ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com
International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 3, Special Issue 2, March 2016

Study of Surface Roughness Characteristics of Drilled Hole in Glass Fiber Reinforced Plastic (GFRP) by CNC Milling

S.Anandagiri
Mechanical Engineering SRM
UNIVERSITY, Ramapuram Chennai

ABSTRACT
Now-a-days glass fiber-reinforced plastics (GFRP) are always applicable in variety of engineering applications. It is used in aerospace, automotive and aircraft industries due to their well known properties. Milling of GFRP composite materials is very difficult due to its heterogeneity and the number of troubles like as surface delamination during machining affects uniqueness of the material and the machining parameters. Present paper focuses the experimental details to find out delamination factor on GFRP composite laminates by using Taguchi"s DOE L9 orthogonal array. The main objective of the present work is to optimize the process parameters in the drilling of GFRP composite using Taguchi DOE and to find the significance of each process parameter using ANOVA. As far as the effect of input factors are considered, the factors drilled material and spindle speed both have nearly predominant influence on the delamination factor of drilled holes on GFRP composite by using CNC milling process.

Keywords: ANOVA, CNC Milling, GFRP Composite, Surface Roughness, Taguchi DOE.

I. INTRODUCTION

Milling is the common frequently used machining operation in manufacturing parts of fiber reinforced plastics, because components made of composites are commonly produced by netshape components that often require the removal of excess material to control tolerances, and milling is used as a curative operation to produce well-defined and high quality surfaces.

Now a day, glass fibre-reinforced plastics (GFRP) are being widely used in variety of engineering applications in many different fields such as aerospace, automotive and aircraft industries due to their light weight, high modulus, high specific strength and high fracture toughness. Much of the literature reported on milling of GFRP material by conventional tools has shown that the quality of the cut surface especially drilled hole is strongly dependent on the cutting parameters, tool geometry, tool material, work piece material, machining process, etc.

Milling of GFRP composite materials is a rather complex task owing to its heterogeneity and the number of problems, such as surface roughness and delamination of drilled hole, which appear during the machining process, associated with the characteristics of the material and the cutting parameters. An improper selection of these parameters can lead to unacceptable material degradation, such as fiber pull out, matrix cratering, thermal damage and widespread delamination.The main objective of the present work is to optimize the process parameters in the drilling of GFRP composite using Taguchi DOE and to find the significance of each process parameter using ANOVA. In the present work, statistical analysis software MINITAB 16 is used to perform the Taguchi and ANOVA analysis. Taguchi design with L9 orthogonal array is employed. The response variable chosen is surface roughness of the drilled GFRP components. For measuring machined surface characteristics contact measurement technique is considered. The main objective of the work is to find out roughness of drilled GFRP substrate"s hole. Following paragraphs shows some of the recent key publications on machining of GFRP.

II. LITERATURE REVIEW

P. Praveen Raj et al. (2010) studied the surface roughness, precision and delamination factor in use of Ti-Namite carbide K10 end mill, Solid carbide K10 end mill and Tipped Carbide K10 end mill. A plan of experiment based on Taguchi was established with prefixed cutting parameters and the machining was performed [3]. Author examined that the depth of cut are recognized to make the most significant contribution to the overall performance as compared to cutting velocity and feed rate. The factors which lead to the surface delamination existing in milling carbon fiber reinforced plastic (CFRP) with PCD tool have been studied by Yong Guo Wang et al. (2011) [4]. The surface delamination is summarized by analyzing the experiment results based on studying cutting velocity and cutting feed. Experimental results show that the increasing cutting feed leads to the increment of cutting force which in turn causes the increasing delamination of CFRP materials. B. Ramesh et al. (2012) examined a non-laminated GFRP composite manufactured by pultrusion process

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com
International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 3, Special Issue 2, March 2016

was drilled with coated cemented carbide drill [5]. The thrust force and torque during drilling examined by piezoelectric dynamometer. Taguchi‟s OA and analysis of variance (ANOVA) were employed to study the influence of process parameters such as feed and spindle speed on the force and torque.

M. P. Jenarthanan et al. (2013) used Taguchi‟s L27 orthogonal array, milling experiments were conducted for GFRP composite plates using solid carbide end mills with different helix angles [6]. The machining parameters such as, spindle speed, feed rate, helix angle and fibre orientation angle are optimized by multi-response considerations namely surface roughness, delamination factor and machining force. N. Naresh et al. (2013) conducted an experiment by using Taguchi‟s L27 orthogonal array on milling with prefixed cutting parameters for GFRP composite plates using solid carbide end mills [7]. The machining parameters such as, and fibre orientation angle, helix angle, spindle speed and feed rate are optimized with the objective of minimizing the surface roughness, machining force and delamination factor. GDilli Bab et al. (2013) used Taguchi techniques and on the analysis of variance (ANOVA), was established considering milling with prefixed cutting parameters in Natural Fiber- Reinforced Plastic (NFRP) composite materials using cemented carbide end mill [8]. The results of NFRP composite were compared with Glass Fiber- Reinforced Plastic (GFRP) composites. Xuda Qin et al. (2014) conducted a full factor experimental design, helical milling experiments were performed by using a special cutter. Using the data obtained from the experiments, the correlation between the delamination and the process parameters was established by developing an artificial neural network (ANN) model [9]. Vinod Kumar Vankanti et al. (2014) carried out experiment as per the Taguchi experimental design and an L9 orthogonal array was used to study the influence of various combinations of process parameters on hole quality [10]. Analysis of variance (ANOVA) test was conducted to determine the significance of each process parameter on drilling.

