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Optimum Parameter Selection for Milling Different Laminate Composites Made by Hand Layup with CNC Milling Machine

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HIGHLIGHTS

- Fibers, metal and resin were made up together using mold and compression method.
- Hand layup was used and Taguchi method for obtaining the optimum parameter.
- The workpiece with most significant parameters is FG-Al with polyester resin.
- The best Ra after milling is for FG-Al, CF-Al with polyester resin.

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ABSTRACT

Recently, composite materials were widely used in different applications due to their lightweight, and good thermal and mechanical properties. In this study, an attempt to manufacture laminate composites by hand layup was performed. Also, optimal parameters for the best surface roughness were investigated. Therefore, three parameters had been examined; spindle speed, feed rate, and depth of cut. The L9 Taguchi orthogonal array, signal to noise (S/N) ratio, and analysis of variance (ANOVA) were selected to determine the optimum parameters. To create composites, the compression method was employed. Four different types of composites were manufactured with 2.8 mm thickness, to determine the effect of the parameters on the surface roughness and for specified parameters using the CNC milling machine. The weight fraction ratio of fibers was 39%, the polymer was 34%, and 27% for Aluminum. The results showed that the optimum parameters for surface roughness in milling machine of composites for Polyester resin for aluminum–fiberglass composite are; spindle speed=5000 r.p.m, feed rate=1600 mm/min, depth of cut=1.6 mm and Ra=1.853 µm, and for epoxy resin; aluminum–carbon fiber composite is spindle speed=4000 r.p.m, feed rate=800 mm/min, depth of cut=1.2 mm and Ra=2.43 µm.

1. Introduction

In this paper, the materials used were 6.35 mm thick aluminum and CFRP (Carbon fiber reinforced polymer) with and without PML thermal protection. The metal substrate was an aluminum alloy rolled plate (AA2024-T351) cut into 600 mm long, 50 mm wide test specimens. The CFRP was fabricated from unidirectional carbon fiber-epoxy prepreg tape. The advantage of the PML is that, in non-fire conditions, it contributes to the appearance and load-bearing capability of the structure without being prone to damage or water absorption [1]. The aluminum alloy 2024-0 sheets were used and unidirectional carbon fiber prepreg. The prepreg fiber was bonded to the two sheet metal layers. The FML was fabricated by a compression molding technique. The pressure was applied by placing a moderated load on it and cured at room temperature for 24 hours. the result of 1 mm/min in the plain weave CFRP has lower loading than unidirectional fiber [2]. To produce metallic-coated carbon fiber-based composites, a new innovative technique that combines Cold Spray and lay-up molding of composites are envisioned. This paper presents the experimental approach developed to produce metallic-coated carbon fiber reinforced composites and demonstrates the manufacturability of such components. The results produced show that it is possible to produce metalized composites of various shapes that are easily removable from the mold and have low porosity and high conductivity [3]. The authors in this paper evaluated laminate carbon bi-woven strands strengthened with vinyl ester composites. Vinylester polymer was utilized as the resin to manufacture composite. Composites were prepared to utilize the hand lay-up procedure. A mold was prepared. The closed mold was held under compression for 24hours at room temperature. To make sure that complete curing is done, the composite examples were post cured at 80˚C for 45min. The laminate composite examples with lesser thickness lead to the increasingly tensile strength of fiber directions. Young's modulus of examples increments with increment in laminated irrespective of its direction. Flexural strength and tensile were seen as

