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Optimization of drilling parameters on Ramie-jute fibres Reinforced hybrid epoxy composite using Taguchi method

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Abstract

The reason behind development of this paper is to identify the ideal process parameters to be set for the drilling of hybrid FRP (Ramie and Jute) composite using HSS drill bits with different volume fractions by means of statistical reproduction of the delamination factor using Taguchi Analysis. The contemplated process parameters are Feed, Speed and Volume fraction. With the help of Taguchi's L-9 factorial design the trials were carried out. Three factors, three level Taguchi Orthogonal Array design was used to carry out the trial study. In order to identify the damage around the drill region Video Measuring System (VMS) was used. 'Minitab 18' was used to examine the data collected by taking advantage of the various statistical and graphical tools available. Examination of variance is used to legitimize the model in identifying the best notable variable.

Keywords: Taguchi, Drilling, Optimisation, Delamination factor, Characterization

1. Introduction

Fibre-reinforced composites have numerous applications in our daily life because of their usability and strength. Fibres oriented in the same direction produce enhanced strength properties. Natural fibres can be used as replacements for synthetic fibres. Natural fibres are obtained from things which we consider as waste, they are eco-friendly and easily available. They are mainly used in aerospace, automotive and construction industries as a result of its less weight, enhanced specific strength and toughness towards fracture. In fabrication of fibre reinforced parts, drilling is one of the most crucial machining processes. Fibre Reinforced Polymer components are contrived closer to the final shape and further removal of material is restricted to deburring, trimming and contour shape accuracy. The dimensional precision is improved by reducing the surface roughness and delamination factor and it also improves the performance of composite and the machinability of the composite.[1] To find out the surface quality and dimensional properties, theoretical models are applied for conjecture. Taguchi methodology is one of methods that is used to figure out the process parameters for various performance attributes. Best drilling parameters are chosen to attain maximized performance characteristics for drilling process. Taguchi method is a competent tool for process optimization for constrained number of trials.[2] Retrogradation data collection and graphical interpretation was done using a software called "Minitab 18". Analysis of variance (ANOVA) is used to verify cogency of model and parameters. The delamination factor of drilled components can be found out using this model.

2. Experimental Study

In the experiment as discussed, 3 composites with different volume fractions of Ramie fibres and Jute fibres were fabricated with different volume fractions being 40%, 50% and 60%. Epoxy resin (LY556) and hardener (HY 951) is concocted to form Hybrid Fibre Reinforced Polymer laminates by adopting hand lay-up technique. The thickness of the material is 4.02 mm. The drill bit used for drilling is made of HSS with Tungsten Carbide coating. The delamination factor is considered as the important factor of quality in any drilling operation. The various parameters considered in the trial are: Feed, Speed and Volume fraction. To curtail the number of trials, Taguchi's L-9 factorial design was employed in the procedure. After a circumstantial study, minimum and maximum limit was identified for the above discussed laminate. Low limits of feed rates are recommended in drilling Fibre Reinforced Polymer composites.[4] The drilling parameters as recognized are given in Table 1. All the drill holes were augured using ATC CNC machines using the 5, 10, 15 mm HSS drill bits with Tungsten Carbide coating. The holes were then measured, using Vision Measuring System (VMS).

$$F_d = D_{\max}/D \quad (1)$$

wherein, D_{\max} represents maximal diameter - drill hole after damage (mm), D represents original diameter - drill hole (mm) and F_d represents delamination factor.[5]

Factors	Cutting parameters	Levels			
		Units	1	2	3
A	Feed	mm/min	450	300	150
B	Cutting Speed	rpm	3000	2000	1000

C	Volume fraction	%	40	50	60
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Table 1. Cutting parameters with their levels.**3. Design of Experiments**

Taguchi's L-9 orthogonal formation is chosen. Output delamination factor is the performance attributes. The values as obtained is considered in 'lower-the-better' approach.

