Optimization of Drilling Parameters on Alkaline Treated Jute fiber Sandwich Material

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Abstract: The present work efforts to determine CNC drilling performance and optimization of drilling parameters during drilling of treated JFRPPU-foam sandwich structures. In this drilling operation the ensuing process performance structures viz thrust, torque and delamination factor for entry and exit hole have been recognized. The effort has been made to regulate the optimal drilling parameters set. Taguchi method employed for design of experiment. The effects of parameters process such as composite geometry type, feed rate, drill speed, and drill size varied each at three different levels. In this experimentation sandwich structures L27 orthogonal array is used. A nonlinear regression model is measured and formulates the function based on the drilling parameters and fitness function. The result shows the minimization thrust force, delamination of hole drill diameter and feed rate more effect than the speed. TAN coated carbide twist drilled hole gives the result more percentage to reduce the hole wall delamination.

Keywords: ANOVA, CMM, CNC, Taguchi method and Treated JFRPPU-foam sandwich structures

I. INTRODUCTION

The vacuum bagging method is the best for laminating the jute fiber mat reinforced mat vinyl ester composites. The benefits of their use are related with a significant weight reduction, moisture and swelling of jute fiber. Two mechanism occurs during drilling in sandwich composite. They are peel up and pushout in the top layer and bottom layer [1]. Tsao et al. accessible a novel method for decrease of delamination through drilling of composites by means of active backup force. High feed rate technique show slow cost and minor delamination in fabricate composite components [2].Zitoune et al. assessed experimentally the parametric influences on torque, thrust force, and surface finish. The results show that correct selection of cutting parameters, to improve the quality of the holes [3]. In drilling operation of hole the parameter process and tool geometry is the significant factor for thrust force. Marques et al. originate that asfeed rate rises, the thrust force rises, whereas, as the speed high the thrust force low up to a certain value beyond which it rises[4]. Madhavan et.al. Hypothesize that as the spindle speed higher, torque will lower for a value of speed beyond which it rises [5]. Wen-Chou-Chen initiate that as point angle increases, the thrust force advanced and torque lesser [6]. Mansheel Cheong et al. said that as the drill diameter rises, the thrust, torque forces will rises [7]. Panda et al. inspected that increase in drill diameter will increase the thrust force[8]. Abrao et al. detected an increment in the amount of thrust force made with the higher in thickness of the composite work material [9].Zhang et al. model was built on unbroken distribution of thrust and torque laterally the lip and chisel edge of the twist drill [10].Wang et al. accessible a method which contains the growth of a dynamic uncut chip thickness for each cutting element at the lips and chisel.The mean thrust and torque enlarged as feed rises below constant vibration parameters. Furness et al presented the statistical analysis of hole quality features found feed and speed have a small effect[11]. Rincon and Ulsoy [12] exposed that the variations in the relative motion of the drill ensure affect the dissimilarities of the forces. An increase in the drill motion results in an increase in the torque and thrust.

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II. MATERIALS AND METHOD

The material used for experiments are jute fiber mat, vinyl ester resin, rigid polyurethane foam and treated with 5% NaOH solution. Drilling hole of 3, 4 and 5 mm by HSS and TAN coated twist drill bit point angle 118°.The present study, the jute fiber mat treated by 5% NaOH at different time of exposure before, exact and after 4hours. It can be taken as 3, 4 and7 hours kept in hot air oven at temperature of 130°Cin 1hour. This jute fiber mat reinforced with vinyl ester ration (60:40) composite are laminate by using the vacuum bagging method to prepared sheets of the (length x width x thickness) size as 200 mm x 200 mm x 5 mm. This can be drying by kept in atmospheric temperature at 32°C in 24 hours. The properties of young's modulus, poisons ratio and rigidity modulus as shown in the table B.I

Table I . Young's modulus, poisons ratio & rigidity modulus

Materials	E_x (Gpa)	E_y (Gpa)	E_z (Gpa)	ν_{xy}	ν_{yz}	ν_{zx}	G_{xy} (Gpa)	G_{yz} (Gpa)	G_{zx} (Gpa)
JFRP composites	16.92	16.92	5.57	0.5	0.5	0.5	2.12	2.12	2.12
PU-foam	2.5	2.5	2.5	0.3	0.3	0.3	2.55	2.55	2.55