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improved up to layer-3 yet diminished a while later [4].The milling of composites is a hard process due to its heterogeneity and the wide types of issues, containing surface delamination, fiber pullout identified with the attributes of the material, and the cutting parameters that show up during the machining procedure. This paper depended on an arrangement of test dependent of Taguchi's L27 orthogonal arrays was set up and processing tests had been done for GFRP composite through the utilization of solid carbide end mill. The machining parameters which included, fiber direction angle, helix angle, spindle speed, and feed rate are optimized to limit the surface roughness, machining forces, and delamination factor. The objective was to set up a connection between cutting parameters and reactions. The relationship was gotten by utilizing numerous variable linear regressions through the use of Minitab 14 programming. The significant contribution of parameters is decided by utilizing analysis of variance (ANOVA) [5]. The workpiece material used was unidirectional GLARE (glass laminate reinforced epoxy) fiber metal laminate. Each glare sample consists of layers of aluminum 2024-T3 having a nominal thickness of 0.4064 mm and prepregs of S2-glass fibers with 0.133 mm. The samples were cured in an autoclave for around 300min at a temperature of 120°C and under the pressure of 6 bars. The results showed that during the machining process, the workpiece surface temperature increased with the increase in feed rate and fiber orientation influenced the developed temperature in the laminate [6]. The work presented in [7] used woven carbon fibers, woven E-glass strands, in EpoxAmite matrix, and hardener resin as the materials. The direction of woven carbon (C) and glass (G) fibers was organized in the grouping of [CGCG] these strands were stacked in the glass mold until thickness 4 mm has been accomplished and they were fixed and compacted with a vacuum sack under a vacuum from 11 to 15m bar. Response surface methodology (RSM) was used in finding the exact connections between test parameters and surface roughness dependent on the Taguchi results. The test examinations uncover that surface finish is incredibly affected by feed rate and tool geometry instead of the spindle speed. This research presented in [8] deals with a random arranged fiberglass example that has been set up so that the strands are in direct contact with the resin. Holes of different diameters were done (10, 12, 16 mm) by CNC processing machine, Taguchi structure with L9 orthogonal array is utilized for the analyses. The four parameters taken in the processing of fiberglass sheets are tool radius, cutting velocity, and depth of cutting and feeds. The optimization of parameters has been accomplished with the assistance of main effects plots using Taguchi Design and ANOVA tables to discover which parameter has affected the most for increasing the surface finish. The optimal parameters for the minimum surface roughness are the feed rate at 3 inches/min, the cutting speed at 1400 r.p.m, end mill diameter at 16 mm and the depth of cut at 2.5 mm. This exploration work desire to discover the machinability in processing way of GFRP laminates produced with the assistance of hand lay-up. An arrangement of analyses dependent on Taguchi was set up and the processing was performed with prefixed lessening parameters. An analysis of variance (ANOVA) has been utilized to explore the effect of cutting parameters on surface finish. The objective is to assess the machinability of GFRP laminate in normal for fiber direction (15°,60° and 105°) and solid carbide with mill gear about 25°, 35° and 45° helix demeanor and to ensure a useful machinability list. The results showed that GFRP composite with fiber orientation of 15° gives smaller values of Ra than 60° and 105°. Feed rate is the cutting parameter that has the highest effect as well statistical influence on Ra followed by the helix angle of the end mill cutter [9]. In the problem of laminate composites, the workpiece for the end milling experiments is fabricated using two layers of aluminum alloy 2024-T3 and 18 layers of unidirectional carbon fiber (UDCF) prepregs in 0∘, 45∘, and 90∘ directions, and the epoxy as matrix material. The CFRP-Aluminum composite laminates are fabricated using an autoclave process. During the fabrication, the UDCF prepregs are laminated and layered with Al 2024-T3 alternately. The machining operations are carried out using CNC Milling machine under dry conditions. An end mill tool was used in this experiment. The three important machining parameters in this experiment are cutting speed, feed rate, and depth of cut, which affected the surface roughness Ra. The surface roughness is better at high spindle speed, low feed rate, and low depth of cut. Feed rate has the most dominant factor in influencing the surface roughness Ra, followed by spindle speed [10]. The use of Taguchi enhancement system was explained by [11] in advancing the cutting parameters of milling processing for machining the halloysite nanotubes (HNTs) with aluminum fortified epoxy hybrid composites through the dry condition. The machining parameters are depth of milling, cutting velocity, and feeds. While the reaction variables to be estimated is the surface finish of the machined composite surface. An orthogonal array of the Taguchi technique was set up and used to investigate the impact of the processing parameters on the surface finish. The results indicated the best surface finish, depth of milling=0.4 mm, feeds=60mmpm, spindle speed=1500 r.p.m. The aim of the research is to manufacturing several types of laminate composite materials containing different percentages of carbon fiber and fiberglass which are used with common metals like aluminum, and as binder, epoxy resin, and polyester resin. And then run their grooves by the milling machine and with certain parameters including the spindle speed, feed rate, and depth of cut in the composite materials. By using Taguchi method and MINITAB 17, the optimum parameters were found for each type of composite.

