Literature of Optimized Machining of Carbon Fiber Epoxy Composites Material

Suresh aadepu[1, a *],Lachiram[2, b]and Ramesh babu[3, c]

[1]Suresh.Aadepu (Author) is a PhD Scholar of Osmania University, Hyderabad, Telangana state, India-500007.

[2]Dr: Lachiram, Supervisor, Scientist-F, DLRL-Hyderabad, Telangana, India - 500058.

[3]Dr.P. Ramesh Babu, Co-supervisor, Associate professor, Department of mechanical engg., OsmaniaUniversity, Hyderabad, Telangana, India-500007.

[a]adepusuresh97@gmail.com, [b]lachiram@gmail.com, [c]prbmechou@yahoo.com

Keywords: Design of Experiment, Taguchi Design, Optimization, Machining Parameters, Drilling, CFRP material and MINITAB software.

I.Abstract. Current work focuses on the machining aspects of CFRP (epoxy) composites using a single point HSS cutting tool. Optimal setting, i.e. the most favorable combination of process parameters (such as spindle speed, feedrate and fiber orientation angle) is given when considering the productivity requirements outsourcing and contradicting each other, viz. surface roughness, SR(Ra), thrust and shear force. This study initially provides mathematical models (objective functions) using nonlinear regression statistics to correlate different process parameters in order to determine optimal machining conditions to achieve high efficiency. Satisfactory processing capacity. Controlled factors have the most influence on yarn direction, speed, feed. Laminate must be drilled for assembly purposes. It is known that a drilling process that reduces the thrust of the drill bit can reduce the risk of delamination. The results show the importance of choosing the right machining parameters to prolong the life of these CFRP materials due to increased reliability.

Introduction: Carbon fiber reinforced polymer (CFRP) composites can be described as fiber reinforced composite material that makes use of carbon fiber because the number one structural component (reinforcement) and thermosetting resins together with epoxy, polyester, or vinyl ester as matrix. In latest years, CFRP composites are getting pretty famous with inside the production industries specifically in aerospace and car industries because of their outstanding mechanical and thermal properties, mechanical strength and low weight, true fatigue resistance, true corrosion and climate resistance, very low coefficient of thermal enlargement and excessive energy-to-weight ratio.With the expanded call for of CFRP composites in aforementioned industries, producers are emphasizing greater to have a look at the machinability components of those composites. In general, CFRP output material is made to near-net-shape; but, machining is frequently finished that allows you to remove of extra material to satisfy dimensional accuracy and tolerance.

But machining of those composites is quite extraordinary from machining of traditional metals; it's far pretty tough due to their material discontinuity, anisotropic and in homogeneous nature. Machining CFRP materials presents several challenges: The fibers are characterized by high strength, making the material difficult to cut, resulting in: tool wear and breakage/fraying. It has a high modulus of elasticity, making it abrasive. The resin matrix is heat sensitive and can be melted. The structure is made up of layers of material, which can lead to delamination. We cannot eliminate delamination (defect) during machining, but we can minimize the delamination factor (defect factor). Therefore, it is necessary to minimize the defect factor by using optimized machining parameters. The input parameters are speed, feed, cutting depth and yarn direction, and the output parameters are torque, thrust, delamination coefficient and surface roughness.

The use of composite materials has been increasing in recent years, due to their special mechanical, thermal and structural properties. Most researchers used fiberglass-reinforced polymers for their studies. CFRP material is an inexpensive material compared to other composite materials and has wider industrial applications. Drilling is an important machining process required to fasten components of an assembly. To establish the best quality of the hole produced by the drilling operation, the hole must be free of any damage like delamination etc. It is quite difficult to make a hole without any damage, but changing the machining parameters has the same effect. The quality of the hole surface mainly depends on the cutting parameters, such as tool material, tool geometry, cutting force, etc.

