International Journal of Advanced Technology in Engineering and Science www.ijates.com
Volume No 03, Special Issue No. 01, May 2015 ISSN (online): 2348 – 7550

EXPERIMENTAL ANALYSIS ON DE-LAMINATION IN DRILLING GFRP COMPOSITE MATERIAL

N.Parkunam[1], G.Gopi[2], Dr.D.Threshkumar[3]

[1]PG Scholar, PTR College of Engineering and Technology, Madurai, Tamilnadu, (India)
[2]Assistant Professor, [3]Dean/Head of the Department, Department of Mechanical Engineering,
PTR College of Engineering and Technology, Madurai, Tamilnadu, (India)

ABSTRACT

Glass fibre reinforced plastic composite materials are increased application in aeronautical, automobile and structural applications. Most of fibre reinforced composite material parts are processed to a near net shape, machining is often like finishing, trimming, drilling, grinding, etc. Among the several research processes, drilling of composite materials causes several damage modes, such as: de-lamination, fibre-pull out, edge chipping, uncut fibres, surface roughness and dimensional errors and others. During machining, the reduction of tool wear is an important aspect. The objective of this study is was an optimization technique has been developed to predict the de-lamination on the machining of GFRP composites using Taguchi method in order to study the main and interaction effects of machining parameters, viz., feed rate and spindle speed. Drilling test was carried out on E- glass fibre composites using uncoated and diamond coated HSS twist drill bits with same tool geometry.

Keywords: GFRP composites, De-lamination, L9 orthogonal array, Taguchi approach, Diamond coated HSS twist drill.

I. INTRODUCTION

Fiberglass is an immensely versatile material due to its light weight, inherent strength, weather-resistant finish and variety of surface textures. The development of fiber-reinforced plastic for commercial use was extensively researched in the 1930s. It was of particular interest to the aviation industry. A means of mass production of glass strands was accidentally discovered in 1932 when a researcher at Owens-Illinois directed a jet of compressed air at a stream of molten glass and produced fibers.

In aerospace industry, more and more composite laminates are primarily used in structural components instead of metal alloys allowing for weight reduction. GFRP composite laminates are used in fairings, storage room doors, landing gear doors, and passenger compartments. CFRP composite laminates are often used in wing boxes, horizontal stabilizers, vertical stabilizers, and wing panels.

In automobile, glass fiber reinforced plastics (GFRP’s) are the most commonly used in mechanical joints in pieces and structures in industry. However, the mechanical joints require good surface quality holes for bolts and rivets.

J Babu, Tom Sunny studied about the de-lamination of composite materials by conducting drilling experiments using Taguchi’s L25, 5-level orthogonal array and Analysis of variance (ANOVA) was used to analyze the data obtained from the experiments and finally determine the optimal drilling parameters in drilling GFRP composite materials using Four Fluted End Mill.

Vinod Kumar Vankanti, Venkateswarlu Ganta mentioned the optimize process parameters namely, cutting speed, feed, point angle and chisel edge width in drilling of glass fiber reinforced polymer (GFRP) composites. In this work, experiments were carried out 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. Analysis of variance (ANOVA) test was conducted to determine the significance of each process parameter on drilling [8].

Desh Bandhu, Sandeep Singh Sangwan and Mukesh Verma aims to present a literature survey on the drilling of composite materials, more specifically on drilling of carbon fiber reinforced plastics. Aspects such as tool materials and geometry, machining parameters and their influence on the thrust force and torque are investigated [2].

Zhenchao Qi, Kaifu Zhang, Yuan Li, Shunuan Liu, Hui Cheng The aim of this paper is to study about de-lamination during drilling metal-FRP (Fiber Reinforced Polymer Composite) stacks, with the effect of the metal part taken into account [10].

Turgay Kıvak, Gurcan Samtas, Adem Cicek focuses on the optimization of drilling parameters using the Taguchi technique to obtain minimum surface roughness (Ra) and thrust force (Ff). A number of drilling experiments were conducted using the L16 orthogonal array on a CNC vertical machining centre. The experiments were preformed on AISI 316 stainless steel blocks using uncoated and coated M35 HSS twist drills under dry cutting conditions [7].