Fig 1. CNC drilling machine drilling hole on JFRP PU-foam composite

A. Experimental setup Fanuc CNC drilling machine

Fanuc CNC vertical drilling machine is operated with the pre-set computercontrolled programs. It allows the automatic performance of the machine to deliver the specific task. This machine is automated; high production capacities and quality of perform operations controlled by computer. It enables the continuous working and constant operation with better consistency and accuracy. The important benefits of CNC machining industry is time factor.

B. HSS and TAN coated carbide twist drill tool

Fig 2. HSS and TAN coated carbide twist drill tool of tip angle of 118°

Fig A.2shows the High speed steel (HSS) drill tool and TAN coated carbide twist drill tool of tip angle of 1180 hard bits resistant to heat. The flutes of drill take the more pass remove material from the specimen. These tools to maintain a sharp cutting edge produce a better finish in the hole parts, and their temperature resistance it allows faster machining.

C. Co-ordinate Measuring Machine (CMM)

Fig 3. Coordinated Measuring Machine (CMM)Motorized automated probe

CMM and motorised automated probe applications are the measurement of linear dimensions and geometrical features like surface, cylinder, cone, circle, flatness, straightness, parallelism, ovality, concentricity and perpendicularity. The probe had a spring-loaded steel ball (later, ruby ball) stylus. As the probe touched the surface of the component the stylus deflected and simultaneously sent the X.Y, Z coordinate information to the computer. During drilling of holes on JFRPPU-foam sandwich structures the damage encountered around the hole analyzed with the various parameters.

D. Design of experiments

Main factors and their levels

Table II. Drilling parameter variable levels

Type	levels	Main Factor	Factor	Values
Fixed	3	A	Speed (rpm)	500, 1000, 1500
Fixed	3	B	Feedrate (mm/min)	80, 120, 150
Fixed	3	C	Drill diameter(mm)	3, 4, 5

According to Taguchi's design of experiments, forthree parameters and three levels L27Taguchi orthogonal array [20] was selected. The number of factors and their corresponding levels are shown in TableB.2.The experimental results are then converted into a signal-to-noise (S/N) ratio.Is a measure of quality appearances deviating approaching to the desired values in three categories shown below.

Chen [28] proposed a comparing factor that enables the evaluation and analysis of delamination extent in laminated composites. The delamination Factor (Fd) was defined has the ratio of the maximum delaminated diameter (Dmax) and the hole nominal diameter (D).

$$Fd = Dmax / Dnom \quad (2.4)$$

This design consists of three factors, each at three levels. It expressed as a 3x3x3=33 design. In such cases, main effects have 2 degrees of freedom, two-factor interactions have 2+2+2 = 4 degrees of freedom and k-factor interactions have 2k degrees of freedom. The model contains total degrees of freedom is 2 + 2 + 2 + 4 + 4 + 4 = 18 required. The computation of minimum number of experiments required is total degrees of freedom+1= 18+1=19. R2 is the percentage more than the confidence level of variation in the response by the model. Usually, the higher the R2, the better the model fits for data. F-test is a ratio of mean square. Variances are a measure of dispersion from the mean. F-test the larger value indicates model significant evidence effect in minimizing thrust force, torque and hole wall delamination.

