IARJSET

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

REPSE-17

Sri Venkateshwara College of Engineering, Bengaluru

Vol. 4, Special Issue 7, May 2017

Statistical Optimization of Drilling Process Parameters on Quality of Hole of Glass FRP Composites

Veeresh Chandra M S[1], Dr. N Chikkanna[2]

Assistant Professor, Mechanical Engineering, S J C Institute of Technology, Chikkaballapur, India [1]

Professor, Aerospace Propulsion Technology, VTU-CPGS, Bengaluru Region, India [2]

Abstract: The objective of the research work was to investigate a Taguchi statistical model and estimate drill quality of glass fiber reinforced plastic (FRP) composites prepared by hand lay-up technique. The design of experiment technique has experimentally identified the influence of the drilling parameters such as feed rate, spindle speed and drill diameter on delamination factor, thrust force and torque in drilling FRP laminates. Significance level of each drilling process parameters have been analyzed using analysis of variance (ANOVA) method. The statistical models reveal that the drill diameter and feed rate significantly affects the drilling responses. The drilling delamination was investigated by using stereomicroscope.

Keywords: FRP, drilling, Taguchi, delamination, optimization.

I INTRODUCTION

Now a days, fiber reinforced polymer materials are used in many applications from automotive to aerospace industries [1]. Glass fiber reinforced plastics (GFRP) is found to be a replacement of conventional materials due to high strength / weight ratio, high corrosion resistance, durability and reliability [2]. GFRP applications also include domestic, commercial purpose and engineering applications. Drilling is most significant machining process in industrial applications to assemble the composite material in mechanical structural system [3]. The use of lightweight materials like GFRP can be used in aeronautical fields to reduce the weight of the system which in turn reduces fuel consumption and also reduces emission to environment [4].
During the drilling of GFRP, the quality of hole is the most significant parameter to assess drilling performance because it influences the performance of the assembled performance [5]. Many researchers [6-10] developed a methodology for assessing quality of the hole based on the type of defects associated with holes created in FRPs, the quality of hole based on surface cracks, surface damage, internal cracks in peripheral zone, roughness and dimensional errors. For optimization of machining parameters many approaches such as numerical, statistical and experimental methods are used. The objective of the research work was to optimize the process parameters on drilling performance on GFRP composites.

II EXPERIMENTAL STUDY

Wet Hand lay-up process was used for the fabrication of the GFRP as per the standard. Before lay-up, the TEFLON mould was applied with a mould releasing agent (Paraffin wax) to ensure smooth removal of the laminate from the mould and to avoid its adhesion to the mould. The fibre - matrix ratio of 65: 35 wt % was maintained for all the specimen. A brush was used to impregnate the fibres with the resin. Hydraulically operated Hot Press of 2 ton capacity was used for the final pressing of the laminate stacked in the mould to ensure the uniform distribution of the resin throughout the laminate. The drilling machine used for the GFRP drilling studies and drilling tool dynamometer was used for measuring torque and thrust force. Stereomicroscope was used to measure the delamination factor.

The experimental study was formulated as per full factorial method. As per this study 27 experiments were conducted for gathering data for statistical analysis using Minitab. The ANOVA was used for estimating the effect of each parameter on the various responses. Table 1 shows the main factors and their levels selected for the design of experiments.

The drillability test was formulated as per Taguchi technique considering three factors and three levels for all the three samples as presented in Table 1. The array chosen was the L27. The tests were repeated thrice for getting accurate results.

IARJSET

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

REPSE-17

Sri Venkateshwara College of Engineering, Bengaluru

Vol. 4, Special Issue 7, May 2017

TABLE 1 MAIN FACTORS AND THEIR LEVELS CHOSEN FOR THE DRILLING STUDY

Sample	Main factor	L1	L2	L3	DOF
A	Feed rate (mm/rev)	0.104	0.211	0.315	2
B	Spindle speed (rpm)	450	852	1860	2
C	Drill diameter (mm)	2.5	3.5	4.5	2

III RESULTS AND DISCUSSION

The multiple line graphs for main parameters such as feed rate, spindle speed and drill diameter and their responses on delamination are shown in Fig. 1. The three curves show almost quadratic nature and they definitely influence on delamination more significantly. The drill diameter is the highest significant process parameter on delamination and followed by spindle speed.