K. Palanikumar conducted experiments on GFRP composites using Brad & Spur drill and optimized drilling parameters by using two input variables with four levels and concluded that low feed rate and high spindle speeds are beneficial to reduce de-lamination [5].

T.V. Rajamurugan, K. Shanmugam, K. Palanikumar In the present study the experiments are carried out using end mill (Carbide) to find the optimum drilling parameters using Taguchi’s L25 orthogonal array. To develop empirical relationships between the drilling parameters such as fiber orientation angle, tool feed rate, rotational speed and tool diameter with respect to de-lamination in drilling of GFR–polyester composites. The empirical relationship has been developed by using response surface methodology [8].

II. TECHNIQUES OF DE-LAMINATION

Among the several research processes, drilling of composite materials causes several damage modes, such as: de-lamination, fiber-pull out, swelling, edge chipping, uncut fibres, surface roughness and dimensional errors and others. De-lamination is considered as the major concern.

2.1 Peel up de-lamination

Peel-up is caused by the cutting force pushing the abraded and cut materials to the flute surface.

The cutting edge of the drill will first abrade the laminate initially. It then, by moving forward, tends to pull the abraded material away along the flute.

Before material is machined completely it spirals are up. This action introduces a peeling force upwards to separate the upper laminas from the uncut portion held by the downward acting thrust force.

2.2 Push Down De-Lamination

The laminar under the drill thus tend to be drawn away from the inter-laminar bond around the hole. At the end of the drill, the uncut thickness becomes smaller and the resistance to deformation decreases. In particular point, the loading exceeds the inter-laminar bond strength and de-lamination occurs.

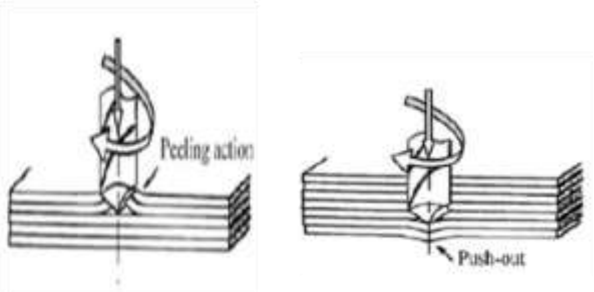

Fig. 1 Peel-Up and Push Down De-Lamination

2.3 De-Lamination Factor (F_d)

The factor used to determine the extent of de-lamination is called de-lamination factor.

$$F_d = D_{max}/D$$

D_{max} - The maximum diameter created due to de- lamination around the hole.

D - The hole or drill diameter.

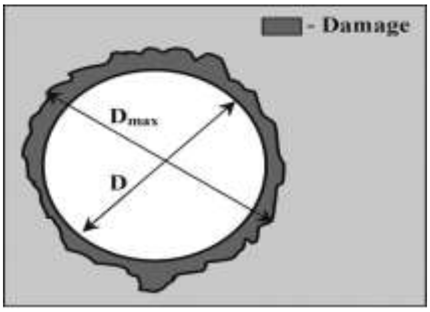

Fig. 2 De-Lamination

III. MATERIALS & EXPERIMENTAL PROCEDURE

Four layered UD-GFRP specimens of 5mm thickness were prepared using the hand lay-up process. The reinforcement was in the form of unidirectional E-glass fiber mat and the matrix was epoxy, araldite Ly 556 with hardener HY (anhydride hardener). A gel coat was applied on the mould prior to the lay-up process to facilitate easy removal of the laminate. Specimens were cured at room temperature for 24 hr in ambient conditions.

Fig.3 E-Glass Fibre

From this experiment, the analysis is mostly depending on the tool (drill bit) selection. The uncoated and diamond coated HSS twist drill bits with 5mm diameter are used in the experiments to drilling the GFRP composite materials.

Fig.4 Uncoated HSS twist bit

Fig.5 Diamond coated HSS twist bit

The experimental set-up is shown in fig.6. Drilling experiments are conducted on computer numerically controlled CNC vertical milling machine. Tool maker micros scope is used to measure the maximum diameter due to de-lamination around the hole.

