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Comparative Investigation on Drilling Characteristics (Material Removal Rate) of Novel Kitchen Waste Blended GFRP and Bagasse Blended GFRP With Plain GFRP

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ABSTRACT

Aim: The present work aims to study the Material Removal Rate (MRR) of epoxy based Glass Fibre-reinforced polymer composite with and without novel kitchen waste filler and bagasse filler. **Materials and Methods:** Polymer composites were fabricated in three groups (Experimental = 2 and Control Group = 1) by hand layup method. Three groups with 9 specimens each are equally divided to measure the MRR of the three different composites using CNC drilling operation. The Material Removal Rate of the samples for each group is analyzed. Spindle speed, feed and drill diameter were controlled factors. To analyze and compare the test data, one -way ANOVA test was carried out. **Results:** Material Removal Rate of samples with and without fillers were analysed from the test data and compared. The significance of the results was analysed using SPSS software and $P < 0.05$ of significance value was attained . **Conclusion:** The comparison of results with plain GFRP shows that the Material Removal Rate of alkaline treated glass fibre/novel kitchen waste composite was found to increase by 4.53%, respectively. Similarly, the Material Removal Rate of alkaline treated glass fibre/bagasse composite was found to increase by 13.19%, respectively.

Keywords: Glass Fibre Reinforced Polymer (GFRP), Novel kitchen waste filler, Bagasse filler, Material Removal Rate, CNC drilling, Hand layup method

INTRODUCTION

This study deals with the comparison of material removal rate of the novel kitchen waste blended GFRP and bagasse blended GFRP with plain GFRP. Composite materials have emerged as one of the materials with such advanced properties that they can be used in a variety of fields. A composite material is made up of at least two constituents, one of which is present in the matrix process and the other in the particle or fibre structure [1]. Composites have become increasingly important as a result of the need for modern and alternative materials with low weight and high strength ratios. The composites are designed with affordability, and supplying a community with environmentally sustainable material in mind. Because of their mechanical properties, such as corrosion resistance, chemical stability, relatively high heat resistance capability, lightweight, high specific strength, machinability, ease of availability, and low cost, glass fibre materials are commonly used in composite materials [2]. Glass fibre reinforced polymers have a wide variety of uses in the manufacture of vehicle frames, ship parts, space shuttle casings, windmill blades [3]) ([4].

Over the past few years, a lot of research has been done on glass fibre reinforced polymer composites.Around 723 papers were published in google scholar. Around 99 papers were published in sciencedirect. The properties of composites containing polymer matrix are improved by using alkaline treated natural fillers.Fibers treated with alkaline NaOH and improved fiber-matrix compatibility resulted in improved mechanical properties [5]. The epoxy composite with alkali treated natural fibers show higher mechanical properties compared to untreated natural fiber composites [6]. The addition of different volume fractions of food waste (Citrus limetta peel) filler on novel epoxy composite increased the mechanical properties of the composite ([7]) ([8]. The work carried out by Sood and Dwivedi et al. is considered as the best reference paper for this work.Our team comes from a rich background of working on various research projects across diverse disciplines[9]–[18]

Despite its widespread availability and numerous applications as a synthetics fibre in composite construction, research on glass fibre composites and the use of natural fillers such as novel kitchen waste and bagasse filler has been limited. As a result, an effort was made to examine the material removal rate of epoxy-based hybrid composites containing Glass fibre with novel kitchen waste and bagasse filler (10 wt%) as reinforcement.It is intended to compare the MRR of novel kitchen waste-blend GFRP, bagasse-blend GFRP, and plain GFRP in this study.

MATERIALS AND METHODS

A study was conducted at the Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences (SIMATS). No ethical approval was required since this project is regarding fabrication of polymer composites. The sample size required for this study is calculated using the ClinCalc application by considering a threshold of 5%, CI of 95% and g-power 80% [19].Glass fibre reinforced polymer composite was fabricated using glass fibre (200 GSM) with epoxy resin LY556 (density 1.20 g/cm^3) and hardener HY951 (density 0.99 g/cm^3) in appropriate proportions. Material Removal Rate of glass fibre reinforced polymer composite was tested with novel kitchen waste filler (10%) and bagasse filler (10%) . The samples were categorized into three groups (with novel kitchen waste, with bagasse and without fillers) with 20 samples per group and were fabricated using a hand layup method. This method is an open forming method and least expensive for manufacturing hybrid composites.