E. ANOVA Result and discussion

A statistical technique ANOVA is used to determining General regression analysis. It shows the standard error co-efficient of speed, feed rate and drill diameter effect on thrust force, torque and delamination of hole and responses calculated in S/N ratios

General regression analysis for thrust force (N), torque and hole wall delamination on treated JFRPPU-foam sandwich structures

1 Thrust force (N) by HSS and TAN coated carbide twist drilled hole

Thrust force (N)=29.5360-0.00588889A+0.210961B+14.0556C ------- (2.5)

Coefficients

Table III. Signal to Noise ratio drilled hole response for the thrust force (N)

Term	Coefficient	SE Coefficient	T	P
Constant	29.5360	7.00408	4.2170	0.000
A: speed	-0.0059	0.00249	-2.3670	0.027
B: feed rate	0.2110	0.03542	5.9558	0.000
C:drill diameter	14.0556	1.24395	11.2991	0.000

Summary of Model: S = 5.27764 R^2 = 88.00%

$R^2_{(adj)}$ = 86.44%

PRESS = 901.307 R^2_{pred} = 83.12%

The table III shows T-values measure the ratio between the coefficient and its standard error. The standard error shows the speed (A=0.000249) is smaller than the feed rate (B=0.00003542) and drill diameter (C=1.24395). Thus drill diameter and feed rate is more significant factor for minimizing the thrust force (N). The predicted R2 value drops from 88% to 83.12% of model of hole wall delamination.

2.4.1.2 Torque (N-m) by HSS and TANcoated carbide twist drilled hole

Torque (N-m)= -0.149417 - 1.15556e-005 A + 0.00045961 B + 0.07975 C --- (4.18)

Coefficients

Table IV. Signal to Noise ratio drilled hole response for the torque (N-m)

Term	Coefficient	SE Coefficient	T	P
Constant	-0.149417	0.0173364	-8.6187	0.000
A	-0.000012	0.0000062	-1.8765	0.073
B	0.000460	0.0000877	5.2423	0.000
C	0.081750	0.0030790	26.5507	0.000

Summary of Model: S = 0.00568231 R^2= 96.97%
R^2(adj) = 96.57%
PRESS = 0.00617504 R^2_{pred} = 95.61%

In this table IV shows the T-values measure the ratio between the coefficient and its standard error. The standard error shows the speed (A=0.0000062) is smaller than the feed rate (B=0.0000877) and drill diameter (0.0030790).Thus drill diameter and feed rate is more significant factor for minimizing the torque (N-m). The multivariable linear regression analysis results in torque predicted R2 value drops from 96.97% to 95.61%

General Regression Analysis hole wall delamination

HSS entrance hole = 1.02529-6.76278e-006A+4.74374e-006B+0.00277593C -(2.7) Coefficients

Table V. Signal to Noise ratio response for the drilled entrance hole

Term	Coefficient	SE Coefficient	T	P
Constant	1.02529	0.0038448	266.667	0.000
A: speed	-0.00001	0.0000014	-4.952	0.000
B: feed rate	-0.00000	0.0000194	0.244	0.809
C:drill diameter	-0.00278	0.0006829	4.065	0.000

Summary of Model: S = 0.00289712 R^2 = 64.12% , $R^2_{(Adj)}$ = 59.44%
PRESS = 0.000260681, $R^2_{(pred)}$ = 51.55%

Table V shows T-values measure the standard error shows the speed (0.0000014) is smaller than the feed rate (B=0.0000194) and drill diameter (C=0.0006829).Thus drill diameter and feed rate is more significant factor for minimizing the delamination entrance hole. The multivariable linear regression analysis results the delamination of hole predicted R2 value drops from 64.12% to 51.55%.

HSS exit hole =1.03057 — 6.76278e-006 A + 4.74374e-006 B + 0.00210926 C—(2.8)

Coefficients

Table VI. Signal to Noise ratio response for the delamination factor exit hole

Term	Coefficient	SE Coefficient	T	P
Constant	1.03057	0.0057043	262.923	0.000
A: speed	-0.00001	0.0000014	-4.857	0.000
B: feed rate	0.00000	0.0000196	0.239	0.813
C:drill diameter	-0.00211	0.0006961	3.030	0.006

Summary of Model; S = 0.00295351 R^2 = 58.80% $R^2_{(Adj)}$ = 53.43%
PRESS = 0.000270576 $R^2_{(pred)}$ = 44.44%

Table IV shows theT-values measure the ratio between the coefficient and its standard error. The standard error shows the speed (A=0.0000014) is smaller than the feed rate (B=0.0000196) and drill diameter (C=0.0006961). Thus drill diameter and feed rate is more significant factor for minimizing the delamination of exit hole. The predicted R2 value drops from 58.80% to 44.44 % of model of hole wall delamination.

