COMPARATIVE ASSESSMENT OF MATERIAL REMOVAL RATE IN KENAF FIBER ALUMINIUM REINFORCED LAMINATE FILLED WITH PORTUNUS POWDER AND KENAF ALUMINIUM COMPOSITE BY DRILLING PROCESS

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ABSTRACT:
Aim: This research is about the comparison of material removal rate of novel kenaf fiber aluminium reinforced laminate by adding Portunus filler with kenaf aluminium composite. **Materials and Methods:** In this research, kenaf fiber reinforced aluminium laminates were fabricated by varying weight of Portunus filler from 0 to 10 wt.% in steps of 5% and are designated as KAL, PKAL-5 and PKAL-10. PKAL-5 and PKAL-10 were considered as experimental groups and KAL as control groups. So the total number of groups is 3 and samples per group are 20. To find the material removal rate (MRR), the holes were drilled by an 8mm HSS drill bit using a radial drilling machine. **Results:** The mean material removal rate value obtained for the experimental group is 0.193655 g/sec (PKAL-5) and 0.15864 g/sec PKAL-10), but for the control group, the value is 0.137525 g/sec (KAL). **Conclusion:** Within the limitations of the study, it is observed that the material removal rate of Portunus filled kenaf fiber aluminium reinforced laminate composite is greater than the MRR of novel kenaf aluminium composite.

KEYWORDS: Novel kenaf fiber, Portunus filler, Hand layup technique, Material removal rate, Drilling, Aluminium

1. INTRODUCTION

Fiber metal laminate (FML) is a lightweight composite structure made up of thin metal layers and fiber-reinforced polymers (FRP) bonded together (Ostapiuk, Surowska, and Bieniaś 2014). Because of their outstanding fatigue and impact resistance, lightweight FMLs are commonly used in the aviation and automotive industry (Sivakumar et al. 2018);(Subramaniam et al. 2019). Fiber-based aluminium laminates are prominent and ARALL, which is made of aramid fibers, and GLARE, which is made of high-strength glass fibers, are the two most commonly produced FMLs (Vasumathi and Murali 2013; Osman et al. 2019). Natural fibers are incorporated in composites, minimising reliance on synthetic fibers and increasing the use of sustainable materials (Gholampour and Ozbakkaloglu 2020). However, the current trend of using natural fibers instead of man-made fibers in FRP composites can be applied to FMLs (El-Baky et al. 2020). Fiber-reinforced metal laminate composites have numerous applications in our daily life and they are mainly used in aerospace, automotive, marine and construction industries due to their less weight, high modulus, specific strength and high fracture toughness (Alagappan, Vijayaraghavan, Jenarthanan, et al. 2020). Due to various benefits, such as superior strength to weight ratio, toughness, and lightweight, natural composites are primarily used in the aerospace, automotive and construction industries. When sustainability is taken into consideration, plant fibers show significant benefits when they are used in composite materials than synthetic fibers (Feng et al. 2020). Because of its improved flexural and impact strength, lower weight, and cost-effectiveness, the hybrid FRP laminate composites can be used in the exterior layer of automotive seat moulds and doors (Alagappan, Vijayaraghavan, Giridharan, et al. 2020).

DOI: 10.9756/INT-JECSE/V14I3.698

The previous researchers focused on the optimum drilling parameters for better productivity of various composites and limited studies focused on the material removal rate of kenaf composites. Hence this research aims to compare the material removal rate of novel kenaf fiber aluminium reinforced laminate by adding Portunus filler with kenaf aluminium composite

2. MATERIALS AND METHODS

Fabrication and drilling of the composite laminates were conducted at Central Workshop, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences (SIMATS), Chennai. The Portunus filled kenaf fiber aluminium reinforced laminate was considered as the experimental group and the kenaf aluminium composite was taken as the control group. The PKAL-5 and PKAL-10 composites were the two subgroups under the experimental group. The sample size per group based on the sample size calculator was 20 with 80% g power and the maximum accepted error is fixed as 0.05 (Parthipan et al. 2020)(Jayaprakash et al. 2020)(Parthipan et al. 2020).