Fig.6 Experimental Setup

Traditional experimental design methods are too complicate and difficult to use. Additionally, these methods require a large number of experiments, when the number of process parameters increases In order to minimize the number of tests required, Taguchi experimental design method is a powerful tool for designing high quality system was developed by Taguchi.

Fig.7 View Of Entrance Side Of Drilled Holes For Different Cutting Parameters By Both drills

The experimental design was according to an L9 array based on Taguchi method, while using the Taguchi orthogonal array would markedly reduce the number of experiments. Using Analysis of Variance (ANOVA), the effect of input parameters on de-lamination factor is studied

TABLE I L9 ORTHOGONAL ARRAY

Experiment no	Feed rate	Spindle speed
1	1	1
2	1	2
3	1	3
4	2	1
5	2	2
6	2	3
7	3	1
8	3	2
9	3	3

IV ANALYSIS OF RESULTS AND DISCUSSION

A drilling test was conducted to evaluate the effect of cutting parameters on the damage at work piece. The damage around the work piece was measured using a toolmaker micros scope.

After measuring the maximum diameter D_{max} in the damage around each hole, the de-lamination factor is determined by utilizing equation as mentioned in the section II for both drills. Table IV illustrates the influence of cutting parameters on the de-lamination factor.

From the table 2 it was observed that the de-lamination factor was vary with feed rate and spindle speed for both uncoated and diamond coated HSS twist drill.

TABLE 2 L9 ORTHOGONAL ARRAY AND EXPERIMENTAL RESULTS

Test no	Spindle speed	Feed rate	De-lamination factor	
			Uncoated	Diamond coated
1	2000	25	1.064	1.056
2	2000	30	1.084	1.052
3	2000	35	1.162	1.066
4	2400	25	1.106	1.060
5	2400	30	1.090	1.049
6	2400	35	1.092	1.062
7	2800	25	1.150	1.041
8	2800	30	1.128	1.062
9	2800	35	1.126	1.087

The highest value of de-lamination factor was observed from the table 2 is 1.162 for uncoated and 1.087 for diamond coated drill bit. The lowest value of de-lamination factor was 1.064 for uncoated and 1.041 for diamond coated drill bit.

There are three categories of quality characteristics in the analysis of the S/N ratio, i.e. the lower the better, the higher the better, and the nominal the better.

Here, I prefer

Lower-the-better

This is usually the chosen S/N ratio for all undesirable characteristics like defects for which the ideal value is zero. Also, when an ideal value is finite and its maximum or minimum value .The generic form of S/N ratio then becomes,

$n = -10 \text{Log}_{10}$ [mean of sum of squares of {measured - ideal}]

TABLE 3 S/N Response Table For Delamination Factor (Uncoated)

Test number	Feed rate	Spindle speed	De-lamination factor	S/N ratio
1	25	2000	1.064	23.8764
2	30	2000	1.084	21.5144
3	35	2000	1.162	15.8097
4	25	2400	1.106	19.4939
5	30	2400	1.090	20.9151
6	35	2400	1.092	20.7242
7	25	2800	1.150	16.4782
8	30	2800	1.128	17.8558
9	35	2800	1.126	17.9926

From the above table we can clearly seen that the de-lamination factor is indirectly proportional to the S/N ratio. It is also vary with the varying feed rates and spindle speeds. For smaller de-lamination factor we get the higher S/N ratio for both the drill bits.

The highest value of S/N ratio is 23.8764 for uncoated and 27.7443 for diamond coated drill bit. The lowest value of S/N ratio was 15.8097 for uncoated and 23.6091 for diamond coated drill bit.

From the table 3 the lowest de-lamination factor occurs at the feed rate 25 mm/min and spindle speed 2000 rpm for drilling E-glass fiber by uncoated HSS twist drill bit.