The control group samples are made using a regular mould measuring 300 x 300 x 3 mm. The epoxy matrix was mixed for 10 minutes in a container with a 10:1 weight ratio of epoxy and hardener. A coating of wax was evenly applied to the mould's base, supplemented by a layer of glass fibre. Glass fibre was laid down layer by layer, rehashed up to ten times, after the epoxy matrix was poured and uniformly spread. With the aid of a roller, the mould was closed after it was set, and uniform pressure was forced to expel the gas pores. The dried polymer composite plates were expelled from the mould and carved into specimens after being allowed to cure for 36 hours with a uniform load.

In the experimental group, the novel kitchen waste and bagasse fillers are chemically refined in alkaline NaOH for one week to eliminate a waxy coating that causes non-uniform bonding between reinforcement and matrix. Each layer of glass fibre is layered with an epoxy matrix and alkaline treated fillers (10% novel kitchen waste and 10% bagasse). Kitchen waste/GFRP and bagasse/GFRP were made using the same methodology.

The drilling experiments were designed using the Taguchi technique. To design the experiments, differences in cutting speed and feed rate were used.Table 1 lists the cycle parameters and their stages. Table 2 shows the experimental method, which is built on the L9 orthogonal array, which has 9 rows and 3 columns. SPSS software, a statistical and analysis software, was used to model and analyse the drilling experiments in this study. Experiment was conducted in the vertical machining Centre CNC Machine. A CNC machine tool holder is used to hold the drill bits in the tool position of the CNC automatic tool changer. First, the HSS tool is fixed in the holder. The specimen/workpiece is supported by the machine vice on the CNC bed and is used to set up the specimen tightly. With a manual reference point, I fixed the tool offset and measured the drill position location coordinates in CNC auto measure itself just by clicking the measure button in the CNC control panel. There are several parameters such as spindle speed and feed rate that are sustain into the program. After setting up the parameters, the program cycle is ready and is set to run and start the cycle to drill the hole one by one in the composite plate.

Time taken to perform drilling was very crucially measured in the stopwatch from the point of nose touching the specimen until the through hole drill was achieved. Same procedure was followed to drill the next two composite plates. Each specimen was measured using a Vernier caliper for their internal diameter and thickness/depth of cut of the specimen useful for further calculations. Three repeated readings were taken for both thickness and diameter for each specimen and its average value was recorded. The samples subjected to MRR after CNC drilling were depicted in Fig. 1. The SPSS bar graph of material removal rate was depicted in Fig. 2.

Statistical Analysis

By using Statistical Software SPSS (V.26), One-way ANOVA analysis was carried out by considering glass fibre/novel kitchen waste/ bagasse reinforced composites as independent variables and material removal rate (MRR) as dependent variables. The analysis was done successfully and the graph was plotted against the material removal rate and trial numbers of each sample.

RESULTS

Glass fibre reinforced polymer composites with 10% novel kitchen waste filler and 10% bagasse filler was fabricated by hand layup method. The test data collected, organized and analyzed using standard practice are described here.The experimental data collected in standard testing procedures was arranged and analysed by experimental group (with filler) and control group (without filler). Process Parameters and levels used to analyze Material Removal Rate (MRR) were tabulated in Table 1. Descriptive tabular columns of MRR of synthesised composites were tabulated in Table 2. Descriptive tabular column of MRR (Mean value, Standard deviation and standard error) of composite laminates were tabulated in Table 3. ANOVA Analysis of material removal rate depicting sum of square and significant value were tabulated in Table 4. Multiple comparison of material removal rate shows reasonable significance values for all experimental groups and control group were tabulated in Table 5.