2. Materials and method

In this research, the materials used were 0.1mm aluminum alloy 6061 as the metal and the common part in all types of composites, in addition to fibers; two types were chosen, continuous woven carbon fiber in (±60°, ±45°) orientation, shown in Figure 1 (a) and also chopped strand mat fiberglass VISION KATARA, shown in Figure 1 (b). Two types of polymer were used; the first one is Polyester which consists of two parts shown in Figure 1 (c). The second resin is Epoxy (Sikadur®-52) that is two parts, solvent-free, low viscosity as shown in Figure 1 (d).

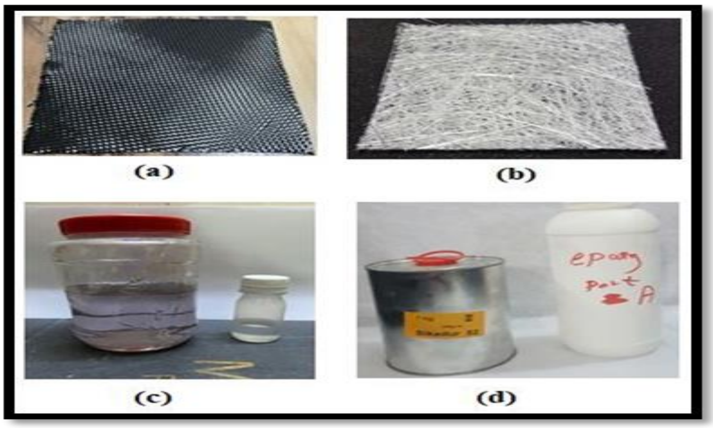

Figure 1: (a) woven carbon fiber, (b) random fiberglass, (c) polyester resin, (d) epoxy resin.

To get better stacking between the metal layer and the fiber layer, surface treatment is an important step. The aluminum surface is soft and smooth that will cause separation between layers, so it was roughened using an iron brush to make it less soften as illustrated in Figure 2. The compression method according to the researcher [10] was used to fabricate four specimens of laminate composites and both were made up manually with 100mm×100mm×2.8mm dimensions of the specimen. A fixed weight of fibers was used despite the difference in the number of layers in each composite due to the weight of two layers of fiberglass equals eight layers of carbon fibers. The method included compression of the samples in their mold at 500N force. Multiple Layers were stacked together in the two specimens depending on the weight of the fiber used as shown in Figure 3. The first specimen consists of three aluminum layers and four fiberglass layers with epoxy resin and another specimen with polyester resin with the same number of fiberglass layers, stacking sequence was in a certain order and different orientation angles as described in Table 1. The other specimens were made up of three layers of aluminum and sixteen layers of woven carbon fiber, once with epoxy resin and another with polyester resin. The releasing agent was applied to the glass mold to prevent the samples from sticking in the mold.

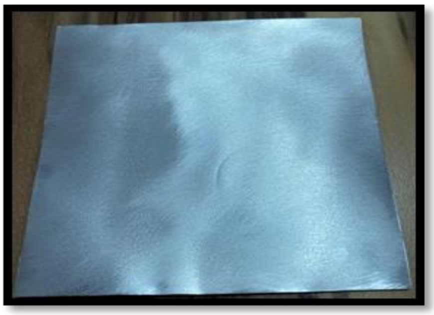

Figure 2: Aluminum sheet after surface treatment

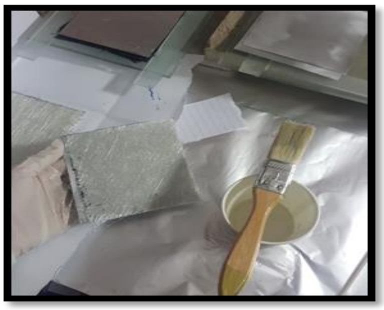

Figure 3: Fabrication of the composite specimens

Table 1: Stacking sequence of the specimens

Composite type	Aluminum-Fiber Glass 4 layers of fibers	Aluminum-Carbon Fiber 16 layers of fibers
Stacking sequence from bottom to top	aluminum sheet,	aluminum sheet,
	fiber glass,	+45, +60, -45, -60 carbon fiber,
	fiber glass,	+45, +60, -45, -60 carbon fiber,
	aluminum sheet,	aluminum sheet,
	fiber glass,	-60, -45, +60, +45 carbon fiber,
	fiber glass,	-60, -45, +60, +45 carbon fiber,
	aluminum sheet.	aluminum sheet.