Delamination is the most serious of the errors caused by drilling operations. Delamination reduces the bearing strength, thereby reducing the structural integrity of the material. studied the drilling of multilayer composite materials using conventional tools and concluded that the quality of the cutting surface depends on the cutting parameters, the tool geometry and the tool material. Delamination (Figure 1) is the most serious failure in composite drilling because it reduces the load capacity and should be avoided. Surface quality and delamination coefficient depend on many factors such as cutting parameters, tool geometry, tool wear and cutting force. Compared with metalworking, the study of composite materials is rare and the study of delamination of different tools is necessary.

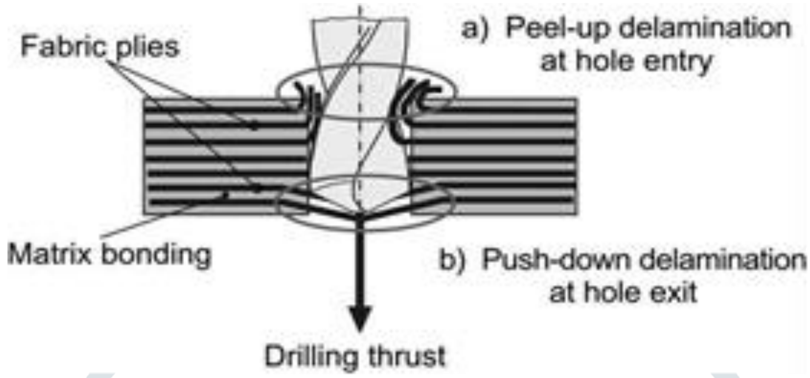

Fig.1.Types of delamination's

In addition to experimental techniques, the thrust pressure and delamination may be predicted with the aid of using an analytical way. A comparative take a look at aiming to assess the have an effect on of the drill geometry on unidirectional laminate carbon reinforced plastics has investigated the machining of CFRP composites. Studied the delamination the use of mainly designed drills and relation among feed rate, cutting speed and fiber orientation.Taguchi techniques have carried out and optimized the reducing parameters for surface finish and hole diameter accuracy in dry drilling operation.

II.Materials and method: Material and machine used: Carbon fiber reinforced epoxy as specimen and Drilling machine.
Input parameters: Drill speed, federate and Fiber orientation.

Table I: Domain of experiments

Factors (Notation)	Unit	Level 1	Level 2	Level 3
Drill Speed (N)	[RPM]	N1	N2	N3
Feed rate (f)	[mm/min]	f1	f2	f3
Fiber orientation	angle	Φ1	Φ2	Φ3

C. **Experimental design**:
The layout of experiments is a powerful device to optimize the numerous machining parameters. In this study, a 3 level and three factors L27 orthogonal array decided on and fundamental impact layout become used. This level has a bonus of decreasing the wide variety of experiments. The recognized parameters have been fiber orientation, spindle velocity and feed rate. The elements and the degrees of things used are indexed within side the Table

Table II: Design of experiment (L27 Orthogonal Array)

Sl. No.	Parametric Settings		
	N [RPM]	f [mm/min]	d [mm]
1	N1	f1	Φ1
2	N1	f2	Φ2
3	N1	f3	Φ3
4	N2	f1	Φ2
5	N2	f2	Φ3
6	N2	f3	Φ1
7	N3	f1	Φ3
8	N3	f2	Φ1
9	N3	f3	Φ2
10	N1	f1	Φ1
11	N1	f2	Φ2
12	N1	f3	Φ3
13	N2	f1	Φ2
14	N2	f2	Φ3
15	N2	f3	Φ1
16	N3	f1	Φ3
17	N3	f2	Φ1
18	N3	f3	Φ2
19	N1	f1	Φ1
20	N1	f2	Φ2
21	N1	f3	Φ3
22	N2	f1	Φ2
23	N2	f2	Φ3
24	N2	f3	Φ1
25	N3	f1	Φ3
26	N3	f2	Φ1
27	N3	f3	Φ2

Determination of delamination value (Table III): The damage around the hole is measured and the diameter of the hole in the damaged area is measured four times and the maximum value recorded is the Dmax value. The delamination factor is determined by the ratio of the maximum diameter (Dmax) of the damaged area to the diameter of the hole (D). Therefore, the equation used to find the delamination as below

$$F_d = \frac{D_{max}}{D}$$

Where, Fd is the delamination factor, Dmax is the maximum diameter of the damage zone in mm and D is the diameter of the hole in mm.Fin= Delamitation factor at entry and Fout = Delamination factor at exit.