III. EXPERIMENTAL DETAILS

Experimental plan

For conducting the experiments Taguchi L9 (3^4) array is selected. In this array, the numbers of factors are 4 and the numbers of levels are 3. However total numbers of runs are 9. Therefore, numbers of factor selected for the experiments are feed rate (100-140-180mm/min), spindle speed (600-800-1000 rpm), diameter of drill (9-9.5-11.5 mm) and drill material (HSS.M2-HSS.M42-Carbide). Table (1) shows the actual experimental run with L9 orthogonal array and Table (2) shows the input parameters and their setting for experiment. Roughness (*Ra*) of drilled hole is selected as a response variable for the experiment.

Table (1):- Actual experimental design

Parameters	Settings		
	Level 1	Level 2	Level 3
Drill Material	HSS.M2	HSS.M42	Carbide
Feed Rate (mm/min)	100	140	180
Spindle Speed (rpm)	600	800	1000
Drill Diameter (mm)	9	9.5	11.5

Table (2):- Input parameters and their levels of setting for experiment

Expt. Runs	Drill Diameter (mm)	Spindle Speed (rpm)	Feed Rate (mm/min)	Drill Material
1	9	600	100	HSS.M2
2	9	800	140	HSS.M42
3	9	1000	180	Carbide
4	9.5	600	140	Carbide
5	9.5	800	180	HSS.M2
6	9.5	1000	100	HSS.M42
7	11.5	600	180	HSS.M42
8	11.5	800	100	Carbide
9	11.5	1000	140	HSS.M2

Tooling measurements

The preparation of the experiment started with the cutting of nine work pieces to the required size from a plate of GFRP. These GFRP work pieces are exactly made to size 57 mm X 57 mm X 5 mm. A Vertical Milling Centre (VMC-1260) is used for machining purpose having 12KgF maximum load table capacity. The GFRP workpiece is hold by vice as shown in Fig. (1). Initially a centre drill was made so as to ensure accurate drilling of GFRP workpiece. Then according to L9 orthogonal array a drilling is conducted in each workpiece. After drilling the workpiece is unclamped from vice and then it was dried by a pressurised air nozzle. Each drilled workpiece is covered by a plastic sticky paper for protecting hole by dust andswarf.

Fig (1): Closed view photograph of experimental set up

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com
International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 3, Special Issue 2, March 2016

A roughness tester shown in Fig. 2. made by Strumentazione, Japan Model RT10G having LC
0.001 µm is used to find out Roughness value (*Ra*) of each drilled hole. The probe may be turned by 90º to persist the measurements in the grooves between shoulders. On the integrated display, which is shielded by a protective membrane, the roughness parameter can be read easily. In this machine up to 30 readings can be save to ensure mobility. The tester delivered with the skidded pickup SM-SB10, V- block, roughness master.

Fig (2): Set up of measuring surface roughness of drilled hole in GFRP by roughness tester

Results and discussions

The experiment is performed according to Taguchi L9 orthogonal array. Based on the experimental work, the results were analyzed and are presented in this section. The analysis is conducted to determine the significant factors influencing output variables using statistical software named as „Minitab R-16‟. An analysis is done to predict the response variable for the unknown value of the input factors.

Table (3):- ANOVA for roughness value (*Ra*) of drilled GFRP

Source	DF	SS	MS	F	p	%Contri
Drill diameter	2	3.475	1.740	2.17	0.195	57.4
Spindle speed	2	0.781	0.25	0.19	0.830	12.9
Feed rate	2	0.47	0.83	0.76	0.509	7.76
Drill material	2	1.327	1.320	1.40	0.317	21.92
Error	0	0	-	-	-	-
Total	8	6.053	-	-	-	-

Table (4):- Results of Roughness values of drilled holes in GFRP (*Ra*)

Substrate no.	1	2	3	4	5	6	7	8	9
Ra Values (µm)	2.855	1.667	0.458	1.602	3.364	3.054	0.865	1.431	1.250

The main effects plots for roughness values (ANOM) and the table of analysis of variance (ANOVA) are shown in Fig. 3 and its roughness value from Table (4) respectively. It is observed from the ANOVA that none of the factors show statistical significance on roughness of drilled hole at 95% confidence level as the P-value in the ANOVA for anyinput variable is not less than 0.05.