DISCUSSION

The glass fiber reinforced polymer composites with fillers in this study showed better material removal than GFRP without fillers.Especially glass/bagasse reinforced composites showed high material removal rate compared to other composites.

The addition of natural fillers to GFRP decreases the tensile strength and hardness of the material, according to published literature. This may be because the filler materials have waxy layers. Furthermore, the inclusion of lignin and hemicellulose in the filler material induces non-uniform reinforcement-matrix bonding [20]. GFRP composites are being studied in order to improve their mechanical properties. Chemical treatment was applied to the fillers. For one week, the fillers were fed with alkaline NaOH. As a result of this, the waxy coating, lignin, and hemicellulose in natural fillers have all been removed. Furthermore, the bonding between the matrix and reinforcement has improved, resulting in a higher rate of material removal from composites (Abhishek K et al. 2017). The estimated mean value of material removal rate for the plain GFRP is 0.2492 mm^3/min. The maximum and minimum values measured for the plain GFRP are 0.4073 mm^3/min and 0.1137 mm^3/min, respectively. The mean material removal rate of GFRP with novel kitchen waste is 0.2605 mm^3/min ([21]. The maximum and minimum values measured for the GFRP with novel kitchen waste are 0.4136 mm^3/min and 0.1215 mm^3/min, respectively. The mean material removal rate of GFRP with bagasse is 0.2821 mm^3/min. The maximum and minimum values measured for the GFRP with bagasse are 0.4322 mm^3/min and 0.1426 mm^3/min, respectively. [22]. The paper of Abhishek et al. is in close agreement with the study.

The results show that adding filler to composites changes the rate of material removal dramatically. Filling voids and avoiding crack forming, according to the researchers, increases interstitial bonding strength and changes the surface volume characteristics of the composite. As a result, the rate at which the material is removed increases. Figure 2. Bar graph shows the comparison between the material removal rate of GFRP, novel kitchen waste blended GFRP and bagasse blended GFRP. The graph shows the material removal rate is high for the composites containing bagasse filler (0.282156 mm3/min) compared to the material removal rate of GFRP (0.249267 mm3/min) and novel kitchen waste blended GFRP (0.260567 mm3/min).The error bars +/- 1 SD was attained.

There are some limitations to this research. Fabrication of composites using the hand layup process results in the forming of gas pores between the layers of the fibres, a non-uniform distribution of fillers that decreases the composite's interstitial bonding strength, crack formation, and inconsistent results. The future scope for this work is the evaluation of material removal rate of glass epoxy composites using different fillers with varying volume fractions along with other fabrication methods.

CONCLUSION

Within the limits of this study, glass fibre reinforced epoxy composites with fillers and without fillers were prepared by using hand layup technique and analyzed. The drilling parameters like cutting speed, feed rate and diameter of drill bit were considered in analysing the MRR. MRR was statistically analyzed in SPSS V.26 through ANOVA. Higher MRR was achieved at cutting speed of 1000 rpm, a feed rate of 0.1 mm/rev, and a drill bit diameter of 10 mm. From the ANOVA results, drill diameter was observed as the most significant parameter on the combined response followed by cutting speed and feed rate. Glass fibers with 10% volume fraction of bagasse were found to have higher MRR than the composite fabricated with 10% volume fraction of novel kitchen waste and plain GFRP.

DECLARATIONS

Conflict of Interest

The authors declare that there is no conflict of interest in this manuscript.

Authors Contribution

Author IMS was involved in data collection, data analysis, Manuscript writing. Author Dr.GA was involved in conceptualization, data validation, and critical review of the manuscript.

