Study on the Effects of Drill Parameters on the Quality of Drilled Hole in GFRP Composites

Veeresh Chandra M S
Mechanical Engineering Department
SJCIT
Chickballapur, India

Dr N Chikkanna
Department of APT
VIAT, Muddenahali
Chickballapur, India

***Abstract*— The main objective of the research work was to investigate the effect of major drill parameters on the main factors such as delamination factor, thrust force and torque on the quality of drilled hole in GFRP composites. Master plan was generated using Design of Experiments and the graph was plotted to view the response obtained after conducting experimental trails based on the statistical model built by taguchi technique. It was clearly revealed by the graphs that, parameters such as drill diameter and feed rate majorly affect the drilling responses.**

***Keywords*— Glass Fibre Re-inforced Plastics (GFRP), Delamination Factor, Taguchi Technique, Design of Experiments (DOE)**

I. INTRODUCTION

Even in the major applicational fields and in the day to day life the use of composite materials has become a very realistic approach to replace many conventional materials almost in all the important fields [1]. The composite materials known to everyone have enhanced properties in all aspects compared to any other conventional materials. GFRPs, a class of composites having high strength/weight ratio, high corrosion resistance, durable nature and reliable property, make them highly usable [2]. They are replacing many conventional materials in domestic, aeronautical, marine and many more applications.

The quality of a hole plays a major role in any kind of material application as it is very important for the fabrication (joining) process [5]. Major concern in the field of composite materials including GFRP is the machining (drilling), as they develop surface cracks, damage, internal cracks in peripheral zone and many errors regarding dimensions. Many researchers [6-10] have worked on the optimization of machining parameters in the drilling process and have tried to use many numerical, statistical and empirical techniques for the same. The present work mainly concentrates on the study on the effects of process parameters on the quality of hole drilled considering the three major responses (deformation factor, thrust force and torque).

II. EXPERIMENATAL STUDY

For the fabrication of GFRP Wet Hand lay-up process was used for the fabrication of the specimen as per the standard procedure. 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 specimens. A brush was used to impregnate the fibers with the resin. A hydraulic hot press was used for the final pressing for ensuring uniform distribution of resin throughout each laminate.

Full factorial Technique was utilized for the study using 27 experiments to gather data statistically and analyzing it by Minitab software. Test for drillability was formulated using taguchi method with three factors and three levels for all the three samples. An array of L27 was chosen. Each test was repeated thrice to get realistic results. Delamination factor was found out by using Fd = D/d, where, D = maximum diameter (D in m) of the damage zone, d = standard hole diameter (d in m) of the drill bits. Thrust force and torque were directly recorded by using drill tool dynamo meter with maximum thrust force: 500KgF and maximum torque: 20Kgm. 2.5mm, 3.5mm and 4.5mm HSS drill bits were used.

III. RESULTS AND DISCUSSIONS

The main factors and their levels selected for the Design of Experiments using taguchi technique is shown below. The selection of levels for the corresponding factor is chosen by considering the literature survey done on the respective field extensively [1-10]

TABLE 1. Main factors and their levels

Sample	Main factor	L 1	L 2	L 3	DOF
1	Feed rate (mm/rev)	0.104	0.211	0.315	2
2	Spindle speed, rpm	450	852	1860	2
3	Drill diameter, mm	2.5	3.5	4.5	2

By conducting the experiments and repeating for three times the responses obtained are tabulated. The effect of

each individual parameter on all the responses were gathered together and tabulated so as to get the detailed results which were helpful for plotting the graphs. The table 2 shows the response obtained after conducting experimental trails based on the master plan generated using DOE.

TABLE 2. Drilling factors and Delamination factor, Thrust, Torque of Glass/Epoxy

Feed rate (mm/rev)	Spindle speed (rpm)	Drill diameter (mm)	Glass/Epoxy composites		
			Delamination factor (Fd=D/d)	Thrust Force (Kg-F)	Torque (N-m)
0.104	450	2.5	1.460	11	30.24
0.211	450	2.5	1.452	14	38.08
0.315	450	2.5	1.578	20	54.88
0.104	852	2.5	1.360	9	24.64
0.211	852	2.5	1.548	12	32.48
0.315	852	2.5	1.327	16	43.68
0.104	1860	2.5	1.460	8	22.40
0.211	1860	2.5	1.452	9	24.64
0.315	1860	2.5	1.435	18	49.28
0.104	450	3.5	1.248	16	61.60
0.211	450	3.5	1.291	22	84.00
0.315	450	3.5	1.370	28	107.52
0.104	852	3.5	1.228	13	49.28
0.211	852	3.5	1.270	16	60.48
0.315	852	3.5	1.346	26	99.68
0.104	1860	3.5	1.219	15	57.12
0.211	1860	3.5	1.297	21	80.64
0.315	1860	3.5	1.303	13	49.28
0.104	450	4.5	1.185	18	88.48
0.211	450	4.5	1.318	20	98.56
0.315	450	4.5	1.315	21	103.04
0.104	852	4.5	1.219	19	92.96
0.211	852	4.5	1.258	25	123.20
0.315	852	4.5	1.251	31	152.32
0.104	1860	4.5	1.207	13	63.84
0.211	1860	4.5	1.239	14	68.32
0.315	1860	4.5	1.257	18	88.48