By starting the fabrication, first start by applying some of the resin on the aluminum sheet and then on the fiber layer till the last layer of aluminum, after that the specimen is placed in the glass mold then put in the hydraulic press, at 500N for 12 hours. Then the specimen is left in the open air for 7 days for full solidification of the polymer. The four composites are shown in Figure 4. The weight fraction for each epoxy resin composites is 37% fibers (for either carbon fibers or fiberglass due to using a different number of layers but the same weight of fibers), 34% matrix, and 27% metal. The weight fraction for each polyester resin composites is 33% fibers (for either carbon fiber or fiberglass), 41% matrix, and 25% metal. Since the weight of fibers and metal is fixed for all composites the change will be in the weight of the epoxy resin or polyester resin that was used in each composite.

Figure 4: (a) carbon fiber – aluminum with polyester resin specimen, (b) fiberglass – aluminum with polyester resin specimen, (c) carbon fiber – aluminum with epoxy resin specimen, (d) fiberglass – aluminum with epoxy resin specimen

3. Experimental design

A vertical CNC milling machine model ACCUWAY UM-85, was used to perform the experimental work as shown in Figure 5. Uncoated carbide end mill cutter was used with a diameter 6mm; with four flutes, Figure 6 shows the end mill cutter.

Figure 5: CNC milling machine

Figure 6: End mill cutter with four flutes

3.1 Taguch design

After manufacturing the specimens, experiments are carried out to select the optimum parameters for each composite specimen. Using Design of Experiments (DOE) and Taguchi method to minimize experiments number and also to find the optimum parameter selection for the best surface roughness. In this study, L9 orthogonal array (OA) was used and three parameters with three levels were selected to apply on the composites. Table 2 describes the parameters and their levels.

Table 2: The parameters and their levels.

Parameter	Symbol	Level 1	Level 2	Level 3
Spindle speed (r.p.m)	A	3000	4000	5000
Feed rate (mm/min)	B	800	1200	1600
Depth of cut (mm)	C	1.2	1.6	2.0

3.2 Surface roughness

The surface roughness was calculated for nine experiments for each composite specimen using roughness measuring device POCKET SURF shown in Figure 7. Four values were taken to each groove square for each experiment, and then all measured roughness was analyzed using MINITAB 17 software to get the optimum parameters for surface finish.

Figure 7: Surface roughness device

4. Results and discussion

The objective of this experiment is to optimize the milling parameters to get minimum surface roughness of machined surface using the smaller the better characteristics, as in the equation below [10].

$$\frac{S}{N} = -10\log\left(\frac{1}{n}\sum_{i=1}^{n} x^2\right) \quad (1)$$

Where n is the number of observations and x is the observed data [10].

The most significant parameter defers in each composite type, yet feed rate affects the most in specimens with polyester resin. The feed rate and spindle speed affect the surface roughness of fiberglass laminates and carbon fiber laminates [8][12]. The specimens with epoxy resin once were affected with the spindle speed and another with the depth of cut as shown in Table 3. In general, average surface roughness was found to be reduced with the use of high cutting speed and low feed rate [13]. surface roughness is decreased when decreeing depth of cut [14].

Table 3: The final results for each parameter contribution after the milling process and rank for each composite

Parameter	Composite type	A	B	C	R-sq
Contribution & Rank Polyester resin	Aluminum – fiberglass (%)	4.01%	79.34%	16.64%	98.68%
	Rank	3	1	2	
	Aluminum – carbon fiber (%)	34.67	57.44	7.88%	96.70%
	Rank	2	1	3	
Contribution & Rank Epoxy resin	Aluminum – carbon fiber (%)	74.95%	3.05%	21.99%	94.13%
	Rank	1	3	2	
	Aluminum – fiberglass (%)	7.02%	25.99%	66.97%	91.07%
	Rank	3	2	1	