Bi-directional kenaf fiber mat, Al6061 alloy, epoxy resin and epoxy hardener required for the fabrication of the composite are supplied by Hayael Aerospace India Pvt. Ltd Poonamallee, Chennai, and the mechanical properties of the kenaf fiber are tabulated in Table 1 (Saba, Paridah, and Jawaid 2015). The hand lay-up process was used in this study to fabricate all the laminates i.e., KAL, PKAL-5 and PKAL-10. All the composites contain 4 layers of kenaf mat/1 layer of Al6061 alloy sheet/4 layers of kenaf mat, but varying Portunus filler percentage. The weight of the resin mixture and the Portunus filler were noted down each time using a weighing machine before applying onto the reinforcement. For curing, a load of 30 kgs was applied on each of the laminates separately. Figure 1 shows the novel kenaf fiber aluminium reinforced laminate of size (300 X 300 X 5 mm) fabricated using the hand layup technique.

Material removal rate (MRR) is the amount of material removed per unit time from the workpiece by a metal tool using a lathe, drilling, milling machine etc. Drilling is a cutting technique that involves making a circular cross-section hole in solid materials with a drill bit. High-Speed Steel(HSS) drill bit of Φ8mm was used to make holes using a radial drilling machine on the fabricated composite and the spindle speed of 500 rpm was constant for all the holes.

Fig. 2. represents the HSS drill bit and Fig. 3. represents the radial drilling machine. The workpieces, KAL, PKAL-5 and PKAL-10 after drilling 20 holes on each, are represented in Fig. 4. MRR calculated by weight loss method using the equation-(1)

$$MRR = \frac{W_b - W_a}{t} \text{----------(1)}$$

Where, MRR = Material removal rate (g/sec)
W_b = Weight of workpiece before drilling (g)
W_a = Weight of workpiece after drilling (g)
t = Machining time (s)

Statistical Analysis

SPSS V 2.6 statistical software was used to calculate mean, standard error and standard deviation. The weight of the filler percentage added with the matrix of the novel kenaf fiber aluminium reinforced laminate is the independent variable in this research. And the dependent variable is the MRR of each of the composite laminates.

3. RESULTS

The values of material removal rate (MRR) for various percentages of Portunus filled kenaf fiber aluminium reinforced composite laminate are tabulated in Table 2. The mean MRR are the 0.137525 g/sec, 0.193655 g/sec and the 0.15864 g/sec for the KAL, PKAL-5 and PKAL-10 composites respectively and these are obtained from mass analysis which is shown in Fig. 5.

SPSS analysis was done and the outcomes of the Descriptive test, ANOVA test and Multiple comparison test are tabulated in Table 3, Table 4 and Table 5 respectively. From the descriptive table, it is noted that the total standard deviation and the total standard error for all the three groups are 0.0345608 and 0.0044618 respectively. Table 4 ANOVA shows the significant value of MRR between and within the groups was $p=0.002$. From the comparison test, all the values are significant ($p<0.05$). Fig. 6. represents the bar chart of impact strengths of each specimen for KAL, PKAL-5 and PKAL-10.

4. DISCUSSION

DOI: 10.9756/INT-JECSE/V14I3.698

MRR is higher for the 5 wt.% Portunus filled kenaf aluminium reinforced laminate. The addition of Portunus fillers to the kenaf fiber aluminium reinforced composite laminate leads to an increased MRR when compared with the fabricated composite without filler. Similar studies were done by the other researchers and mostly their findings supported the addition of filler to the fibre-reinforced composite increases the MRR.

The addition of fillers with the fiber metal laminated composites of this experiment is in line with the findings of the following studies. The drilling characteristics by adding silicon (IV) oxide nanoparticles to the kenaf fiber-reinforced epoxy composite was studied. This study reveals that the addition of filler gives better dimensional stability and also reduces the peel off pullout with a better surface finish (Parthipan et al. 2020). The machinability characteristics of hybrid natural fibers were carried out and found out that the use of fillers in a hybrid composite helps to protect the composite's strength and adhesive properties while machining (Jani et al. 2016). Because of lower hardness, it was observed that higher MRR was recorded when the fly-ash filler was added and minimal MRR was recorded when no fly-ash filler was used (Sumesh and Kanthavel 2020). And this may be due to the filler increasing the adhesion between the fiber and matrix with very few voids.