But among the selected parameters the drill diameter shows statistical significance at 95 % C.I. The percentage contribution of the input variables influencing the roughness is drill diameter: 57.40 %, spindle speed: 12.90 %, feed rate: 7.76 % and drill material: 21.92 % showing the higher impact of drill diameter on the roughness of drilled hole. The effect of each input factors on the roughness is presented using ANOM plots.

Effect of drill material on roughness of drilled hole

In CNC milling operation drill material shows a linear effect on the roughness of drilled hole. From the main effect plot it is shown that the roughness value is minimum up to 1.5, when carbide material is used. However, for HSS M42 material roughness is nearly as 1.82 and for HSS M2 material, roughness is about highest as 2.5. In dry drilling, tool material is having higher impact on drilled surface quality due to the material behavior changes in machining with different drill materials.

Effect of feed rate on roughness of drilled hole

In CNC milling operation feed rate shows a non linear effect on the roughness of drilled hole in GFRP. From the MEP‟s it is shown that the roughness is maximum up to 2.4, when feed rate is 100 mm/min. However, for feed rate 140 mm/min roughness is quiet minimum, it is about 1.42 and for feed rate of 180 mm/min roughness is again increased about 1.5. It is observed that when the feed rate is high a sudden temperature rise in between tool and chip interface on account of higher friction. In this case burned black chips are generated while machining. Lower feed rates gives a better drilled hole quality on GFRP material.

Effect of spindle speed on roughness of drilled hole

It is observed from the main effect plot that spindle speed also shows a non linear effect on drilled GFRP substrates. At lower spindle speed i.e. at 600 rpm the roughness is at 1.7. When the spindle speed increases up to 800 rpm, the roughness value is increases up to 2.2. However, next step of spindle speed increment the roughness value suddenly dropped up to 1.5 as in Fig(3).

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com
International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 3, Special Issue 2, March 2016

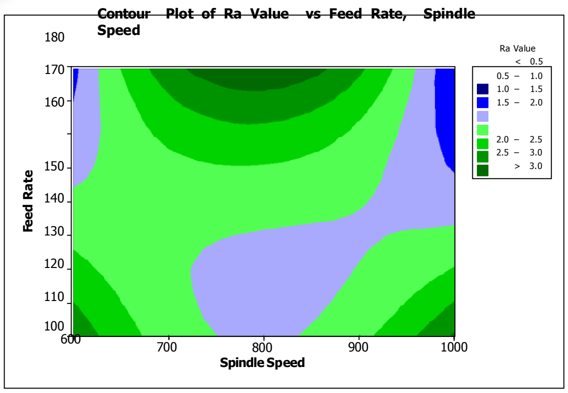

Fig (3): Contour plot of surface roughness vs feed rate and spindle speed

Effect of drill diameter on roughness of drilled hole

It is observed from the main effect plot that drill diameter shows a non linear effect on drilled GFRP substrates. For drill diameter 11.5 mm the roughness is minimum up to 1.15. However, for drill diameter 9.5 mm the roughness is high up to 2.7 and for drill diameter 9.0 it is up to 1.6. It is seen that as the drill diameter increases it plays a crucial role in maintaining the quality of drilled hole in GFRP substrates. The effect of all parameters is show in fig (4).