4.1 For Aluminum - Carbon fiber with epoxy resin composite

For the Aluminum – Carbon fiber composite with the epoxy specimen, the experiments were good in final square shape due to the compression method. In Figure 8, it's clear that in some experiments the small square was separated from the base of the composite because of the large amount of feed rat, and also the depth of cut influences on the milling process, the separation is distinct when the depth increases. All the experiments are good in final shape after milling, but in exp. 5 and exp. 7, separation occurs in the middle small square. The Top 10 layers were separated and the last layer to be seen is fiber as shown in Figure 8. The influence on the surface roughness for the experiments is listed in Table 4. From Figure 9 optimum parameters are A2B1C1(A2=4000 r.p.m, B1=800 mm/min, C1=1.2 mm) with Ra= 2.43 µm. From Tables 5, and 6 S/N ratios and ANOVA results, significant factors can be seen, F-value and contribution of each parameter are clear that Spindle speed is the most significant factor by 74%. Feed rate affects the lowest by 3%. Model summary of the process leads to that all the parameters can be effective due to R-sq is 94%.

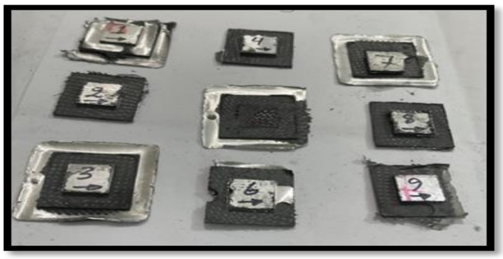

Figure 8: The impact of the nine experiments on the composite

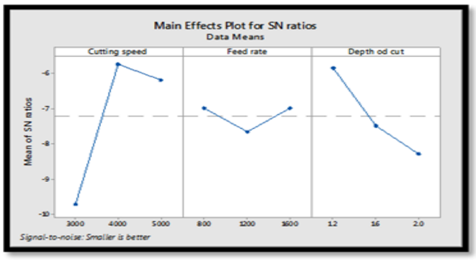

Figure 9: Plot effect for S/N ratios

Table 4: Results of surface roughness from experiments

Exp.	Spindle speed (r.p.m)	Feed rate (mm/min)	Depth of cut (mm)	Ra 1 (µm)	Ra 2 (µm)	Ra 3 (µm)	Ra 4 (µm)	Ra mean (µm)
#1	3000	800	1.2	1.58	1.75	3.18	3.01	2.38
#2	3000	1200	1.6	2.29	4.59	1.44	5.43	3.4375
#3	3000	1600	2	4.36	3.89	2.8	2.88	3.4825
#4	4000	800	1.6	1.82	2.46	1.61	2.16	2.0125
#5	4000	1200	2	3.59	1.6	1.56	1.88	2.1575
#6	4000	1600	1.2	1.4	1.73	1.64	1.91	1.67
#7	5000	800	2	3.3	2.69	1.57	1.75	2.3275
#8	5000	1200	1.2	1.97	1.9	1.67	2.05	1.8975
#9	5000	1600	1.6	0.9	3.18	1.58	2.02	1.92

Table 5: Response table for S/N ratios

Level	A	B	C
1	-9.698	-6.981	-5.850
2	-5.736	-7.656	-7.489
3	-6.189	-6.986	-8.285
Rank	1	3	2

Table 6: ANOVA Results for composite

Source	DF	Adj SS	Adj MS	F-Value	%Contribution
A	2	2.44652	1.22326	12.02	74.95%
B	2	0.09971	0.04986	0.49	3.05%
C	2	0.71788	0.35894	3.53	21.99%
Error	2	0.20350	0.10175		
Total	8	3.46761			

4.2 Confirmation test for Aluminum-Carbon fiber with epoxy by compression

Once the optimal level of the design parameters has been selected, the final step is to predict and verify the improvement of the quality characteristic using the optimal level of the design parameters. The estimated S/N ratio using the optimal level of the design parameters can be calculated as [8]:

$$\eta_{\text{predicted}} = \eta_m + \sum_{j=1}^{k} (\eta_j - \eta_m) \qquad (2)$$

Where ηm is the total mean of S/N ratio, ηj is the mean S/N ratio at the optimum level, k is the number of factors [7]. From S/N ratio calculations, it is observed that estimated S/N ratio and mean S/N ratio at the optimal level are almost the same which indicates that our experimental and results validate as illustrated in Table 7 and results of Eq. (2), the S/N ratio = -4.152, Ra experimental = 2.43 µm.