General Regression Analysis of TAN coated carbide twist drilled entrance hole

TAN entrance hole=1.02423-6.76667e-006A+4.62462e-006B+0.00291667 C-- (2.10)

Coefficients

Table VII. Signal to Noise ratio response for the delamination factor entrance hole

Term	Coefficient	SE Coefficient	T	P
Constant	1.02423	0.0038291	267.488	0.000
A: speed	-0.00001	0.0000014	-4.975	0.000
B: feed rate	-0.00000	0.0000194	-0.239	0.813
C:drill diameter	-0.0292	0.0006801	-4.289	0.000

Summary of Model; S = 0.00288602 R^2 = 65.26% $R^2_{(Adj)}$ = 60.73%
PRESS = 0.000258435 $R^2_{(pred)}$ = 53.11%

In regressiong equation the predicted R2 value drops from 65.26% to 53.11% of model of entrance hole wall delamination-values measure the ratio between the coefficient and its standard error. The standard error shows the speed (A=0.0000014) is smaller than the feed rate (B=0.0000194) and drill diameter (C=0.006801). Thus drill diameter and feed rate is more significant factor for minimizing the delamination of entrance hole.

TAN exit hole = 1.02423-6.76667e-006 A+4.62462e-006 B+ 0.00291667 (2.11)

Table VIII. Signal to Noise ratio response for delamination of entrance hole

Term	Coefficient	SE Coefficient	T	P
Constant	1.02423	0.0038291	263.488	0.000
A: speed	-0.00001	0.0000014	-4.975	0.000
B: feed rate	0.00000	0.0000194	0.239	0.813
C: drill diameter	0.00292	0.0006801	4.289	0.000

Summary of Model;S = 0.00288525 R2 = 65.26% R2 (Adj) = 60.73%
PRESS = 0.000258435 R2(pred) = 53.11%

T-values measure the ratio between the coefficient and its standard error. The standard error shows the speed (A=0.0000014) is smaller than the feed rate (B=0.0000194) and drill diameter (C=0.006801). Thus drill diameter and feed rate is more significant factor for minimizing thedelamination of exit hole. The predicted R2 value drops from 65.26% to 53.11%

F. Main effect plot for HSS twist drilled hole

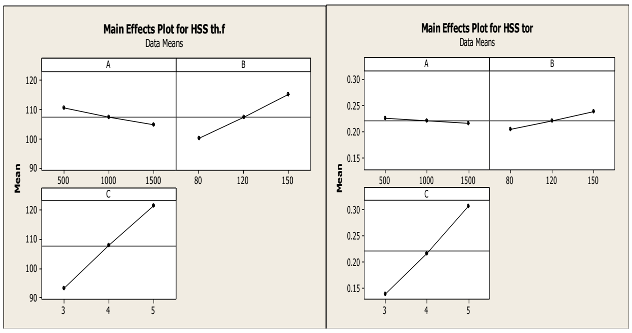


Fig 9. HSS twist drilled hole plot for S/N ratio of thrust force (N)

In HSS twist drilled hole the response of thrust force decreases by increase in speed also thrust force increases by increase in feed rate as well as drill diameter. Where as in case torque speed and feed rate is maintain constant mean level and increases torque by increase in drill diameter.
Delamination of entranceand exit hole.

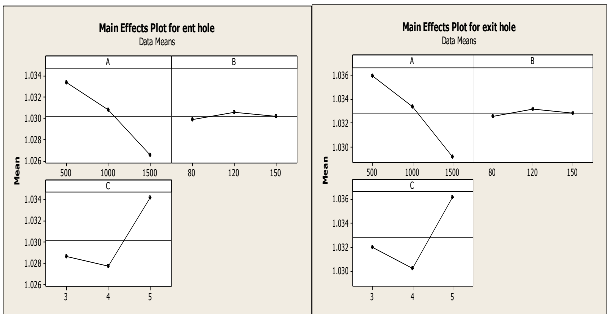


Fig 10. HSS twist drilled entrance and exit hole

In figure A.10 shows the response of hole wall delamination decreases with increase in speed as well as feed rate maintain mean level, also delamination of hole decreases very much in 4 mm drill diameter for both entrance and exit hole. The delamination hole value below the is 1.028 mm.