The highest spindle speed appears to be the best choice to get low value of surface finish, and thus making the process robust to the cutting speed in particular. Since the interaction B × C is significant, it is recommended to use the two ways B × C table to select their levels as calculated. From the two ways B × C table, the optimum combination for factor B and factor C to get the best result is B0C1 as explained. Therefore, the optimal combination to get low value of surface roughness is A1B2C3 within the tested range. The similar results were obtained for thrust force and torque which is shown in Fig. 2 and 3 respectively.

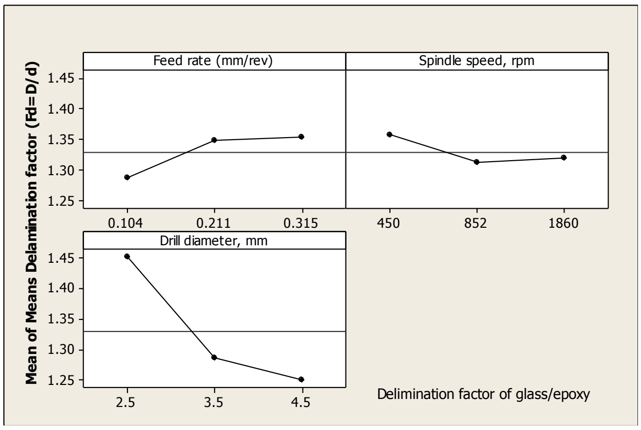


Fig.1. Effect of feed rate, spindle speed and drill diameter on mean delamination factor of glass/epoxy composites

The correlations between the factor (spindle speed, drill diameters and feed rate) and the measured delamination, thrust force and torque were obtained by multiple linear regressions for glass composites are given in the Table 2, 3 and 4 respectively.

The results in Table 2 of ANOVA for delamination factor indicate that diameter of the hole influences the delamination factor by 70.91% for Glass/Epoxy. The influence of speed and feed rate on delamination factor is found to be negligible for all the three material systems considered. Interaction effects were also found to be insignificant in all the cases.

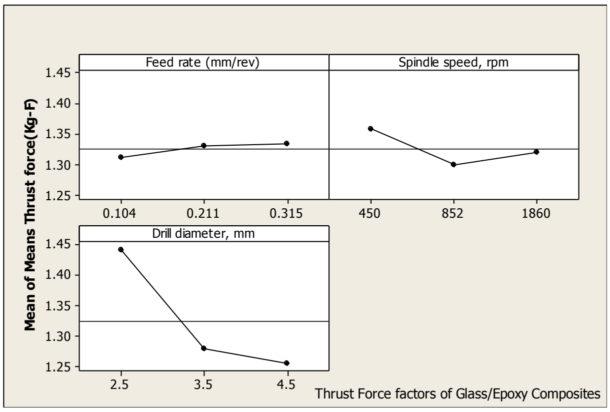


Fig.2 Effect of feed rate, spindle speed and drill diameter on mean Thrust force of glass/epoxy composites

IARJSET

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

REPSE-17

Sri Venkateshwara College of Engineering, Bengaluru

Vol. 4, Special Issue 7, May 2017

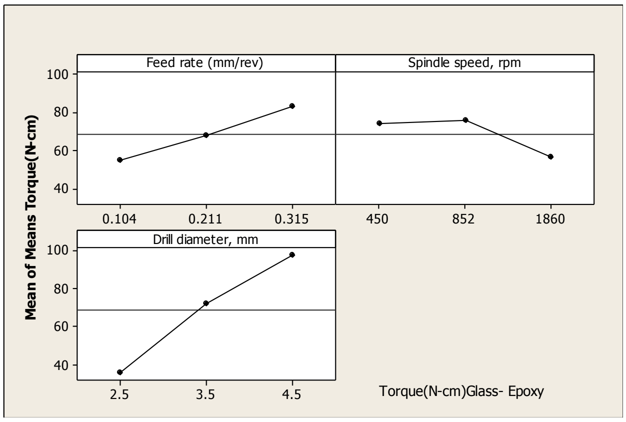


Fig.3 Effect of feed rate, spindle speed and drill diameter on mean Torque of glass/epoxy composites