Analysis of drilling parameters: Analysis of S/N ratio: S/N ratio used to measure the quality characteristic limit from the required value. The term signal represents the required of the response variable whereas the term noise represents the unuseable value of the response variable. The S/N ratio η is defined as:η = - 10 log (MSD)Where, MSD is the mean square deviation is for the response characteristics. It is required to get obtain optimal drilling performance, the-lower-the- better quality characteristic for delamination was taken. The MSD for the-lower-the-better quality characteristic can be given as: MSD = (1/n) ΣF_{di}^2 ; i = 1,…,n Where, n is the number of repeated tests run and Fdi is the value of delamination factor for the ith test.The tests results for delamination factor and the corresponding S/N ratio are shown in the following Table III.Ra is surface roughness; Fin is delamination factor at entry and Fout is delamination factor at exit.

Table III: experimental values

Sl. No.	Torque [kN-mm]	Thrust [kN]	Ra [μm]	Fin	Fout
1	T1	F1	Ra1	Fin1	Fout1
2	T2	F2	Ra2	Fin2	Fout 2
3	T3	F3	Ra3	Fin3	Fout 3
4	T4	F 4	Ra4	Fin4	Fout 4
5	T5	F5	Ra5	Fin5	Fout 5
6	T6	F6	Ra6	Fin6	Fout 6
7	T7	F7	Ra7	Fin7	Fout 7
8	T8	F8	Ra8	Fin8	Fout 8
9	T9	F9	Ra9	Fin9	Fout 9
10	T10	F10	Ra10	Fin10	Fout 10
11	T11	F11	Ra11	Fin11	Fout 11
12	T12	F12	Ra12	Fin12	Fout 12
13	T13	F13	Ra13	Fin13	Fout 13
14	T14	F14	Ra14	Fin14	Fout 14
15	T15	F15	Ra15	Fin15	Fout 15
16	T16	F16	Ra16	Fin16	Fout 16
17	T17	F17	Ra17	Fin17	Fout 17
18	T18	F18	Ra18	Fin18	Fout 18
19	T19	F19	Ra19	Fin19	Fout 19
20	T20	F20	Ra20	Fin20	Fout 20
21	T21	F21	Ra21	Fin21	Fout 21
22	T22	F22	Ra22	Fin22	Fout 22
23	T23	F23	Ra23	Fin23	Fout 23
24	T24	F24	Ra24	Fin24	Fout 24
25	T25	F25	Ra25	Fin25	Fout 25
26	T26	F26	Ra26	Fin26	Fout 26
27	T27	F27	Ra27	Fin27	Fout 27

Taguchi Design: Taguchi Orthogonal Array

DesignL27 (3^3)
Factors: 3, Runs: 27
Interactions
AB, AC &BC
Taguchi Analysis: torque, thrust, surface roughness, delamination factor at entry, Delamination factor at exit versus speed, feed rate, fiber orientation.Response Table for Signal to Noise Ratios.

Table IV: Smaller is betterTable V: Response Table for Means

Level	speed	feed rate	Fiber orientation
1	Nx	fx	Φx
2	Ny	fy	Φy
3	Nz	fz	Φz
Delta	N	f	Φ
Rank	1	2	3

Level	speed	feed rate	Fiber orientation
1	Nmean1	fmean1	Φmean1
2	Nmean2	Fmean2	Φmean2
3	Nmean3	Fmean3	Φmean3
Delta	N	f	Φ
Rank	1	2	3

Taguchi Analysis: Torque, Thrust, Surface roughness, Delamination factor at entry and exit versus Speed, Feed rate, Fiber Orientation:

The main influence chart of the means is shown in Figure [2]. This figure identifies differences in individual responses to the factors of speed, feed rate, and fiber direction, respectively. Key effects plots are used to highlight the optimal conditions for the delamination. As this main effects graph shows, the best conditions for the delamination factor are speed at 2000 rpm, feed at 3, and fiber direction at 3.