TABLE 4 S/N Response Table For Delamination Factor (diamond coated)

st number	Feed rate	Spindle speed	De-lamination factor	S/N ratio
1	25	2000	1.056	25.0368
2	30	2000	1.052	25.6799
3	35	2000	1.066	23.6091
4	25	2400	1.060	24.4370

5	30	2400	1.049	26.1961
6	35	2400	1.062	24.1522
7	25	2800	1.041	27.7443
8	30	2800	1.062	24.1522
9	35	2800	1.087	27.2096

From the table 4 the lowest de-lamination factor occurs at the feed rate 25 mm/min and spindle speed 2800 rpm for drilling E-glass fiber by diamond coated HSS twist drill bit.

After finding the de-lamination factor and S/N ratio, the mean values are predicted and the graphs are plotted between the de-lamination factor and varying parameters like feed rate and spindle speed for both drills called main effects for means shown in fig 6 and 7.

At the same time the graphs plotted between the de-lamination factor, feed rate and spindle speed called interaction effects for means for both uncoated and diamond coated HSS twist drill bits shown in fig 8 and 9.

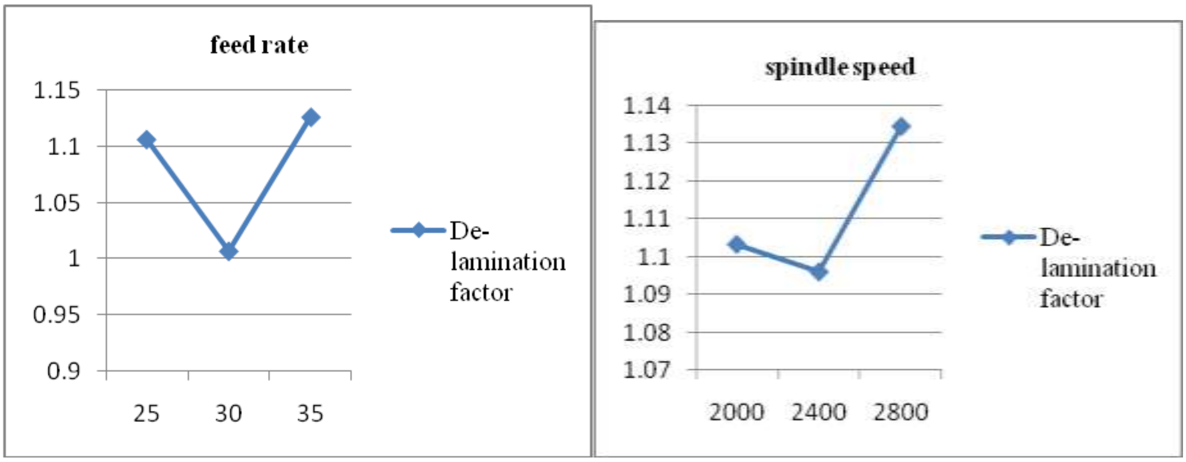

Fig.6 Main effects for means (uncoated)

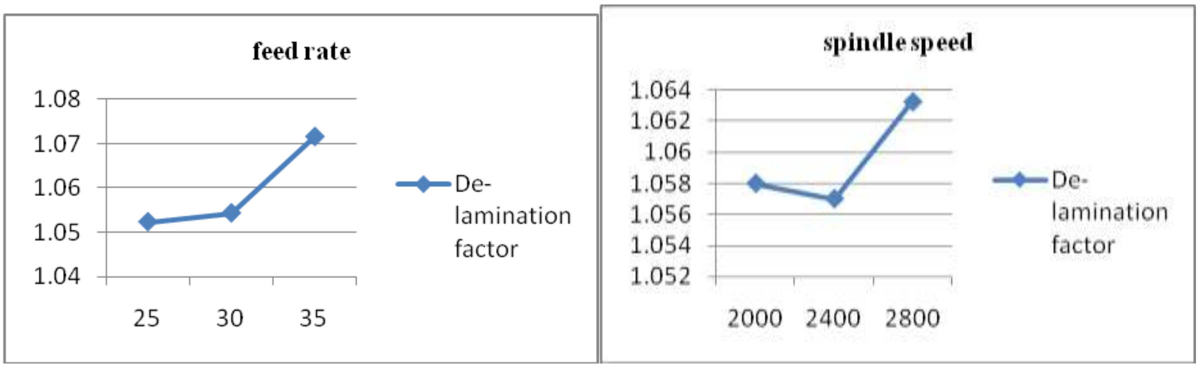

Fig7. Main effects for means (diamond coated)