Table 7: Estimated S/N Ratio using the Optimum Level for Aluminum-Carbon fiber with epoxy

Optimum parameter	η_j	η_m	η_j-η_m
Spindle speed (A2)	-5.736	-7.207	1.471
Feed rate (B1)	-6.981	-7.207	0.226
Depth of cut (C1)	-5.850	-7.208	1.357
Sum	-18.567	-21.622	3.055

$\eta_{\text{predicted}}$ = -7.207 +3.055 = -4.152

4.3 For Aluminum – Carbon fiber with polyester resin composite

For Aluminum – Carbon fiber with polyester resin composite specimen, the experiments were good in final square shape due to the compression method. From Figure 10 the nine experiments are good in final shape, although some burr can be noticed in several experiments, no separation between layers occurred after machining in all the experiments. In Table 8 the experiments, input parameters, output parameters are listed clearly. The optimum parameters for this composite are A2B3C1 (A2=4000 r.p.m, B3=1600 mm/min, C1=1.2 mm) with Ra=1.875 µm, as illustrated in Figure 11. From Tables 9 and 10, S/N ratio and ANOVA results show the significant factors, F-value, and contribution of each parameter are clear that feed rate is the most significant factor by 57%. Depth of cut affects the lowest by 7%. Model summary of the process leads to that all the parameters can be effective due to R-sq is 96%.

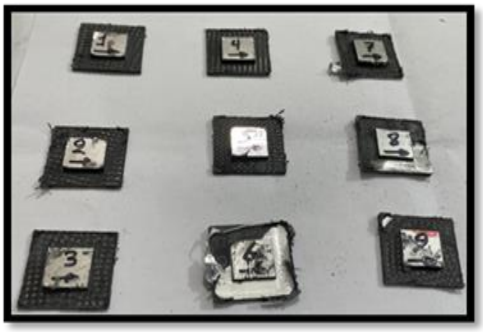

Figure 10: The impact of the nine experiments on the composite

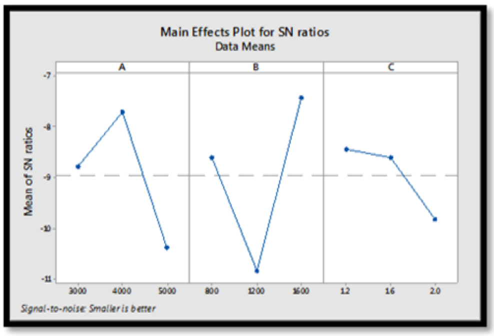

Figure 11: Effect plot for S/N ratios

Table 8: Results of surface roughness from experiments

Exp.	Spindle speed (r.p.m)	Feed rate (mm/min)	Depth of cut (mm)	Ra 1 (µm)	Ra 2 (µm)	Ra 3 (µm)	Ra 4 (µm)	Ra mean (µm)
#1	3000	800	1.2	2.87	2.1	2.03	2.71	2.4275
#2	3000	1200	1.6	2.31	4	2.5	3.99	3.2
#3	3000	1600	2	1.47	3.07	1.61	4.54	2.6725
#4	4000	800	1.6	2.48	2.06	2.33	2.54	2.3525
#5	4000	1200	2	2.28	4.82	Hi	2.64	3.2466
#6	4000	1600	1.2	0.2	1.85	4.12	1.33	1.875
#7	5000	800	2	2.84	2.68	5.58	2.6	3.425
#8	5000	1200	1.2	1.96	Hi	5.42	4.8	4.06
#9	5000	1600	1.6	1.75	1.81	4.01	2.83	2.6

Table 9: Response table for the Signal to Noise Ratios

Level	A	B	C
1	-8.782	-8.609	-8.445
2	-7.706	-10.834	-8.611
3	-10.388	-7.433	-9.820
Rank	2	1	3

Table 10: ANOVA Results for composite

Source	DF	Adj SS	Adj MS	F-Value	%Contribution
A	2	1.1872	0.59359	10.17	34.67%
B	2	1.9667	0.98333	16.85	57.44%
C	2	0.2698	0.13488	2.31	7.88%
Error	2	0.1167	0.05837		
Total	8	3.5404			