The conclusion derived from this experiment is not in line with the findings of the given studies. The effect of the addition of rice husk to the epoxy-based composite was investigated, the results showed that MRR increased significantly, and it was very effective and acts as a lubricating agent and helped in machining operations (Sumesh and Kanthavel 2020). Also, the MRR was continuously increasing when graphene nano-platelets (GNPs) were added with SiC-based composites. When the filler content was raised from 5 wt.% GNPs to 15 wt.% GNPs, the MRR has increased twice approximately and the surface roughness reduced simultaneously (Hanzel et al. 2019). This may be due to the delamination, fiber fraying and spalling of the composites during drilling.

The main drawback of this research is the drilling of all holes at low spindle speed (500rpm) which lead to fiber pull-out. If the holes were drilled at higher spindle speeds, the MRR would be increased and surface roughness would be decreased. Thus the fillers reinforced fiber composites are better in machining properties and can be used in developing any engineering components due to their ability to withstand high cutting forces and better surface finish.

5. CONCLUSION

Within the limitations of the study, fabrication of novel kenaf fiber aluminium reinforced laminates with varying Portunus filler addition was done and holes were drilled on the laminates to analyse the MRR. The holes were drilled in a radial drilling machine with a drill bit of high-speed steel (HSS) of Φ8 mm. It was proved that the MRR is higher for the PKAL-5 (0.193655 g/sec) when compared to PKAL-10 (0.15864 g/sec) and the KAL (0.137525 g/sec). Because of their ability to withstand large cutting forces, these fiber metal laminates are highly recommended in automobile applications.

DECLARATION

Conflict of Interest

The authors of this paper declare no conflict of interest.

Authors Contribution

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

Acknowledgement

The authors would like to express their gratitude towards Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences (Formerly known as Saveetha University) for providing the useful equipment to carry out this research successfully.

Funding

We thank the following organizations for providing financial support that enabled us to complete the study.

1. Hayael Aerospace India Pvt. Ltd,
2. Saveetha University
3. Saveetha Institute of Medical and Technical Sciences
4. Saveetha School of Engineering

DOI: 10.9756/INT-JECSE/V14I3.698

DOI: 10.9756/INT-JECSE/V14I3.698

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TABLES AND FIGURES

Table 1: Mechanical properties of kenaf fiber

Fiber	**Density (g/cm^3)**	**Tensile strength (MPa)**	**Elastic modulus (GPa)**	**Elongation at break (%)**	**Moisture Content (%)**
Kenaf	1.45	930	53	1.6	6.2 – 20

DOI: 10.9756/INT-JECSE/V14I3.698

Table 2: The material removal rates (g/s) of each hole in all the samples of KAL, PKAL-5 and PKAL-10 composites

Sample No.	**Material removal rate (g/sec)**		
	KAL	**PKAL-5**	**PKAL-10**
1	0.1371	0.1835	0.1692
2	0.1413	0.2103	0.1619
3	0.1671	0.1927	0.1625
4	0.1658	0.1591	0.1341
5	0.1489	0.1455	0.1898
6	0.1387	0.2475	0.1549
7	0.0935	0.2449	0.125
8	0.1168	0.2305	0.1667
9	0.1385	0.1879	0.1536
10	0.1334	0.2196	0.1493
11	0.136	0.1604	0.1546
12	0.1428	0.2129	0.1738
13	0.1005	0.2336	0.1564
14	0.1517	0.1487	0.145
15	0.1335	0.1451	0.1402
16	0.1324	0.1723	0.0937
17	0.1409	0.2267	0.1761
18	0.1417	0.1811	0.1963
19	0.1387	0.1899	0.1974
20	0.1512	0.1809	0.1723

Table 3: Descriptive testgave mean, standard deviation and standard error for 0 wt.% Portunus filler, 5 wt.% Portunus filler, 10 wt.% Portunus filled kenaf fiber aluminium reinforced laminate.