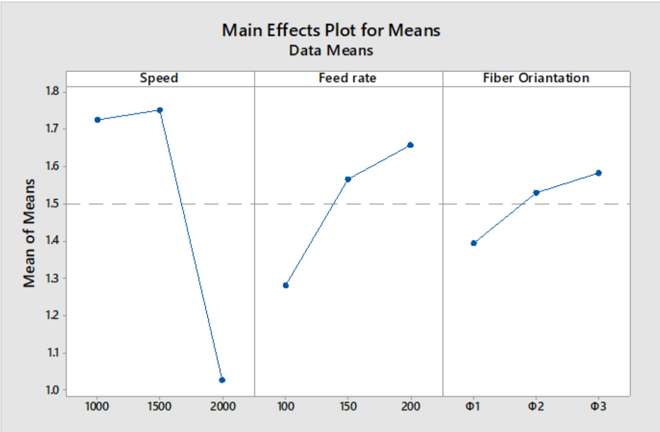

Fig2: Main Effects Plot for Means

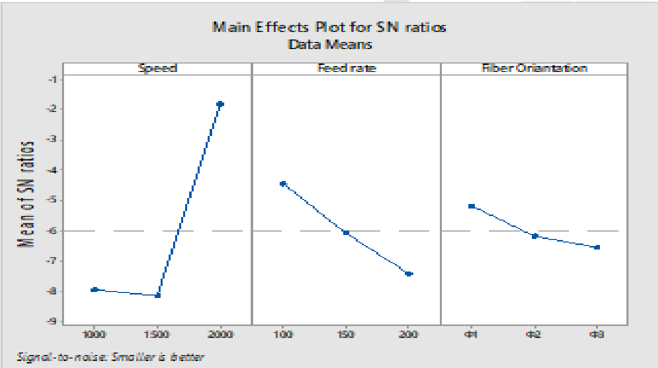

Fig.3: Main Effects Plot for SN ratios

The main effect plot for S/N ratios is indicated in fig [3] this figure explained the variation of each response with speed, feed rate, and fiber orientations parameters respectively.The fundamental consequences plots are used to emphasis the ideal situations for surface roughness. As confirmed via way of means of this fundamental impact plot, the ideal situations for least surface roughness are speed, fiber orientation, and feed rate

Table VI: Predicted valuesTable

S.NO	speed	feed rate	Fiber orientation
1	N1	f1	Φ1
2	N1	f1	Φ2
3	N1	f1	Φ3
4	N1	f2	Φ2
5	N1	f2	Φ3
6	N1	f2	Φ1
7	N1	f3	Φ3
8	N1	f3	Φ1
9	N1	f3	Φ2
10	N2	f1	Φ1
11	N2	f1	Φ2
12	N2	f1	Φ3
13	N2	f2	Φ2
14	N2	f2	Φ3
15	N2	f2	Φ1
16	N2	f3	Φ3
17	N2	f3	Φ1
18	N2	f3	Φ2
19	N3	f1	Φ1
20	N3	f1	Φ2
21	N3	f1	Φ3
22	N3	f2	Φ2
23	N3	f2	Φ3
24	N3	f2	Φ1
25	N3	f3	Φ3
26	N3	f3	Φ1
27	N3	f3	Φ2

