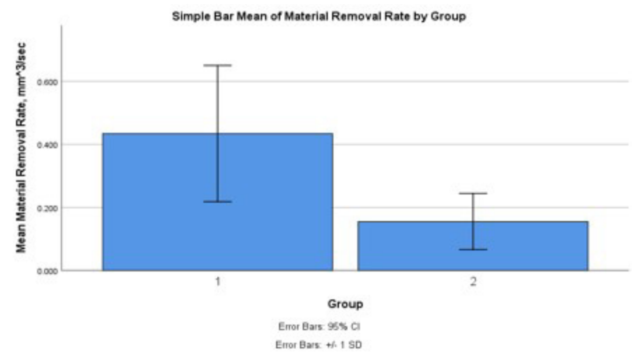

Figure 3: Graphical representation of MRR (mm^3/sec) for group-1 (Epoxy (90%), sustainable areca fiber (5%), nano carbon particles made of tamarind seed (5%)) and group-2 (Plain Epoxy), X-axis: Material groups, Y-axis: MRR (mm3/sec) with mean accuracy of detection 95% CI and +/-1 standard deviation.

Conclusion

The investigation of material removal during CNC drilling of novel fiber-reinforced epoxy composed of sustainable areca fiber (5 wt.%), nanocarbon particles (5 wt.%), and plain epoxy. The novel hybrid reinforced epoxy has a mean MRR of 0.37415 mm^3/sec, which is higher than the plain epoxy's 0.11860 mm^3/sec, The statistical analysis (Independent t-test) on the mean/average MRR of the fiber reinforced epoxy and plain epoxy revealed a significant difference between the material groups considered in this study (t 25.49 = 7.463, p = 0.00). According to the results of this study, areca fiber mat and nanocarbon particles added to epoxy-based composites with natural fiber reinforcement exhibit better MRR than plain epoxy.

Acknowledgements

None.

Conflict of Interest

None.

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