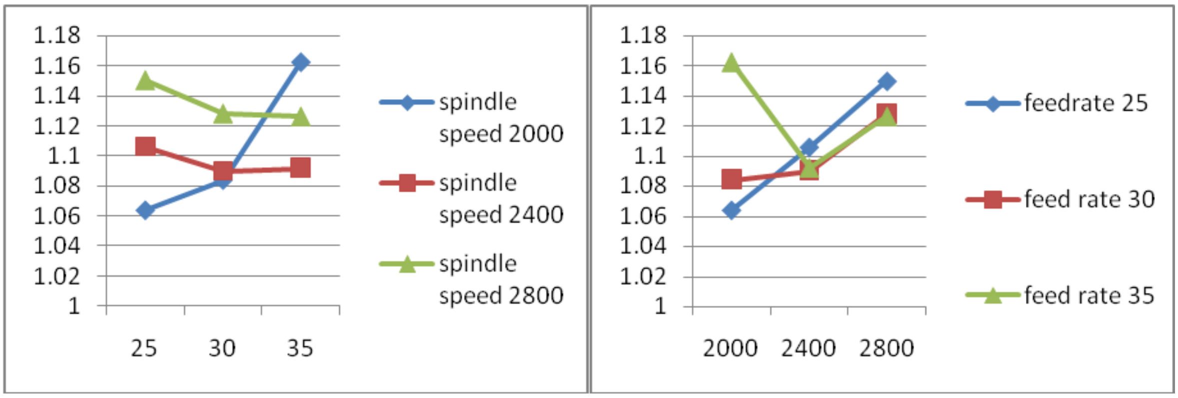

Fig.8 Interaction effects for means (uncoated)

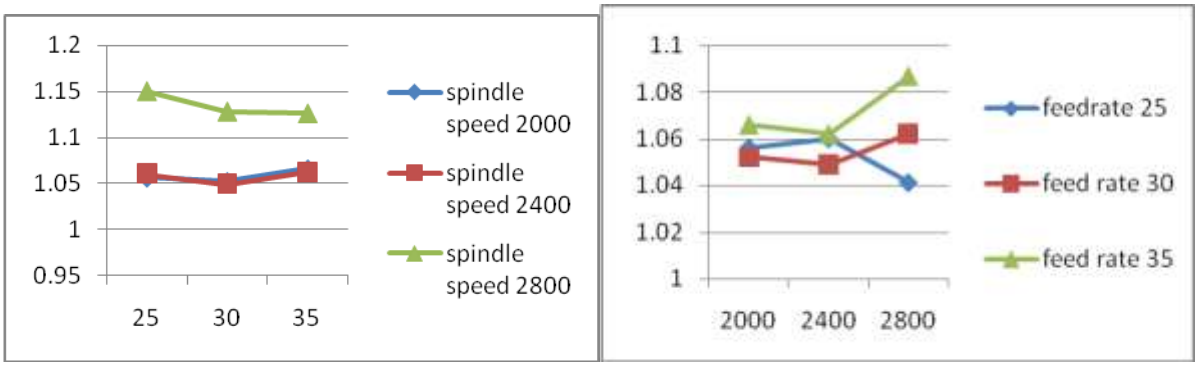

Fig.9 Interaction effects for means (Diamond coated)

From the graphs it is seen that the spindle speed decreased from 2800rpm to 2400rpm, the de-lamination factor decreases for uncoated drill bit. And also the feed rate decreased from 35mm/min to 30mm/min, the de-lamination factor decreases for diamond coated drill bit.

Table 5 Analysis of Variance For Means (uncoated)

source	DF	Seq SS	Adj MS	F	P
Feed rate	2	0.00112	0.00056	0.467	0.627
Spindle speed	2	0.00253	0.00127	1.065	0.426
Residual error	4	0.00475	0.00119		
total	8	0.00840			

Table 6 Response Table for Means (uncoated)

Level	Speed	feed
1	1.1033	1.1066
2	1.0960	1.1006
3	1.1346	1.1266
Delta	0.0386	0.0260
rank	1	2

From the table 6 for uncoated HSS twist drill, the delta value for spindle speed is higher compared to the value of feed rate. The rank for spindle speed is 1 and that the feed rate is 2. Thus from the table 5 (F value larger).It is clear that the spindle speed is mainly affecting the de-lamination factor compared to feed rate.