4.4 For Aluminum – Fiberglass with epoxy resin

For Aluminum – Fiberglass with epoxy resin composite specimens, the experiments were good in final square shape due to the compression method. Although some burr can be noticed in several experiments, no separation between layers occurred after machining in all the experiments occurred as in Figure 12. In Table 11 the experiments, input parameters, output parameters are listed clearly. The optimum parameters for this composite are A1B1C1 as in Figure 13. From Tables 12and 13, the S/N and ANOVA results are shown, significant factors can be seen, F-value and contribution of each parameter are clear that depth of cut is the most significant factor by 66%. Depth of cut affects the lowest by 7%. Model summary of the process leads to that all the parameters can be effective due to R-sq is 91%.

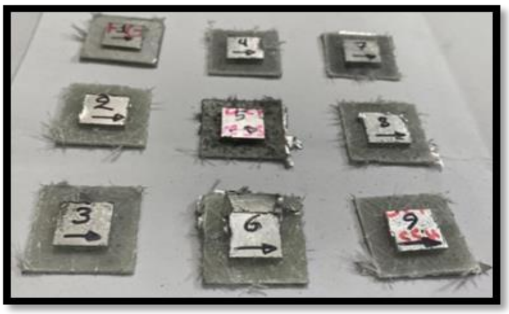

Figure 12: The impact of the nine experiments on the composite

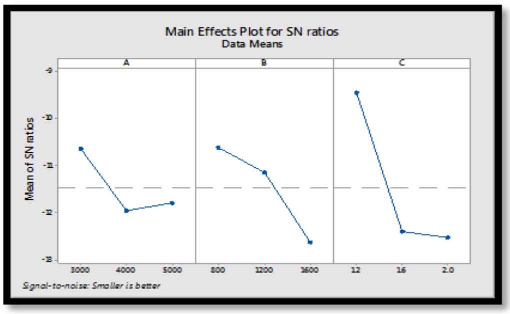

Figure 13: Effect plot for S/N ratios

Table 11: Results of surface roughness from experiments and predicted

Exp.	Spindle speed (RPM)	Feed rate (mm/min)	Depth of cut (mm)	Ra 1 (µm)	Ra 2 (µm)	Ra 3 (µm)	Ra 4 (µm)	Ra mean (µm)
#1	3000	800	1.2	3.71	1.61	2.14	1.59	2.2625
#2	3000	1200	1.6	3.95	3.81	3.69	3.21	3.665
#3	3000	1600	2	3.35	5.26	5.11	5.38	4.775
#4	4000	800	1.6	4.44	5.02	4.83	3.08	4.3425
#5	4000	1200	2	4.47	2.88	2.85	5.72	3.98
#6	4000	1600	1.2	3.25	4.51	3.41	3.23	3.6
#7	5000	800	2	5.11	4.31	3.61	2.92	3.9875
#8	5000	1200	1.2	4.97	2.69	2.64	2.61	3.2275
#9	5000	1600	1.6	5.11	4.63	2.84	5.7	4.57

Table 12: Response table for Signal to Noise Ratios

Level	A	B	C
1	-10.651	-10.620	-9.465
2	-11.960	-11.152	-12.412
3	-11.797	-12.635	-12.530
Rank	3	2	1

Table 13: ANOVA Results for composite

Source	DF	Adj SS	Adj MS	F-Value	%Contribution
A	2	0.2977	0.1488	0.72	7.02%
B	2	1.1009	0.5504	2.65	25.99%
C	2	2.8367	1.4184	6.83	66.97%
Error	2	0.4151	0.2075		
Total	8	4.6504			

4.5 For Aluminum – Fiberglass with polyester resin

For Aluminum – Fiberglass with polyester resin composite specimen, the experiments were good in final square shape due to compression method as in Figure 14. Although some burr can be noticed in several experiments, separation occurs in Exp. 1, and the last layer is the metal, which means the top 3 layers were separated from the original square. In Table 14 the experiments, input parameters, output parameters are listed clearly. The optimum parameters for this composite are A3B3C2 as illustrated in Figure 15. From Tables 15 and 16 the S/N ratios and ANOVA results identified the significant factors, F-value, and contribution of each parameter is clear that feed rate is the most significant factor by 79%. Spindle speed affects the lowest by 4%. Model summary of the process leads to that all the parameters can be effective due to R-sq is 98%.

