Journal of Engineering and Applied Sciences 12 (9): 2521-2524, 2017
ISSN: 1816-949X

Edges Trimming Parameter Optimizations of Hybrid Composite CFRP/AL2024

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Abstract: The application of composite materials is extensively used in automotive and aerospace industries due to their high strength and light weight. Adversely, machining of such material is extremely challenging because of its inhomogeneous nature, anisotropic and abrasive characteristic. Service life and performance of a component is highly dependent on the quality of machined surface produced. An experimental investigation is conducted to determine the effect of the cutting parameter: Spindle speed (N) feed rate (f_r) and depth of cut (d_c) on the surface of a machined CFRP/Al2024 hybrid composite material. Machining operation used is edge trimming using Kennametal burr tool of 6 mm diameter and the machining method is up milling. The aim of the experiment is to set optimum cutting parameters for obtaining quality machined surface. Surface quality was quantified based on surface roughness. Result showed that spindle speed is the most significant effect on surface finish followed by feed rate and depth of cut. The best surface finish between 1-2 μm can be obtained by the combination of N = 2330 rpm, f_r = 500 mm/min and d_c = 0.01 mm. The validation test showed average deviation of predicted to actual value of surface roughness is 6.8% for Al 2024 and 7.25% for CFRP.

Key words: Hybrid composite, surface roughness, edges trimming, inhomogeneous nature, abasive characteristic

INTRODUCTION

The demand for hybrid composite has increased extensively because of their high specific strength, high rigidity and light weight particularly for aerospace and automotive industries. Moreover, it also offers good thermal resistance, corrosion resistance, damping resistance and dimensional stability. Performance and reliability of machined components generally depend on the quality of machined surface. A characteristic can influence the performance of mechanical parts and production costs. Various failures, sometimes catastrophic which leading to high costs have been attributed to the surface finish of the components. For these reasons, there have been research developments with the objective of optimizing the cutting conditions to obtain a good surface finish (Rajpoot *et al*., 2015; Pragnesh and Patel, 2012; Debnath *et al*., 2016; Patel *et al*., 2012). Even though, composite components are produced near-net shape, finishing operations are still required in order to meet the dimensional specifications for assembly with other components.

Obviously for CFRP/Al2024 composites material, integrating into one single machini ng operation has proved to be more challenging and becoming a major concern in the machining industries. The anisotropic and non-homogeneous structure of CFRP and ductile nature of aluminium have introduced several types of damages like matrix cracking and thermal alterations, fibre pullout and fuzzing during drilling and trimming which affect the quality of machined surface (Zubillaga *et al*., 2015). The composites behaviour is not only being non-homogenous and anisotropic but it also conveys diverse reinforcement and matrix properties and the volume fraction of matrix and reinforcement. The tool encounters alternatively matrix and reinforcement materials which response to

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machining can be utterly different (Kumar and Singh, 2015). Secondary processing of machining such as trimming to final shape and drilling is typically essential to facilitate component assembly as it exhibits surface roughness of the workpiece. Surface roughness and tolerance are closely related and it is generally necessary to specify a smooth finish to maintain a fine tolerance in the finishing process.

For many practical design applications, tolerance and strength requirements impose a limit on the maximum allowable roughness (Mathivanan *et al*., 2016). Thus, machining of composite materials enforces special demands on the optimisation of influence and interaction of cutting parameters in order to minimise the defects of the surface produced by machining which can drastically affect the strength and chemical resistance of the material.

Many of these problems occurred were inappropriate used of various cutting tool designs materials and cutting parameters. Some research experiments have been conducted to investigate the influence and interaction of cutting materials and cutting parameters, namely spindle speed, feed rate and depth of cut on surface roughness in drilling (Krishnaraj *et al*., 2012) turning (Kumar *et al*., 2012) milling and trimming (Mohamed *et al*., 2015; Haddad *et al*., 2013) operation.

Thus, the research project aims to set the optimum cutting parameters for obtaining quality machined surface of CFRP/Al2024 using two level full factorial design experimental approach. This research project has three objectives. Firstly to perform the edges trimming process via conventional up milling using kennametal burr tool. The second objective is to statistically analyse the influence and interaction of cutting parameters. Thirdly is to optimize machining parameters in order to obtain the machined surface quality of CFRP/Al2024 between 1-2 μm.