Table 2 ANOVA results of delamination factor for glass/epoxy

Factor	DOF	Sum of squares	Mean sum of squares	F_{cal} = $M.S/M.S_{error}$	F_{tab} for 95% confidence level	P%= SS/SS_T
A	2	0.019747	0.0098	3.7078	4.46	8.13%
B	2	0.008834	0.0044	1.6587	4.46	3.64%
C	2	0.172237	0.0861	32.3403	4.46	70.91%
AB	4	0.010955	0.0027	1.0284	3.84	4.51%
BC	4	0.003226	0.0008	0.3028	3.84	1.33%
AC	4	0.006605	0.0016	0.6200	3.84	2.72%
Error	8	0.021303	0.0026			8.77%
Total	26	0.242907				100.00%

Table 3 ANOVA results of thrust force for glass/epoxy composites

Factor	DOF	SS	MSS=SS/DOF	F_{cal} = MSS/MSS_{error}	F_{tab} for 95% confidence	P% =SS/SST
A	2	265.4	132.70	10.09	4.46	29.98%
B	2	116.0	58.03	4.41	4.46	13.11%
C	2	249.4	124.70	9.48	4.46	28.18%
AB	4	33.7	8.42	0.64	5.05	3.81%
BC	4	102.3	25.59	1.94	5.05	11.56%
AC	4	13.03	3.25	0.24	5.05	1.47%
Error	8	105.1	13.14			11.88%
Total	26	885.1				100.00%

Table 4 ANOVA results of Torque for glass/epoxy composites

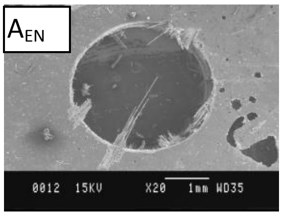
Factor	DOF	SS	MSS=SS/DOF	F_{cal} = MSS/MSS_{error}	F_{tab} for 95% confidence	P% =SS/SST
A	2	2943.6	1471.8	9.09	4.46	13.08%
B	2	1684.5	842.2	5.20	4.46	7.49%
C	2	13980.07	6990.0	43.21	4.46	62.13%
AB	4	530.5	132.6	0.82	3.84	2.36%
BC	4	1933.4	483.3	2.98	3.84	8.59%
AC	4	135.03	33.7	0.20	3.84	0.60%
Error	8	1294.01	161.7			5.75%

Table 3 shows the response (Thrust force) obtained after conducting experimental trials based on master plan. The steps involved remain the same for thrust force as that was done for the delamination factor.

Hence similar computations are performed for torque (Table 4) and the results are tabulated in similar fashion. The thrust force is influenced by feed rate to the extent of 29.98% for Glass/Epoxy. The thrust force is influenced by speed to the extent of 13.11% for Glass/Epoxy. The thrust force is influenced by diameter to the extent of 28.18% for Glass/Epoxy. Interaction effects were found to be insignificant in all the cases.

IV QUALITY OF DRILLED HOLE

During drilling operation the delamination was observed in two cases such as at the entrance and at the exit. They are peel-up delamination and push-out delamination at the entrance and exit respectively. Both cases are dominating equally for quality of holes shown in Fig. 4. The drill tool pierces through the FRP surface with twisting, it increases peeling effect on the fiber and is called as peeling up drilling mechanism. Similarly the drill tool pressing against the last layer of FRP causes push-out during the drilling operation. The FRP layers in laminates were pushed vertically downwards. As the tool advanced, both showed elastic and plastic behaviour. Hence the cutting strain increased on top of the surface and promotes crack growth in all direction. Because of drill tool advancement the pullout fiber are seen but they are not affected by drilling. The cutting tool advanced downward leads to abrade material away from the flute during rotation. The unaffected fiber or materials spirals up during machining before machined completely. The peeling force is acting upward direction along the thrust force. In this situation peeling force in the axial direction occur along the drill flute. The delimitation progresses layer by layer and the unaffected fiber resisting the lamina bending become greater.