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TABLES AND FIGURES

Table 1. Process Parameters and levels used to analyze Material Removal Rate (MRR)

		Level		
S.No	**Parameters**	**1**	**2**	**3**
1.	**Cutting speed (rpm)**	600	800	1000
2.	**Feed rate (mm/rev)**	0.1	0.2	0.3
3.	**Drill dia (mm)**	6	8	10

Table 2. Descriptive tabular column of MRR of synthesised composites

Experiment No.	Cutting speed (rpm)	Feed rate (mm/rev)	Drill diameter (mm)	MRR (GFRP) (mm^3/min)	MRR (GFRP + Kitchen Waste) (mm^3/min)	MRR (GFRP + Bagasse) (mm^3/min)
1.	600	0.1	6	0.1137	0.1215	0.1426
2.	600	0.3	8	0.1952	0.2126	0.2374
3.	600	0.3	10	0.3322	0.3401	0.3632
4.	800	0.1	8	0.2183	0.2201	0.2411
5.	800	0.2	10	0.3851	0.4016	0.4257
6.	800	0.3	6	0.1632	0.1768	0.1945
7.	1000	0.1	10	0.4073	0.4136	0.4322
8.	1000	0.2	6	0.1955	0.2133	0.2358
9.	1000	0.3	8	0.2329	0.2455	0.2669

Table 3. Descriptive tabular column of MRR (Mean value, Standard deviation and standard error) of composite laminates.

Descriptives								
Material Removal Rate								
	N	**Mean**	**Std. Deviation**	**Std. Error**	**95% Confidence Interval for Mean**		**Min**	**Max**
					Lower Bound	**Upper Bound**		
GFRP	9	0.249267	0.1019374	0.0339791	0.170911	0.327623	0.1137	0.4073
GFRP + Kitchen Waste	9	0.260567	0.1014834	0.0338278	0.182560	0.338574	0.1215	0.4136
GFRP + Bagasse	9	0.282156	0.1018062	0.0339354	0.203900	0.360411	0.1426	0.4322
Total	27	0.263996	0.0987349	0.0190015	0.224938	0.303055	0.1137	0.4322

Table 4. ANOVA Analysis of material removal rate depicting sum of square and significant value

ANOVA					
Material Removal Rate					
	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	0.005	2	0.003	0.243	0.043
Within Groups	0.248	24	.010		
Total	0.253	26			

Table 5. Multiple comparison of material removal rate shows reasonable significance values for all experimental group and control group

Multiple Comparisons						
Dependent Variable: MATERIAL REMOVAL RATE						
Bonferroni						
(I) polymer	**(J) polymer**	**Mean Difference (I-J)**	**Std. Error**	**Sig.**	**95% Confidence Interval**	
					Lower Bound	**Upper Bound**
GFRP	**GFRP + Kitchen Waste**	-.0113000*	.0479619	1.000	-.134737	0112137
	GFRP + Bagasse	-.0328889*	.0479619	1.000	-.156326	.090548
GFRP + Kitchen Waste	**GFRP**	.0113000*	.0479619	1.000	-.112137	.134737
	GFRP + Bagasse	-.0215889*	.0479619	1.000	-.145026	.101848
GFRP + Bagasse	**GFRP**	.0328889*	.0479619	1.000	-.090548	.156326
	GFRP + Kitchen Waste	.0215889*	.0479619	1.000	-.101848	.145026
*. The mean difference is significant at 0.05 level.						