MATERIALS AND METHODS

Carbon prepreg of 16 layers with 4.0 mm thickness and aluminium alloy 2024 have been used to form a hybrid stack of 5.2 mm thickness. The lay-up sequence of the unidirectional CFRP prepregs $[90/-45/0/45/90/ 45/0/45]_s$ was adopted to get a symmetric stacking (Mohamed *et al*., 2015). Machining operation was conducted under dry cutting conditions on Mori Seiki NV4000 DCG milling machine using Kennametal burr tool of 6 mm in diameter as depicted in Fig. 1. In this research, up milling method for trimming operation has for CFRP responses,

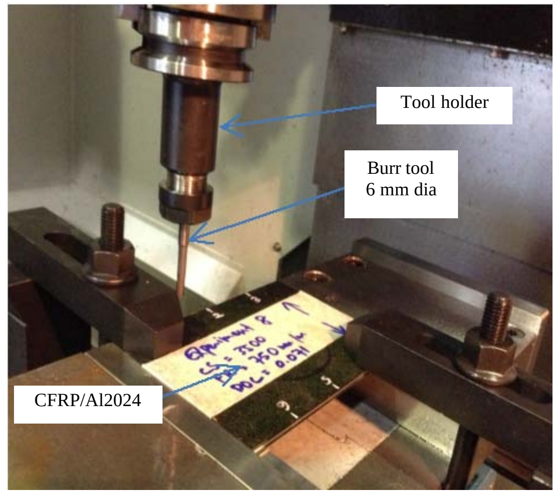

Fig. 1: Experimental set-up

Table 1: Control factors and their levels

Factors	Min.	Max.
Spindle speed (rpm)	1000.00	3500.0
Feed rate (mm/min)	500.00	1000.0
Depth of cut (mm)	000.01	000.5

it was noticed it is notice that the been adopted to achieve the optimal cutting parameter setting. The value of control factors and design matrix used for carrying out trimming operations was given in Table 1. Total eight of runs were performed for this experiment. The surface roughness was measured using mitutoyo SJ 301 with a sampling length cut off, λ of 0.8 mm. To reduce the systematic errors, surface roughness has been measured 5 times along the feed direction of machined surface. The data set then was Analyzed using Analysis of Variance (ANOVA) as to determine a significant effect factors and interaction between variables.

RESULTS AND DISCUSSION

For the purpose of analysis, the measure ments measurement of surface roughness for CFRP and Al2024 are recorded separately. The results of the experiment are shown in Table 2.

From the ANOVA (Table 3) for both of CFRP and Al2024 surface roughness, the model indicates significant effect since the Prob>F value 0.0100 and 0.0114, respectively. These values are less than significant level value of 0.05. The model term refers to A-C that is spindle speed, feed rate and depth of cut. The ANOVA Table 3 shows that the response surface roughness for CFRP and Al2024 mainly depends on individual effect of the factors and not on the interaction effect of the factors. For CFRP responses, it was noticed that the factor A which is spindle speed is the most prominent factor affecting the surface roughness rather than factor Table 4-7 shows a list of optimum combination parameter range where the desire Ra of between 1-2 μm can be achieved. The combination B and C which are feed rate and depth of cut. The same indication obtained for Al2024 where factor aroughness. It is also found that examination of the fit summary output revealed that the linear modelis statistically significant for both responses. The empirical relationship of response surface roughness for up milling and for the control factors is given:

$$\text{Surface roughness of CFRP} = +1.34422 - 2.89020E - 004 \times N + 3.32400E - 003 \times f_r + 3.47755 \times d_c - 7.84000E - 007 \times N \times f_r - 4.97959E - 004 \times N \times d_c \quad (1)$$

$$\text{Surface roughness of Al2024} = +3.13543 - 6.64000E - 004 \times N + 2075951E - 003 \times f_r - 0.14286 \times d_c - 8.6400E - 007 \times N \times f_r + 4.44898 - 003 \times f_r \times d_c \quad (2)$$

