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OPTIMIZATION OF DRILLING PARAMETERS FOR HFRP COMPOSITE USING ANOVA ANALYSIS

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ABSTRACT

Hybrid fiber reinforced polymer (HFRP) composite is a novel methodology in fiber reinforced polymer (FRP). A Laminate is prepared by stacking of alternative layers of carbon fiber reinforced lamina and glass reinforced laminas making a laminate thickness of 4mm. Experiments were conducted HFRP composite for full factorial design to evaluate torque and thrust force at different drilling parameters, such as drill point angle, feed rate and cutting speed. Utilizing (ANOVA) approach and (S/N) ratio analysis the drilling parameters were optimized.

Keywords- ANOVA, Drilling parameters, Factorial design, HFRP,

1. Introduction

Hybrid fiber reinforced polymer (HFRP) composite is an advanced fiber reinforced polymer (FRP) composite that utilized two or more different fibers are used to make a laminate. Advantage of using this composite is that it is possible to improve the failure strain by incorporated high elongation fiber like glass fiber into low elongation fiber such as carbon fiber [1]. Drain grating covers and oil and gas platform are some of the applications HFRP. Holes are constantly required in these applications either for mechanical fastening reason notwithstanding, drilling holes on the fiber reinforced polymer (FRP) composite utilizing traditional drilling draw an incredible it will harm the material's structure because of the unacceptable drilling technique, for example, the choice of consideration as erroneous drill geometry and despicable determination of drilling parameters.

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2. Literature Survey

.**Biran Desai et.al[2]:**Investigates on in drilling the quality of hole is an important requirement for many applications. Thus the choice of optimized cutting parameters is very important for controlling the required hole quality. The focus on the present study optimize the parameters through work piece circularity and hole size. This paper represents a full factorial and ANOVA for formed on thin CFRP laminates using point angles 60 and helix angle 30. By varying the parameters spindle speeds and feed rate to determine the optimum of hole diameter and circularity. **Vijayan Krishna raj et.al[3]:**This paper represents an experimental investigation of full factorial deign on thin CFRP laminates using K20 carbide drill by varying drilling parameters spindle speed, feed rate. To determine the optimum conditions of hole diameter and delamination by using ANOVA and Genetic algorithm method is used in MAT lab. **Shunmughesh et.al[4]:**In this study composite undergo drilling and L27 orthogonal array is used to determine delamination and surface roughness by varying the parameters spindle speed feed rate point angles to determine the optimum conditions of hole diameter in the Grey relational analysis performed. **Mohd Azuwan Maoinser et.al[5]:**Investigates on drilling of Hybrid Fiber Reinforced Polymer(HFRP) and this paper presents optimisation of drilling parameters by varying parameters such as feed rate, spindle speed by using the full factorial design experiment and combination of ANOVA and signal to noise ratios. **M.Ramesh et.al[6]:**The aim of the experiment emphasize machining characteristics of HFRP by varying the parameters cuttings speed and feed rate, point angles and tool diameter. This paper presents the drilling induced damages is analysed with Scanning Electron Microscopy (SEM) analysis to reduce the delamination factor. **B.V.Kavad et.al[7]:**This paper presents the influence of machining parameters on the delamination damage of Glass Fiber Reinforced Polymer (GFRP) during drilling by varying the parameters spindle feed rate and also measure the minimum thrust force. **M.Saravanan et.al[8]:**This paper presents composite materials are used in air craft operations and highly sensitive operations, during drilling delamination, eccentricity of drilled hole which leads to loosening of rivets in joining various structures. For this by varying the parameters like cutting speed feed rate to determine the optimum hole eccentricity and M.R.R. by using Genetic Algorithm technique, numerical method and soft computing technique. **J.Babu et.al[9]:**Investigates the during drilling operations is hard to carry out the induced delamination. This paper presents the optimisation of delamination by conducting drilling experiments using Taguchi's L25 orthogonal array and ANOVA by varying the parameters cutting speed and feed rate.**Vinod Kumar.V et.al[10]:**This paper presents during drilling carry out induced delamination. To determine the optimization of delamination and hole quality by varying the parameters cutting speed point angle chisel edge width. In this work L9 orthogonal array used and ANOVA was conducted to determine significance and minimize the thrust force and torque. **Suresh.N et.al[11]:**Investigates the various drilling parameters like different twist drill bits of different point angles and deferent materials have been taken and the thrust force and torque measure for different machining conditions by using the DEFORM 3D Software in this simulate drilling process and measure the thrust force and torque by varying feed rate, spindle speed and point angles to determine the optimum values of thrust force and torque.