S No	S/N Ratio	Mean	Std. deviation	Ln (Std. deviation)
1	Value	Value	Value	Value
2	Value	Value	Value	Value
3	Value	Value	Value	Value
4	Value	Value	Value	Value
5	Value	Value	Value	Value
6	Value	Value	Value	Value
7	Value	Value	Value	Value
8	Value	Value	Value	Value
9	Value	Value	Value	Value
10	Value	Value	Value	Value
11	Value	Value	Value	Value
12	Value	Value	Value	Value
13	Value	Value	Value	Value
14	Value	Value	Value	Value
15	Value	Value	Value	Value
16	Value	Value	Value	Value
17	Value	Value	Value	Value
18	Value	Value	Value	Value
19	Value	Value	Value	Value
20	Value	Value	Value	Value
21	Value	Value	Value	Value
22	Value	Value	Value	Value
23	Value	Value	Value	Value
24	Value	Value	Value	Value
25	Value	Value	Value	Value
26	Value	Value	Value	Value
27	Value	Value	Value	Value

III.CONCLUSIONS

THE OUTCOMES OF RESEARCH WORK ARE LISTED BELOW:

1) It was found that Taguchi approach using L27 orthogonal array can be used to analyze delamination of CFRP materials during drilling.
2) Signal-to-noise ratio analysis is used to find optimal drilling parameters consistent with minimal delamination, thus improving hole quality when drilling.

3) Experiment has found that the optimal parameters for drilling are determined from the S/N feedback table and Figure 3.

IV. FUTURE SCOPE

In the present study, only three parameters, namely speed, feed and direction, were optimized based on their influence (Delamination and surface roughness). Future span view, other parameters i.e. nose radius, cutting angle etc. can be optimized for CFRP material delamination and surface roughness. Likewise, other output parameters, i.e. power consumption, tool life, tool wear, etc. can be added.

ACKNOWLEDGMENT

It gives me enormous pleasure to express my first thanks and sincere gratitude to my supervisor and co-supervisor for their insistent help and constant guidance; otherwise, it would not have been possible for me to complete this work.

REFERENCES

[1] Abhishek K, Datta S, Mahapatra SS (2013) Response surface modeling on machining of CFRP composites: Effect of process variables on surface roughness, MRR and tool-tip temperature, International Journal of Mechanical Engineering and Research, 3(4): 407-414.

[2]Abhishek K, Datta S, Mahapatra SS, Mandal G, Majumdar G (2013) Taguchi approach followed by fuzzy linguistic reasoning for quality-productivity optimization in machining operation A case study, Journal of Manufacturing Technology Management, 24(6): 929-951.

[3] Abrao AM, Faria PE, Rubio JC, Reis P, Davim JP (2007) Drilling of fiber reinforced plastics:

[4] A review, Journal of Materials Processing Technology, 186(1): 1-7.

[5] Abrao AM, Rubio JC, Faria PE, Davim JP (2008) The effect of cutting tool geometry on thrust force and delamination when drilling glass fibre reinforced plastic composite, Materials and Design, 29(2): 508-513.

[6]Aghakhani M, Jalilian MM, Mehdiabadi M, Jalilian MM, Karami A (2011) Application of Imperialist Competitive Algorithm in optimizing the width of Heat Affected Zone in GMAW process, International Journal of Modeling and Optimization, 1(3): 221-225.

[7] Ahilan C, Kumanan S, and Sivakumaran N (2010) Application of grey based Taguchi method in multi-response optimization of turning process, Advances in Production Engineering and Management, 5(3): 171-180.

[8]Akay B, Karaboga D (2012) Artificial bee colony algorithm for large-scale problems and engineering design optimization, Journal of Intelligent Manufacturing, 23(4): 1001-1014.

[9]Alaghebandha M, Hajipour V (2015) A soft computing-based approach to optimise queuing inventory control problem, International Journal of Systems Science, 46(6):1113-1130.

[10] Al-Aomar R (2006) A GA-based parameter design for single machine turning process with high-volume production, Computers and Industrial Engineering, 50(3): 317-337.

[11]Alazzam A and Lewis HW III (2013) A New Optimization Algorithm for Combinatorial Problems, International Journal of Advanced Research in Artificial Intelligence, 2013; 2(5): http://dx.doi.org/10.14569/IJARAI.2013.020510

[12] Ali HM, Iqbal A, Liang L (2013) A comparative study on the use of drilling and milling processes in hole making of GFRP composite, Sadhana, 38(4): 743-760.