Optimization and validation: Figure 2 show the optimal region under consideration with the range of Ra between

Table 2: Design matrix

Runs	Spindle speed (rpm)	Feed rate (mm/min)	DOC (mm)	Surface roughness, Ra (μm) CFRP	Al2024
1	3500	500	0.01	0.68	0.74
2	3500	1000	0.01	0.88	0.77
3	1000	500	0.50	3.68	4.50
4	3500	500	0.50	1.45	1.67
5	1000	500	0.01	2.48	3.40
6	1000	1000	0.01	3.49	4.23
7	1000	1000	0.50	5.21	6.70
8	3500	1000	0.50	1.82	2.52

Table 3: ANOVA table for the average surface roughness CFRP

Variables	Sum of squares	df	Mean square	F-values	p-values prob.>F	Results
Model	17.150	5	3.430	099.570	0.0100	Significant
A-spindle speed	12.600	1	12.600	365.750	0.0027	Significant
B-feed rate	1.220	1	1.220	035.320	0.0272	Significant
C-depth of cut	2.670	1	2.670	077.450	0.0127	Significant
AB	0.480	1	0.480	13.940	0.0648	
AC	0.190	1	0.190	05.400	0.1457	
Residual	0.069	2	0.034			

SD = 0.12; Mean = 2.46; R^2 = 0.9960; Pred R^2 = 0.9860; Adj. R^2 = 0.9360

Table 4: ANOVA table for the average surface roughness Al2024

Variables	Sum of squares	df	Mean square	F-values	p-values prob.>F	Results
Model	29.49	5	5.900	86.75	0.0114	Significant
A-spindle speed	21.52	1	21.520	316.42	0.0031	Significant
B-feed rate	1.90	1	1.900	27.96	0.0340	Significant
C-depth of cut	4.90	1	4.900	72.04	0.0136	Significant
AB	0.58	1	0.580	8.58	0.0995	
AC	0.59	1	0.590	8.74	0.0979	
Residual	0.14	2	0.068			

SD = 0.26; Mean = 3.07; R^2 = 0.9954; Pred R^2 = 0.9266; Adj. R^2 = 0.9839

Table 5: Optimal solution

Names	Goal	Lower limit	Upper limit	Lower weight	Upper weight	Importance
A: spindle speed	Is in range	1000.00	3500.0	1	1	3
B: feed rate	Is in range	500.00	1000.0	1	1	3
C: DOC	Is in range	0.01	0.5	1	1	3
Ra CFRP	Is in range	1.00	2.0	1	1	3
Ra Al2024	Is in range	1.00	2.0	1	1	3

Table 6: Optimum parameters

Numbers	Spindle speed (N)	Feed rate (f_r)	Depth of cut (d_c)	Ra CFRP	Ra Al2024	Desirability
1	2330	500	0.010	1.454	2.000	0.949
2	2335	503	0.012	1.456	2.000	0.947

Table 7: Optimization of cutting parameters and percentage deviation from actual value

Run No.	Samples	Spindle speed (N) (rpm)	Feed rate (f_r) (mm/min)	Depth of cut (dc) (mm)	Measured Ra (μm)	Prediction Ra (μm)	Error	Error (%)
1	CFRP	2330	500	0.010	1.356	1.454	0.098	7.2
	Al 2024				1.865	2.000	0.135	7.2
2	CFRP	2335	503	0.012	1.356	1.456	0.100	7.3
	Al 2024				1.880	2.000	0.120	6.4