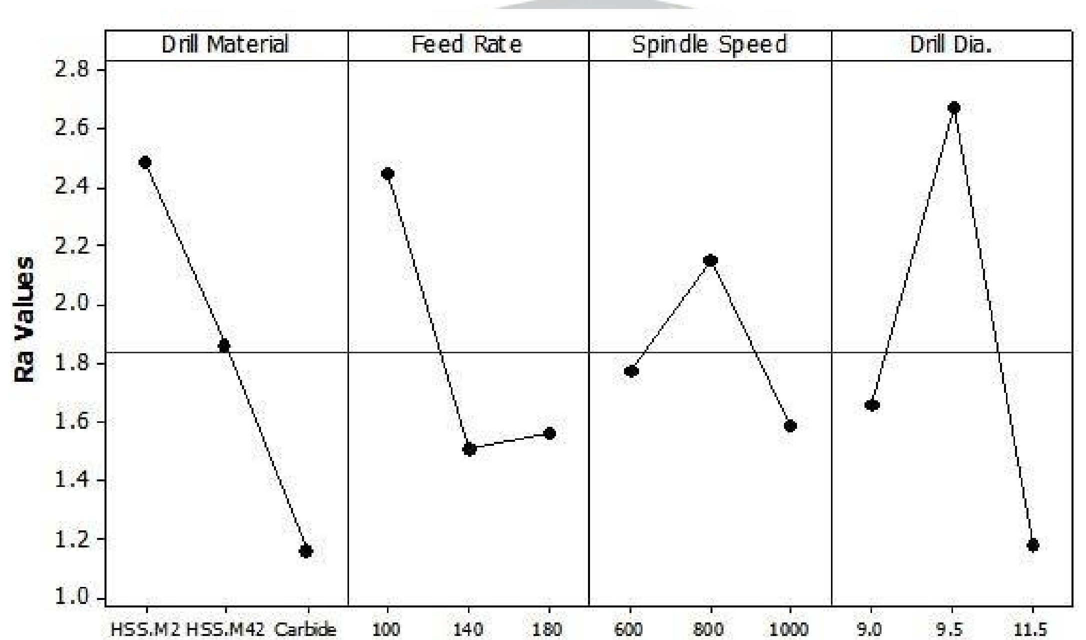

Fig (4): Main effect plot for surface roughness in CNC milling of GFRP

IV. CONCLUSIONS

The present work includes the extensive experimental analysis of CNC milling processes to understand the ability of the process with effective cutting parameters to generate high degree of drilled holes on GFRP composite. From the experimental results and subsequent Taguchi‟s analysis some of the major conclusions can be deduced from the study. As far as the effect of input factors are considered, the factors drill diameter and drill material both have nearly predominant influence on the surface roughness of drilled holes on GFRP composite. It is seen that minimum roughness value observed as 0.458 µm in this experiment. Also the drill material of carbide with bigger diameter drills gives the gooddrilled hole quality in the GFRP composite.

V. ACKNOWLEDGEMENT

I am are grateful to Prof. Dr. S. B. Barve (Head of Dept.), Prof. Dr. R. V. Pujeri (Vice Principal) and Prof. Dr. Mangesh Karad (Executive Director MITCOE, Pune).Also thankful to Accurate Engineering Co. Pvt. Ltd., Nashik for providing the measurement facility for the study.

REFERENCES

[1] Hocheng H, Tsao CC, "Comprehensive analysis of delamination in drilling of composite materials with various drill bits", *Journal of Material Processing Technology* 2003, pp 335–9.

[2] C.C. Tsaoa, H. Hocheng, "Evaluation of thrust force and surface roughness in drilling composite material using Taguchi analysis

and neural network", *Journal of materials processing technology 203* (2008), pp 342–348.

[3] P. Praveen Raj, and A. Elaya Perumal, " Taguchi Analysis of surface roughness and delamination associated with various cemented carbide K10 end mills in milling of GFRP", *Journal of Engineering Science and Technology Review*, 3, 2010, pp 58-64.

[4] Yong Guo Wang, Chang Yu Sun, Xiang Ping Yan, Ke Ren Jiang, "Study on the Surface Delamination in Milling Carbon Fiber Reinforced Plastic with PCD Tool", *Advanced Materials Research, Vol 31*, No. 2011, pp 1-5.

[5] B. Ramesh, A.Elayaperumal, A. Joeprasad, R. Raja Ramnath, "Experimental Investigation And Statistical Analysis For Surface Finish And Ovality In Dry Drilling Of Nonlaminated GFRP Polymeric Composites Using Twist Drill", *Int Journal of Science and Engg. Applications, Vol. 1, Issue 2*, 2012, pp 120-126.

[6] M. P. Jenarthanan, R. Jeyapaul, "Optimisation of machining parameters on milling of GFRP composites by desirability function analysis using Taguchi method", *International Journal of Engineering, Science and Technology, vol. 5, No.4*, 2013, pp 23-36.

[7] N. Naresh, K. Rajasekhar, P. Vijaya Bhaskara Reddy, "Parametric analysis of GFRP composites in CNC milling machine using Taguchi method", *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), e-ISSN: 2278-1684, Vol 6, Issue 1* (Mar. - Apr. 2013), pp 102-111.

[8] G Dilli Bab, K. Sivaji Babu, and B. Uma Maheswar Gowd, "Effect of Machining Parameters on Milled Natural Fiber-Reinforced Plastic Composites", *Journal of Advanced Mechanical Engineering, Vol. 1*, 2013, pp 1-12.

[9] Xuda Qin, Bin Wang, Guofeng Wang, Hao Li, Yuedong Jiang, Xinpei Zhang, "Delamination analysis of the helical milling of carbon fiber-reinforced plastics by using the artificial neural network model", *Journal of Mechanical Science and Technology, February 2014, Volume 28*, Issue 2, pp 713-719.

[10] Vinod Kumar Vankanti and Venkateswarlu Ganta, "Optimization of process parameters in drilling of GFR Pcomposite using Taguchi method", *Journal of Materials Research and Technology, Volume 3, Issue 1*, January and March 2014,pp 35-41.