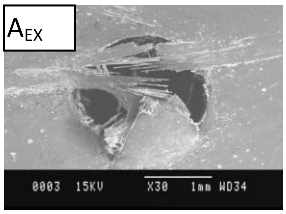


Fig. 4 Typical photographs of surface drilled-hole by twist drill (1) A_{EN} & (2) A_{EX} epoxy /glass laminates

V CONCLUSION

By the optimization of drilling for glass fiber reinforced plastic based on thrust force, torque and delamination factors, the following conclusions are drawn.

- The drill parameters such as drill diameter, spindle speed and feed are more significant influencing parameters on thrust force, torque and delamination.
- The optimal condition of the drill diameter has been level-1 in all the condition. The feed rate has almost at the level 2 and the spindle speed stood at level 3. But interaction of the parameters is negligible.
- The 4.5 mm drill diameter, 85.2 rpm spindle speed and 0.104 mm feed rate shows minimum delamination, thrust force and torque during drilling process.
- The randomly scrapped glass fiber could be seen at the near the drilled hole, which formed due to fiber pulled out. The delamination is dominated due to separating FRP layers due to tool advancement.
- The randomly scrapped glass fiber could be seen near the drilled hole, which formed due to fiber pull out. The delamination dominated due to separating FRP layers with tool advancement.

REFERENCES

[1] Palanikumar, K., Karunamoothy, L., and Karthikeyan, R., Optimization of machining parameters for minimum surface roughness in turning of GFRP composites using design of experiment, Journal of. Material Science Technology, Vol. 20, No. 4 (2004), pp. 373-378.
[2] El-Sonbaty, I., Khashaba, U.A., Machaly, T., Factors affecting the machinability of GFR/epoxy composites, Composite Structures, 63, 329-338, 2005.
[3] Davim, J.P., Mata, F., Optimization of surface roughness on turning fibre-reinforced plastics (FRPs) with diamond cutting tools, International Journal of Advanced Manufacturing Technology, 26, 319–323, 2005.
[4] Mohan, N.S., Ramachandra, A., Kulkarni, S.M. Influence of process parameters on cutting force and torque during drilling of glass–fiber polyester reinforced composites, Composite Structures, 71, 407-413, 2005.
[5] Davim, J.P., Mata, F., A new machinability index in turning fiber reinforced plastics, Journal of Materials Processing Technology, 170, 436-440, 2005.
[6] Jawali, N.D., Siddeswarappa, B., Siddaramaiah. Physicomechanical properties, machinability, and morphological behavior of short glass fiber-reinforced nylon 6 composites, Journal of Reinforced Plastics and Composites, 25(13), 1409-1418, 2006.

[7] Bagci, E., Işık, B., Investigation of surface roughness in turning unidirectional GFRP composites by using RS methodology and ANN, International Journal of Advanced Manufacturing Technology, 31, 10-17, 2006.

[8] Palanikumar, K., Karunamoorthy, L., Karthikeyan, R., Assessment of factors influencing surface roughness on the machining of glass fiber-reinforced polymer composites, Materials and Design, 27, 862–871, 2006.

[9] Palanikumar, K., Karunamoorthy, L., Karthikeyan, R., Latha, B., Optimization of machining parameters in turning GFRP composites using a carbide (K10) tool based on the Taguchi method with fuzzy logics, Metals and Materials International, 12(6), 483-491, 2006.

[10] Palanikumar, K., Karunamoorthy, L., Manoharan, N., Mathematical model to predict the surface roughness on the machining of glass fiber reinforced polymer composites, Journal of Reinforced Plastics and Composites, 25(4), 407-419, 2006.

BIOGRAPHIES

Veeresh Chandra M S, Graduated in BE (Mechanical Engineering) from SJCIT Chickballapur, and M.Tech from Sir MVIT, Bangalore, have 8 years of teaching experience and also in research field from past 4 years in SJCIT. The area research work is machining of composites.

Dr.N Chickkanna Graduated in BE (Mechanical Engineering) from SIT Tumkur, completed ME and PhD from UVCE Bangalore and served in different engineering colleges in various capacities and have proven record of accomplishment of valuable service in teaching and research.