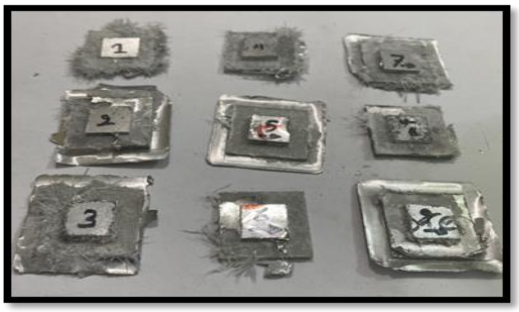

Figure 14: The impact of the nine experiments on the composite

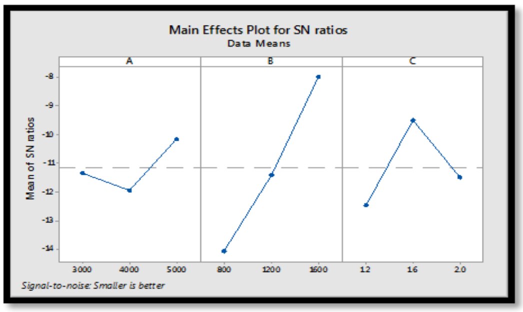

Figure 15: The effect plot for S/N ratios

Table 14: Results of surface roughness from experiments and predictions

Exp.	Spindle speed (RPM)	Feed rate (mm/min)	Depth of cut (mm)	Ra 1 (µm)	Ra 2 (µm)	Ra 3 (µm)	Ra 4 (µm)	Ra mean (µm)
#1	3000	800	1.2	Hi	6.31	5.57	Hi	5.94
#2	3000	1200	1.6	3.12	3.28	1.32	5.04	3.19
#3	3000	1600	2	Hi	2.58	1.73	3.67	2.66
#4	4000	800	1.6	4.54	6.22	2.94	Hi	4.566
#5	4000	1200	2	6.34	4.85	3.72	1.88	4.197
#6	4000	1600	1.2	3.96	2.54	4.11	2.36	3.242
#7	5000	800	2	5.83	6.37	Hi	2.09	4.763
#8	5000	1200	1.2	2.2	4.1	5.23	Hi	3.843
#9	5000	1600	1.6	0.23	1.51	2.42	3.18	1.853

Table 15: Response table for Signal to Noise Ratios

Level	A	B	C
1	-11.350	-14.075	-12.462
2	-11.956	-11.410	-9.514
3	-10.175	-7.996	-11.505
Rank	3	1	2

Table 16: ANOVA Results for composite

Source	DF	Adj SS	Adj MS	F-Value	%Contribution
A	2	0.4794	0.23968	3.01	4.01%
B	2	9.4730	4.73649	59.47	79.34%
C	2	1.9872	0.99361	12.48	16.64%
Error	2	0.1593	0.07964		
Total	8	12.0988			

5. Conclusion

Different laminated composite material manufacturing was successful using the mold and compression method. The cohesion between the metal and the fiber was good in the final workpiece. The best specimen with the most significant parameters is Aluminum – Fiberglass with polyester resin, the optimum parameters, spindle speed, feed rate, depth of cut are 5000RPM, 1600mm/min, 1.6mm respectively. After that Aluminum – Carbon fiber with polyester resin comes the second to the effect of parameters. The optimum parameters, spindle speed, feed rate, depth of cut is 4000RPM, 1600mm/min, 1.2mm respectively. For Aluminum – Carbon fiber, and Aluminum – Fiberglass both with epoxy resin specimens the parameters was less significant to the surface finish. the parameters, spindle speed, feed rate, depth of cut for each specimen are 4000RPM, 800mm/min, 1.2mm and 3000RPM, 800mm/min, 1.2mm respectively.

Author contribution

All authors contributed equally to this work.

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Data availability statement

The data that support the findings of this study are available on request from the corresponding author.

Conflicts of interest

The authors declare that there is no conflict of interest.

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