Table 7 Analysis of Variance For Means (diamond coated)

source	DF	Seq SS	Adj MS	F	P
Feed rate	2	0.00069	0.000334	2.32	0.214
Spindle speed	2	0.00007	0.000034	0.23	0.802
Residual error	4	0.00058	0.000146		
total	8				

Table 8 Response Table for Means (diamond coated)

Level	Speed	feed
1	1.0580	1.0523
2	1.0570	1.0543
3	1.0633	1.0716
Delta	0.0063	0.0193
rank	2	1

From the table 8 for diamond coated HSS twist drill, the delta value for feed rate is higher compared to the value of spindle speed. The rank for feed rate is 1 and that the spindle speed is 2. Thus from the table 7 (F value larger).It is clear that the feed rate is mainly affecting the de-lamination factor compared to feed rate.

V. CONCLUSION

The optimization of cutting process parameters namely speed and feed rate in drilling glass fiber reinforced polymer (GFRP) composites using the application of Taguchi and ANOVA analysis the conclusion drawn from this work are as follows:

The optimum process parameters in the drilling of GFRP composites are

- Uncoated drill bit - Speed of 2000 rpm, feed rate at 25 mm/min for the de-lamination are found to be optimum parameters.
- Diamond coated drill bit- Speed of 2800 rpm, feed rate 25 mm/min and for the de-lamination are found to be optimum parameters.
- The ANOVA results reveal that's that spindle speed is most significant influencing on the de-lamination factor for the uncoated drill bit.
- Speed is the most significant influencing on the de-lamination factor for the diamond coated drill bit.

REFERENCES

[1] DeFu Liu , YongJun Tang , W.L. Cong "A review of mechanical drilling for composite laminates" Elsevier Composite Structures 94 (2012) 1265–1279.

[2] Desh Bandhu, Sandeep Singh Sangwan and Mukesh Verma "A Review of Drilling of Carbon Fiber Reinforced Plastic Composite Materials" INPRESSCO Vol.4, No.3 , June 2014.

[3] J Babu, Tom Sunny "Optimization of Process Parameters in Drilling of GFRP Composites Drilled by an End Mill" IJRDET, Volume 1, Issue 1, 16-23 Oct 2013

[4] J.Paulo Davima, Pedro Reisa, C.Conceic¸ Anto niob "Experimental study of drilling glass fiber reinforced plastics (GFRP) manufactured by hand lay-up" Elsevier Composites Science and Technology 64 (2004) 289–297.

[5] K. Palanikumar, "Experimental investigation and optimisation in drilling of GFRP composites", Measurement 44 (2011) 2138–2148.

[6] Luis Miguel P. Durao, Joao Manuel R.S. Tavares, Victor Hugo. de Albuquerque, Jorge Filipe S. Marques and Oscar N.G. Andrade "Drilling Damage in Composite Material" Materials 2014,7, 3802-3819.

[7] Turgay Kıvak, Gurcan Samtas, Adem Cicek "Taguchi method based optimization of drilling parameters in drilling of AISI 316 steel with PVD monolayer and multilayer coated HSS drills" Elsevier 3 march 2012.

[8] T.V. Rajamurugan , K. Shanmugam , K. Palanikumar "Analysis of de-lamination in drilling glass fiber reinforced polyester composites" Elsevier Materials and Design 45 (2013) 80–87.

[9] Vinod Kumar Vankantia, Venkateswarlu Gantab "Optimization of process parameters in drilling of GFRP composite using Taguchi method" Elsevier j mater res technol 2013.

[10] Zhenchao Qi, Kaifu Zhang , Yuan Li, Shunuan Liu, Hui Cheng "Critical thrust force predicting modeling for de-lamination-free drilling of metal-FRP stacks" Elsevier 31 July 2013.