3. MATERIAL PREPARATION

Materials Used to Prepare A Composite Laminate:

1. Carbon Fiber.
2. Glass fiber
3. Epoxy Resin.
4. Hardener.

3.1. Carbon Fiber:

Carbon fiber is a material consisting of fibers about 5–10 μm in diameter and composed mostly of carbon atoms. To produce carbon fiber, the carbon atoms are bonded together in crystals that are more or less aligned parallel to the long axis of the fiber as the crystal alignment gives the fiber high strength-to-volume ratio (making it strong for its size). Several thousand carbon fibers are bundled together to form a tow, which may be used by itself or woven into a fabric.

The properties of carbon fibers, such as high stiffness, high tensile strength, low weight, high chemical resistance, high temperature tolerance and low thermal expansion, make them very popular in aerospace, civil engineering, military, and motorsports, along with other competition sports. However, they are relatively expensive when compared to similar fibers, such as glass fibers or plastic fibers.

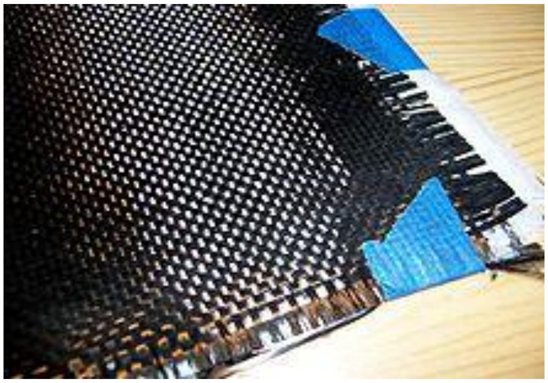

Fig 3.1 Woven Carbon Filaments **Fig3.2 Woven Glass filaments**

Carbon fibers are usually combined with other materials to form a composite. When combined with a plastic resin and wound or molded it forms carbon fiber reinforced polymer (often referred to as carbon fiber) which has a very high strength-to-weight ratio, and is extremely rigid although somewhat brittle. However, carbon fibers are also composed with other materials, such as with graphite to form carbon-carbon composites, which have a very high heat tolerance. Each carbon filament tow is a bundle of many thousand carbon filaments parallel to each other. A single such filament is as thin as 5–8 micrometers.

3.2. Glass Fiber:

Over 95% of the fibers used in reinforced plastics are glass fibers, as they are inexpensive, easy to manufacture and possess high strength and stiffness with respect to the plastics with which they are reinforced. Their low density, resistance to chemicals, insulation capacity are other bonus characteristics, although the one major disadvantage in glass is that it is prone to break when subjected to high tensile stress for a long time

3.3 Laminate Preparation

The HFRP composite specimen of 390mm×340mm×4mm is fabricated by the hand layup process technique at room temperature. The bi-directional plain weaves type glass fabric and carbon fabric with 460 GSM is used as reinforcement. The resin used for the preparation of matrix is Bisphenol A based epoxy resin L-12 and the hardener used is Amino K-6. The resin content of the composite laminate is maintained around 60 wt %. The resin mixture is applied onto each layer by using a brush and a roller. In this laminate 7 layers are used in this 4 layers are glass fabric and 3 layers are carbon fabric. these layers placed alternatively in the mould

3.4 Hand layup process **3.5 Mould**

After 24 hours the mould could be open then the laminate of composites are removed and the laminate are shown below

3.6 HFRP laminate

4. EXPERIMENTAL INVESTIGATION

Work piece used for the experiment is HFRP (Hybrid Fiber Reinforced Polymer) with epoxy resin composite. The size of the specimen used was 390 x340 x4 mm. The drilling process was carried out using radial drilling Machine and KISTLER dynamometer.

4.1 Thrust Force

The axial force required to drill a work piece is called as thrust force. Thrust force is measured using Kistler make piezoelectric dynamometer. The higher the thrust force, the greater is the damage of the work piece (Mellinger *et al*, 2003). Hence the analysis of thrust force is required for various combinations of cutting conditions.