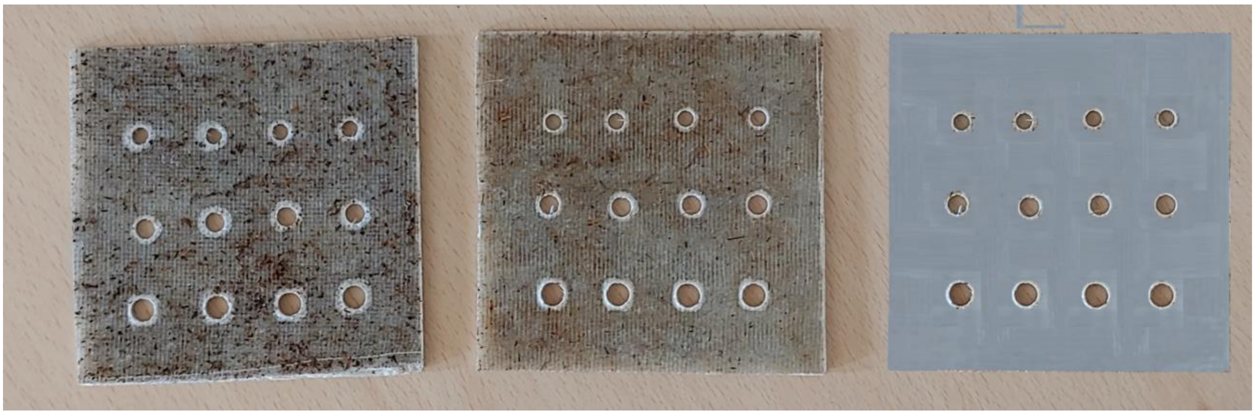

Fig. 1. Photograph of Kitchen waste blended GFRP, Bagasse blended GFRP and Plain GFRP after CNC drilling

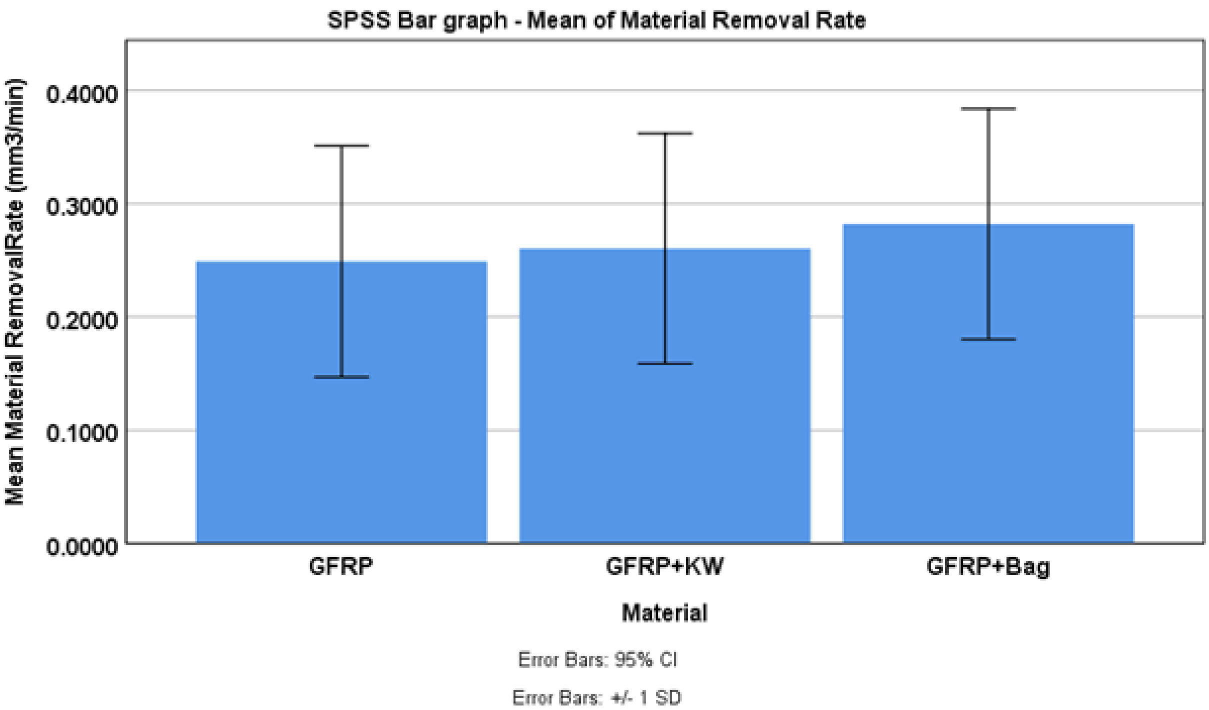

Fig. 2. Bar graph shows the comparison between the material removal rate of GFRP, novel kitchen waste blended GFRP and bagasse blended GFRP. The graph shows the material removal rate is high for the composites containing bagasse filler (0.282156 mm3/min) compared to the material removal rate of GFRP (0.249267 mm3/min) and novel kitchen waste blended GFRP (0.260567 mm3/min).The error bars +/- 1 SD was attained.