MRR

	N	**Mean**	**Std. Deviation**	**Std. Error**
0 wt.% Portunus Filler	20	.137525	.0178689	.0039956
5 wt% Portunus Filler	20	.193655	.033099	.0074013
10 wt% Portunus Filler	20	.158640	.0245378	.0054868

DOI: 10.9756/INT-JECSE/V14I3.698

Total	60	.1632	.0345608	.0044618

Table 4: Anova test listedthe sum of squares, df, mean square and significance values for between groups, within groups and its total. The significance value is 0.000.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.032	2	.016	23.909	.002
Within Groups	.038	57	.001		
Total	.070	59			

Table 5: Multiple comparison tests gave the mean difference, the standard error and the significance values of all the comparisons among 0 wt.% Portunus Filler, 5 wt% Portunus Filler and 10 wt% Portunus Filler and all the comparisons are significant (p<0.005).

Dependent variable: MRR

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.
0 wt.% Portunus Filler	5 wt% Portunus Filler	-.0561300*	.0081996	.001
	10 wt% Portunus Filler	-.0211150*	.0081996	.001
5 wt% Portunus Filler	0 wt.% Portunus Filler	.0561300*	.0081996	.002
	10 wt% Portunus Filler	.0350150*	.0081996	.001
10 wt% Portunus Filler	0 wt.% Portunus Filler	.0211150*	.0081996	.002
	5 wt% Portunus Filler	-.0350150*	.0081996	.001

DOI: 10.9756/INT-JECSE/V14I3.698

Fig. 1. Kenaf fiber Aluminium reinforced laminate of (300 X 300 X 5 mm) fabricated by hand layup technique

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Fig. 2. The high-Speed Steel drill bit of Φ8mm

DOI: 10.9756/INT-JECSE/V14I3.698

Fig. 3. Radial-drilling machine: Drilling capacity - ⌀25 mm. Table size - 400 mm, Range of the speed 2000-rpm, Feed Rate-0.5 -1.5 mm/min, Depth of cut - 0.3 to 0.7 mm, Tool diameter- 10 mm