The cutting tool used for the machining was HSS twist drill bit. The parameters and their levels selected for the experimental design are listed below in

Control factor	Unit	Level-1	Level-2	Level-3
Point angle	Degree	100	118	135
Feed rate	mm/min	18	20	26
Speed	rpm	485	795	1250

4.3 Design of experiment:

The objective of this research work is to study the effect of different parameter such as point angle feed rate and speed for this design model has been prepared by choosing three levels :

- Three levels of point angle have been used
- Three levels of feed rate have been used
- Three levels of speed have been used

The two most important out puts are thrust force and torque for this research work has been analysed the effect of variation in input process parameters will be studied on this two response parameters and the experimental data will be analyzed as per full factorial method to find out the optimum machining condition

4.3.1 Selection of orthogonal array and parameter assignment:-

In this experiment there are three parameters at three levels each in this full factorial design for experimentation by applying (3*3) 27 by taking three levels for each factor

4.3.2 Full factorial standard design:

Full factorial design is used for simultaneous study of several factor effects on the process. By varying levels of factors simultaneously we can find optimal solution. Responses are measured at all combinations of the experimental factor levels. The combination of the factor levels represent the conditions at which responses will be measured. Each experiment condition is a run of an experiment. The response measurement is an observation. The entire set run is a design. It is used to find out the variables which are the most influence on the response and their interactions between two or more factors on responses

5. RESULTS AND DISCUSSION

Drilling tests were conducted to evaluate the effect of cutting parameters on torque and thrust force and tabulated in table 5.1

Experiment no	Point angles(degree)	Feed rate (mm/min)	Spindle speed (rpm)	Thrust force(N)	Torque (Nm)
1	100	18	485	63.5624	3.4
2	100	18	795	69.84	3.72
3	100	18	1250	56.36	3.06
4	100	20	485	66.32	3.6
5	100	20	795	66.30	3.547
6	100	20	1250	59.77	3.23
7	100	26	485	77.01	5.964
8	100	26	795	75.06	3.98
9	100	26	1250	55.75	3.03
10	118	18	485	71.97	3.81
11	118	18	795	98.59	5.15
12	118	18	1250	42.36	2.36
13	118	20	485	45.14	2.52
14	118	20	795	43.13	2.40
15	118	20	1250	42.22	2.36
16	118	26	485	43.21	2.38
17	118	26	795	49.98	2.73
18	118	26	1250	48.82	2.67
19	135	18	485	75.02	3.96
20	135	18	795	66.89	3.57
21	135	18	1250	43.60	2.42
22	135	20	485	72.40	3.83
23	135	20	795	75.83	4.02
24	135	20	1250	74.17	3.95
25	135	26	485	58.48	3.14
26	135	26	795	42.80	2.38
27	135	26	1250	44.71	2.48

Table5.1 Experimental results

5.1 Analysis of Variance for Torque:

Table 5.2 presents the results of ANOVA for torque. It is observed from the table the spindle speed is significant parameter for the torque. However F-test decides whether the parameters significantly different. A larger value F shows the greater impact on the machining performance characteristics

Source	D.F	Seq ss	Adj ss	Adj ss	F	P
Point angle	2	2.0345	2.0345	1.10172	1.47	0.285
Feed rate	2	1.4365	1.4365	0.7182	1.04	0.397
Spindle speed	2	3.4685	3.4685	1.7342	2.51	0.142
Point angle*feed rate	4	4.1671	4.1671	1.0418	1.51	0.287
Point angle*spindle speed	4	1.1301	1.1301	0.2825	0.41	0.798
Feed rate*spindle speed	4	1.7548	1.7548	0.4387	0.64	0.652
Error	8	5.5255	5.5255	0.6907		
Total	26	19.516	19.5169			

Table 5.2 Analysis of Variance for Torque

5.2 Analysis of Variance for Thrust Force

Table 5.3 presents the results of ANOVA for torque. It is observed from the table the spindle speed is significant parameter for the thrust force. However F-test decides whether the parameters significantly different. A larger value F shows the greater impact on the machining performance characteristics

Source	D.F	Seq ss	Adj ss	Adj ns	F	P
Point angle	2	781.6	781.6	390.8	2.69	0.128
Feed rate	2	894.7	894.7	447.3	3.08	0.102
Spindle speed	2	827.0	827.0	413.5	2.84	0.117
Point angle*feed rate	4	1234.9	1234.9	308.5	2.12	0.169
Point angle*spindle speed	4	393.5	393.5	98.4	0.68	0.627
Feed rate*spindle speed	4	963.0	963.0	240.8	1.66	0.252
Error	8	1163.1	1163.1	145.4		
Total	26	6257.8	6257.8			

Table 5.3 Analysis of Variance for Thrust Force

5.3 Main effect plots analysis for torque:

The analysis is made with the help of a software package MINITAB 16. The main effect plots are shown in fig.4. These show the variation of response with the three parameters i.e. point angle, Spindle speed and feed separately. In the plots, x axis indicate the value of each parameter at three level and y- axis the response value. Horizontal line indicates the mean value of the response. The main effects plots are used to determine the optimal design conditions to obtain the optimum torque.