Main effect plot for TAN coated carbide twist drilled hole

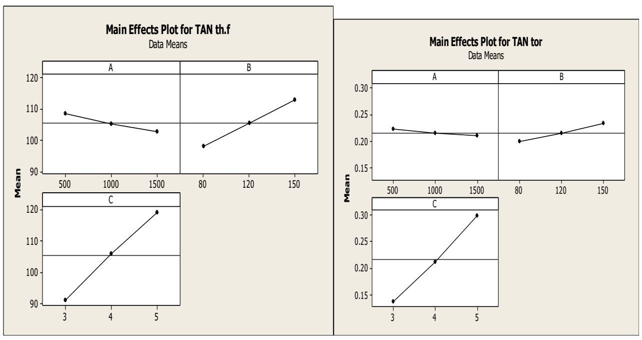
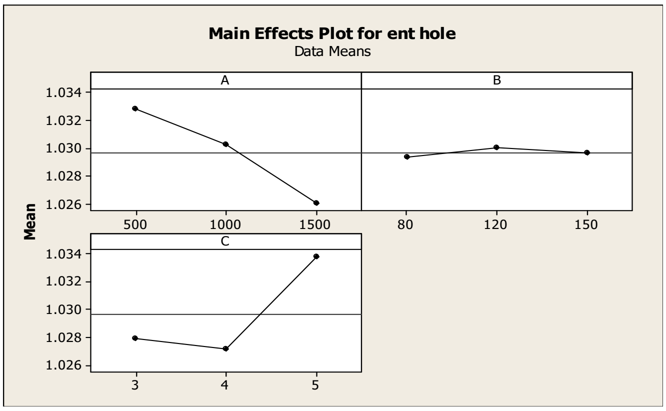


Fig 10 TAN coated carbide twist drilled hole

In TAN coated carbide twist drilled hole thrust force decreases with increase in speed as well as thrust force increases by increase in feed rate and drill diameter both in entrance and exit side of the hole. Delamination of entrance and exit



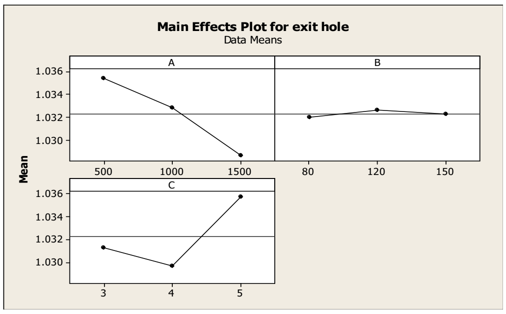


Fig 11. TAN coated carbide twist drilled entrance and exit hole

In figure A.11 shows the response of hole wall delamination decreases with increase in speed as well as feed rate maintain mean level, But delamination of hole decreases still very much in 4 mm drill diameter for both entrance and exit hole.

III. CONCLUSION

Thus drill diameter and feed rate is more significant factor for minimizing the thrust force (N) and delamination of the hole. The multivariable linear regression analysis results in thrust force the predicted R2 value drops from 88% to 83.12% and regression analysis results in torque predicted R2 value drops from 96.97% to 95.61%. Similarly delamination of the hole reduced by the effect of drill diameter and feed rate. In the HSS twist drilled hole multivariable linear regression analysis results the delamination of entrance hole predicted R2 value drops from 64.12% to 51.55%and in exit hole R2 value drops from 58.80% to 44.44 % of model of hole wall delamination. Where as TAN coated carbide twist drilled hole the predicted R2 value drops from 65.26% to 53.11% of model both entrance and exit hole. When comparing R2 value drops between HSS and TAN coated carbide twist drilled hole. TAN coated carbide twist drilled hole more percentage to reduced the delamination of the hole.

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