DOI: 10.9756/INT-JECSE/V14I3.698

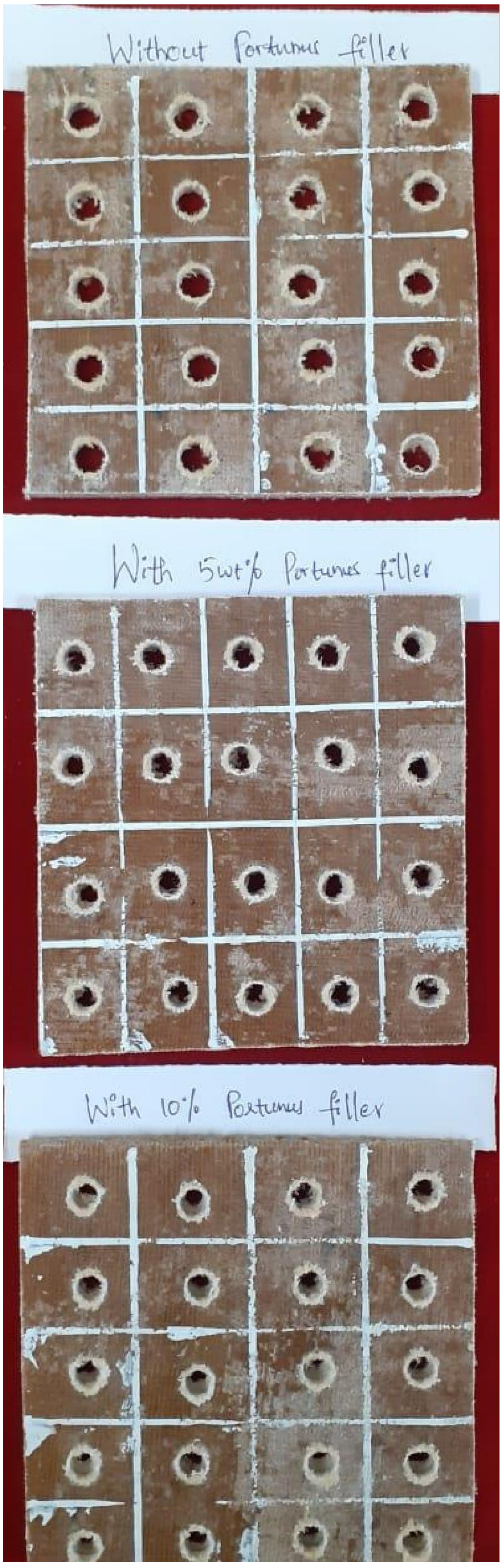

Fig. 4. Workpieces of KAL, PKAL-5 and PKAL-10 after drilling with varying Portunus filler inclusion (Without Portunus filler, with 5 wt.% Portunus filler and 10 wt.% Portunus filler)