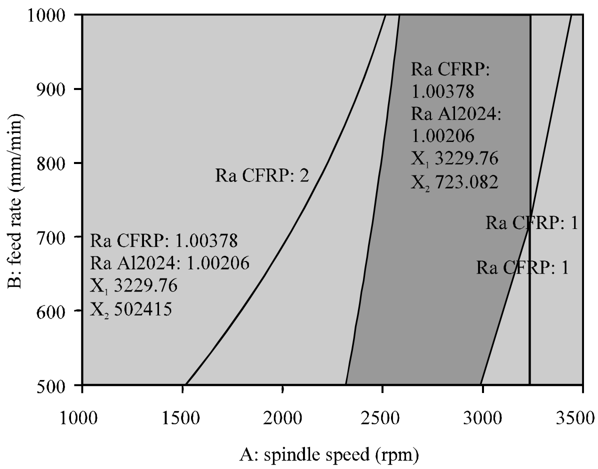

Fig. 2: Overlay plot; Design-expert® Software; factor coding: actual overlay plot; Ra CFRP; Ra AI2024; X_1 = A: spindle speed; X_2 = B: Feed rate; Actual factor; C: depth of cut = 0.01009327

1-2 μm. The shaded area is the specific range of feed rate and spindle speed that meet the response with 0.01 mm depth of cut. Thus, the range of feed rate and spindle speed for a desired Ra fall between the 500-1000 mm/min the and 2317-3229 RPM, respectively and parameter of No. 1 and 2 was selected due to highest desirability score for validation test (Fig. 2).

CONCLUSION

The results showed that the spindle speed is found to be the most significant effect of surface roughness for both CFRP and Al2024. Surface roughness decreases when there is an increase of spindle speed and feed rate.

Spindle speed is the most prominent factors affecting surface roughness for both CFRP and Al2024. Best cutting condition for surface quality is high spindle speed and low feed rate. The worst cutting condition is low spindle speed and high feed rate. As to achieve the surface roughness of between 1 μm, the best setting was suggested to trim at N of 2330 rpm, f_r of 500 mm/min and d_c of 0.01 mm. The validation test (Table 5) showed the of percentage error of >10% have been obtained.

ACKNOWLEDGEMENT

The researcher would like to thank Universiti Sultan Zainal Abidin for funding of this research project (Unisza/12/GU/020).

REFERENCES

Debnath, S., M.M. Reddy and Q.S. Yi, 2016. Influence of cutting fluid conditions and cutting parameters on surface roughness and tool wear in turning process using Taguchi method. Meas., 78: 111-119.

Haddad, M., R. Zitoune, F. Eyma and B. Castanie, 2013. Machinability and surface quality during high speed trimming of multi directional CFRP. Intl. J. Mach. Mach. Mater., 13: 289-310.

Krishnaraj, V., R. Zitoune and F. Collombet, 2012. Study of drilling of multi-material (CFRP-Al) using Taguchi and statistical techniques. Usak Univ. J. Mater. Sci., 1: 95-109.

Kumar, D. and K.K. Singh, 2015. An approach towards damage free machining of CFRP and GFRP composite material: A review. Adv. Compos. Mater., 24: 49-63.

Kumar, S., P.S. Satsangi and H.K. Sardana, 2012. Optimization of surface roughness in turning unidirectional glass fiber reinforced plastics (UD-GFRP) composites using Polycrystalline Diamond (PCD) cutting tool. Indian J. Eng. Mater. Sci., 19: 163-174.

Mathivanan, N.R., B.S. Mahesh and H.A. Shetty, 2016. An experimental investigation on the process parameters influencing machining forces during milling of carbon and glass fiber laminates. Meas., 91: 39-45.

Mohamed, S.B., W.N.F. Mohamad, B.S. Yew, M. Minhat and M.S. Kasim et al., 2015. Machining parameter optimisation in a milling machine using two level full factorial design. Appl. Mech. Mater., 789: 105-110.

Patel, P.R. and V.A. Patel, 2012. Effect of machining parameters on surface roughness and power consumption for 6063 Al alloy TiC composites (MMCs). Intl. J. Eng. Res. Appl., 2: 295-300.

Rajpoot, B.S., D.R. Moond and S. Shrivastava, 2015. Investigating the effect of cutting parameters on average surface roughness and material removal rate during turning of metal matrix composite using response surface methodology. Intl. J. Recent Innovation Trends Comput. Commun., 3: 241-247.

Zubillaga, L., A. Turon, J. Renart, J. Costa and P. Linde, 2015. An experimental study on matrix crack induced delamination in composite laminates. Compos. Struct., 127: 10-17.