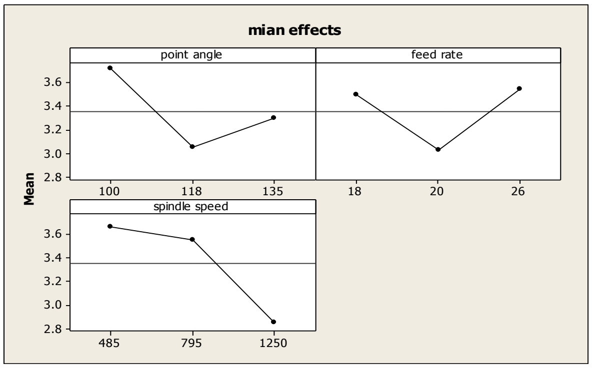

Fig 5.1 Main effects plots for torque

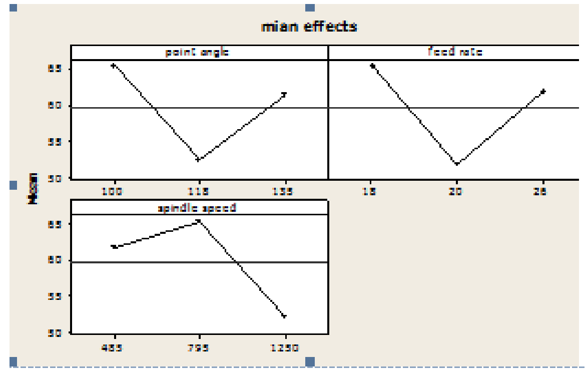

Fig 5.2 Main effects plots for thrust force

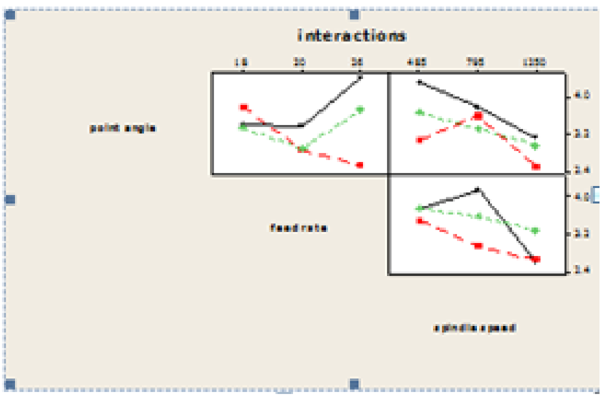

Fig 5.3 Interaction effects plots for torque

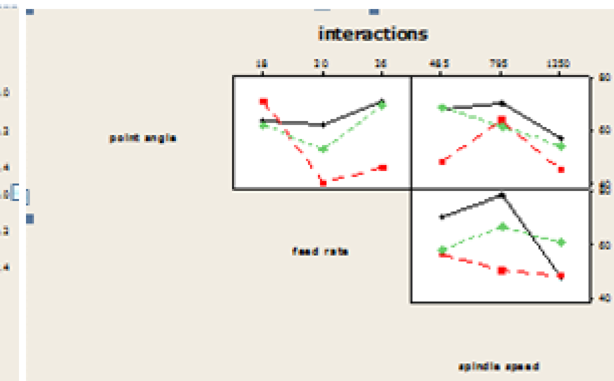

Fig 5.4 Interaction effects plots for thrust force.

5.4 Main effect plots analysis for thrust force:

The analysis is made with the help of a software package MINITAB 16. The main effect plots are shown in fig.4. These show the variation of response with the three parameters i.e. point angle, Spindle speed and feed separately. In the plots, x axis indicate the value of each parameter at three level and y- axis the response value. Horizontal line indicates the mean value of the response. The main effects plots are used to determine the optimal design conditions to obtain the optimum thrust force.

5.5 Interaction effects for torque and thrust force:

The interaction effect for torque and thrust force is shown in figure 5.3 and 5.4

CONCLUSION

This paper presents the optimization of cutting process parameters namely, point angle, feed rate and spindle speed in drilling of hybrid fiber reinforced polymer (HFRP) composites using the full factorial and ANOVA analysis. The conclusions drawn from this work are as follows:

The optimum process parameters in the drilling of hybrid fiber reinforced polymer (HFRP) composites are:

- Point angle 118°, feed rate at 20 mm/min and spindle speed at 1250 rpm thrust force and torque are found to be optimum
- The ANOVA results reveal that feed rate is most significant influencing on the thrust force
- The ANOVA results reveal that spindle speed is most significant influencing on the torque

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