DOI: 10.9756/INT-JECSE/V14I3.698

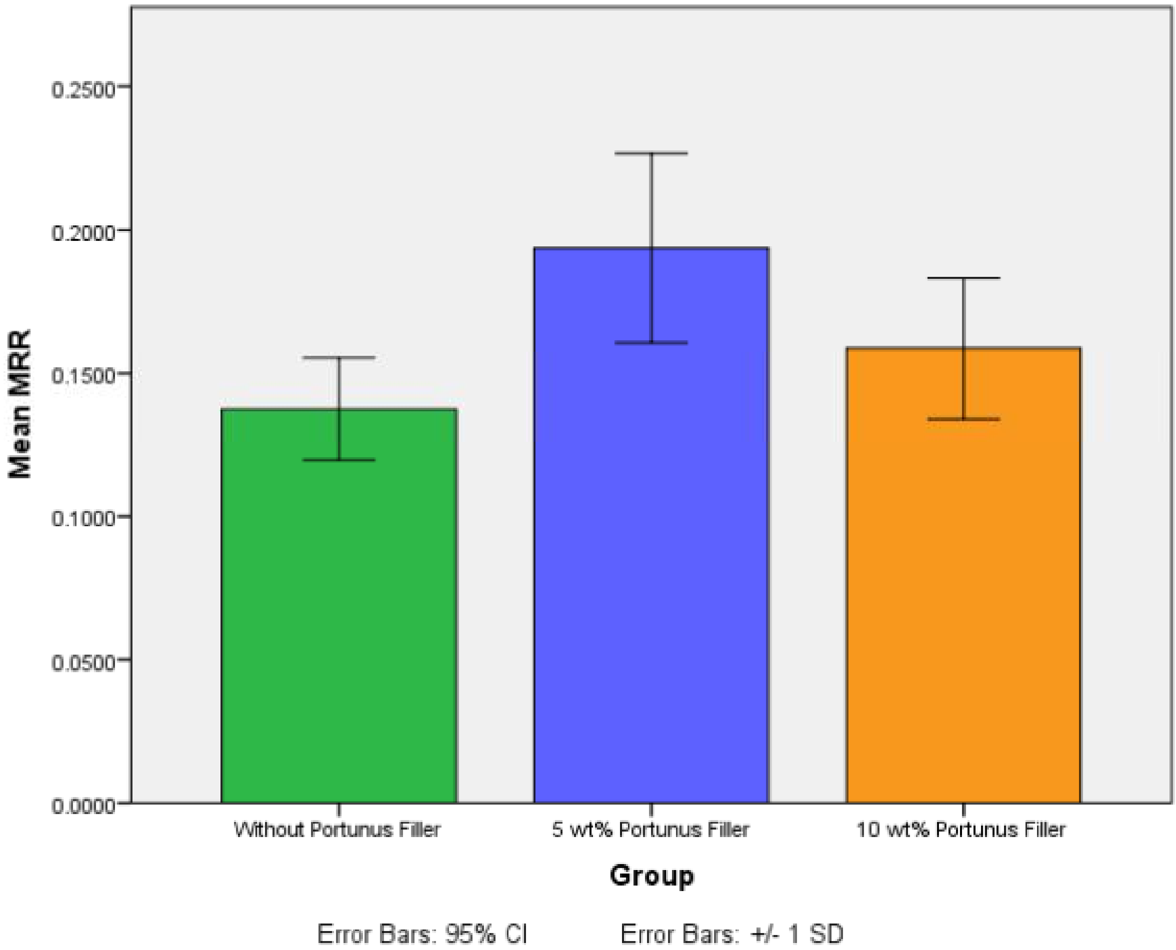

Fig. 5. Mean MRR obtained from the ANOVA test. The mean material removal rate for 5 wt.% Portunus filled kenaf fiber aluminium reinforced laminate is higher than the 10 wt.% Portunus filled and without filler composite. X-Axis: Kenaf fiber aluminium reinforced laminate vs Portunus filled kenaf fiber aluminium reinforced laminate. Y-Axis: Mean accuracy of detection $\pm$ 1 SD

DOI: 10.9756/INT-JECSE/V14I3.698

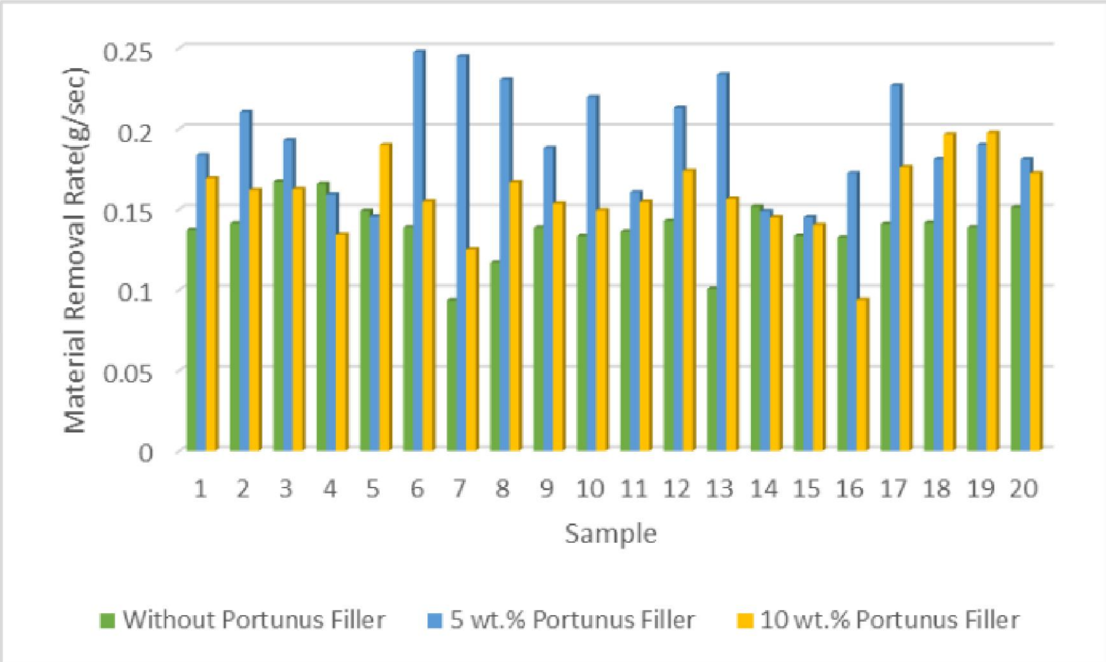

Fig. 6. Bar chart of MRR values for each sample of kenaf fiber aluminium reinforced laminates with varying Portunus filler inclusion (Without Portunus filler, with 5 wt.% Portunus filler and 10 wt.% Portunus filler)

DOI: 10.9756/INT-JECSE/V14I3.698