By the results tabulated the graphs were drawn to discuss the effects on responses using Minitab. Fig.1 shows the effect of speed on delamination factor. The results indicate that delamination factor have shown mixed behaviour but over all decreases with increase in speed and this may be due to the increase in thrust force with drill speed and severe heat generation at the drilling area leading to softening of fibre and matrix. Due to which cutting of fibre may become difficult causing increase in the thrust force resulting in more delamination.

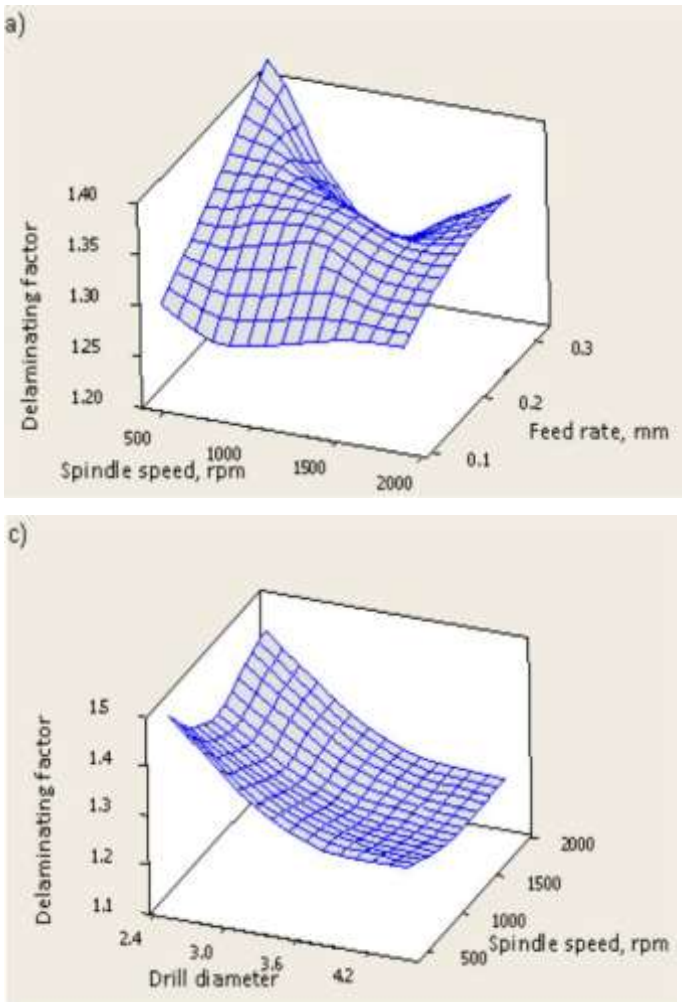
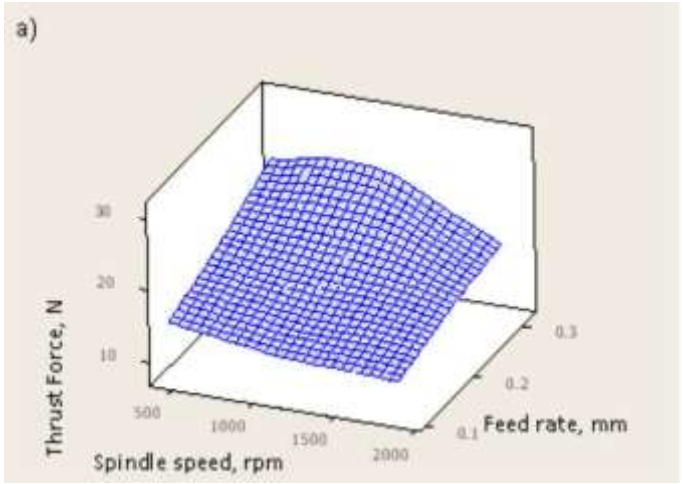


Fig.1.a) and c) Effect of spindle speed, feed and drill diameter on delamination factor



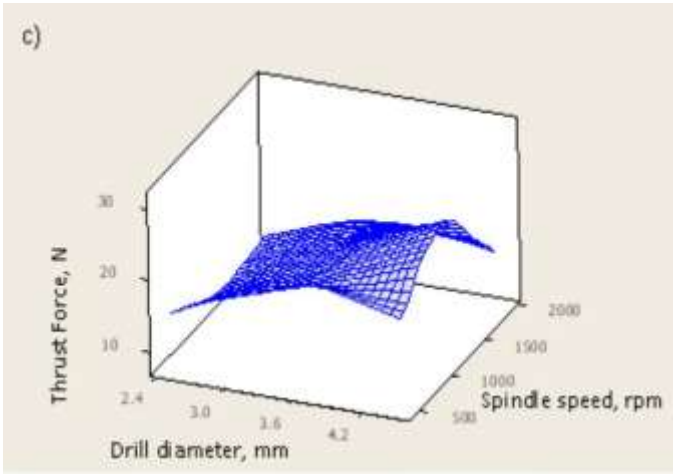


Fig.2.a) and c) Effect of spindle speed, feed and drill diameter on thrust force

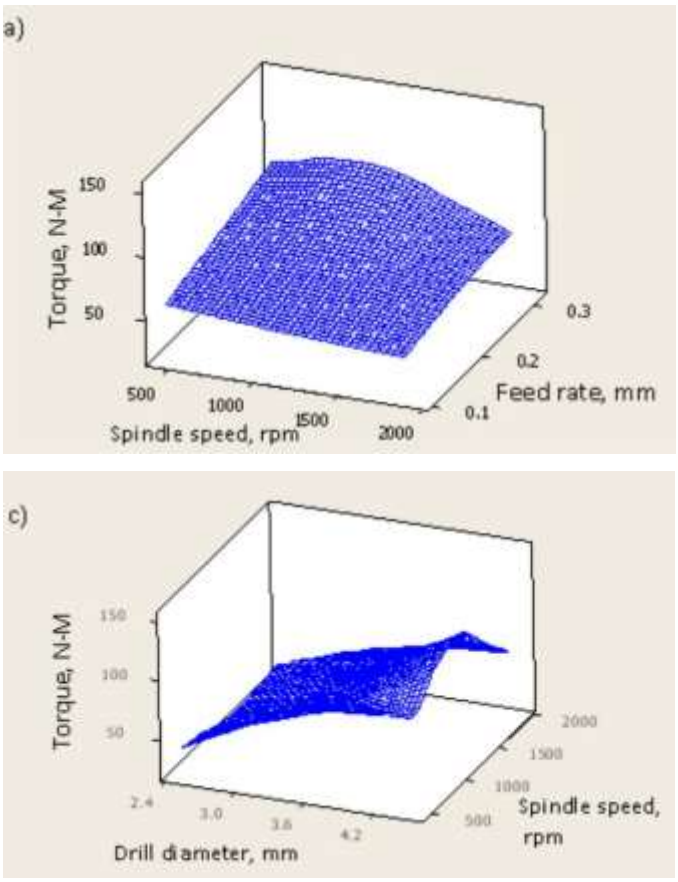


Fig.3.a) and c) Effect of spindle speed, feed and drill diameter on torque

Fig.2 shows the drilling forces induced by HSS drill at variable cutting speeds with constant feed rate in drilling FRPs. It is clear from the fig.2 that as spindle speed increases, thrust force decreases rapidly and significantly and this may be due to generation of more heat with the increase in spindle speed and the same heat accumulates at the cutting zone and leads to softening of the work material. As a result, the magnitude of thrust force decreases. Also when the feed rate is increased, the thrust force increases.

Fig.3 shows the effect of speed and feed on torque in FRPs. It is clear from the plots that the torque increases with feed rate and decreases with the cutting speed. This may be due to the increase of generated heat assisted by low co-efficient of thermal conductivity and low transition temperature of plastics. Matrix stability behind the tool edge is destroyed due to the accumulated heat. Also the stagnated heat around tool edge leads to softening of polymer matrix and this softened material behave as lubricant reducing frictional force on tool margin and moment of forces of friction of the chip on the drill. As a result, resistance to the chip deformation increases and tends to increase the thrust force and torque.

IV. CONCLUSIONS

By investigating the effects of all the parameters (spindle speed, feed rate and drill diameter) on the important responses of drilling process on GFRPs it is clearly visible by the graphs that: Delamination factor decreases with the increase in spindle speed. Thrust force is decreased when the spindle speed is increased whereas thrust force increases with the increase in feed rate. Torque increases with the increase in the feed rate and the torque decreases with the increase in the cutting speed.

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