Table 2. Experimental model using L-9 orthogonal line-up along with their responses

Expt	feed	speed	Vol fraction	Delamination Factor
1	100	1000	40	1.0068
2	100	2000	50	1.0033
3	100	3000	60	1.0068
4	300	1000	50	1.0026
5	300	2000	60	1.0107
6	300	3000	40	1.0033
7	450	1000	60	1.0104
8	450	2000	40	1.0046
9	450	3000	50	1.0060

4. Result and Discussion**Table : Experimental Results**

Expt	Feed	Speed	Vol fraction	Delamination Factor	SNRs
1	100	1000	40	1.0068	-0.0588641
2	100	2000	50	1.0033	-0.0286162
3	100	3000	60	1.0068	-0.0588641
4	300	1000	50	1.0026	-0.0225540
5	300	2000	60	1.0107	-0.0924453
6	300	3000	40	1.0033	-0.0286162
7	450	1000	60	1.0104	-0.0898668
8	450	2000	40	1.0046	-0.0398635
9	450	3000	50	1.0060	-0.0519596

Response table for means

LEVEL	feed	Speed	Vol fraction
1	1.006	1.007	1.005
2	1.006	1.006	1.004
3	1.007	1.005	1.009
DELTA	0.001	0.001	0.005

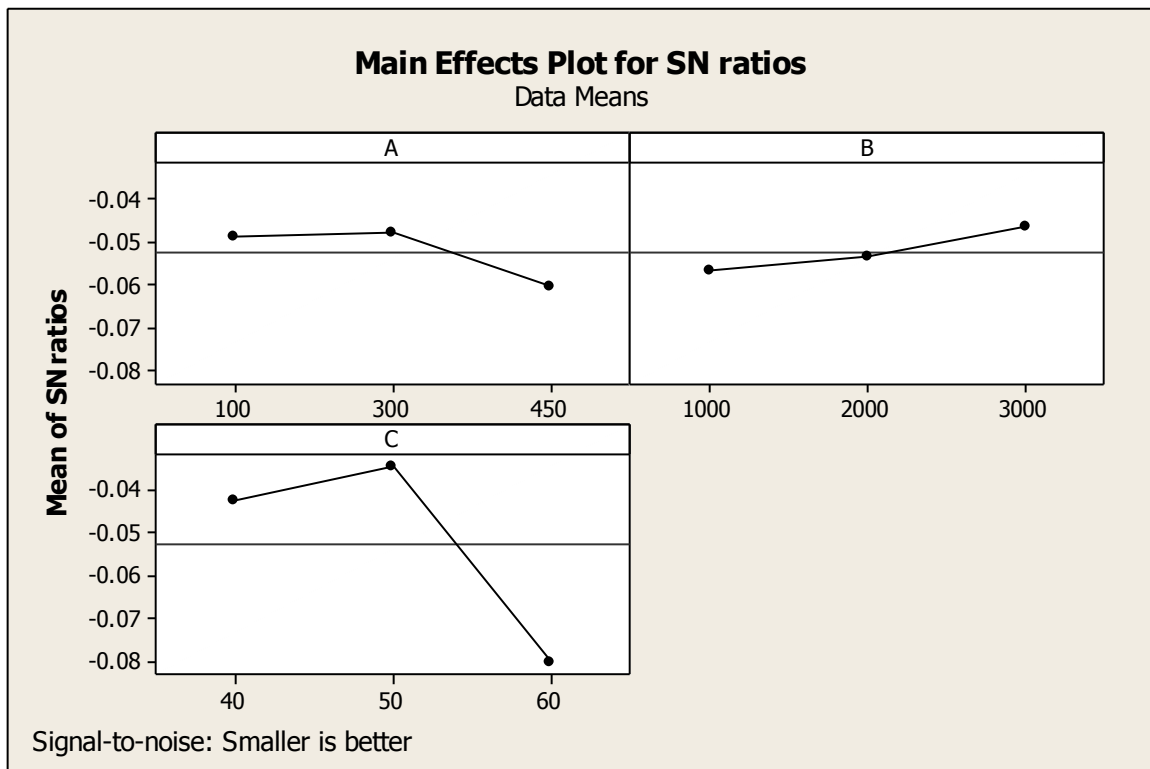


Figure 3. Graphical representation of S/N Ratios on delamination

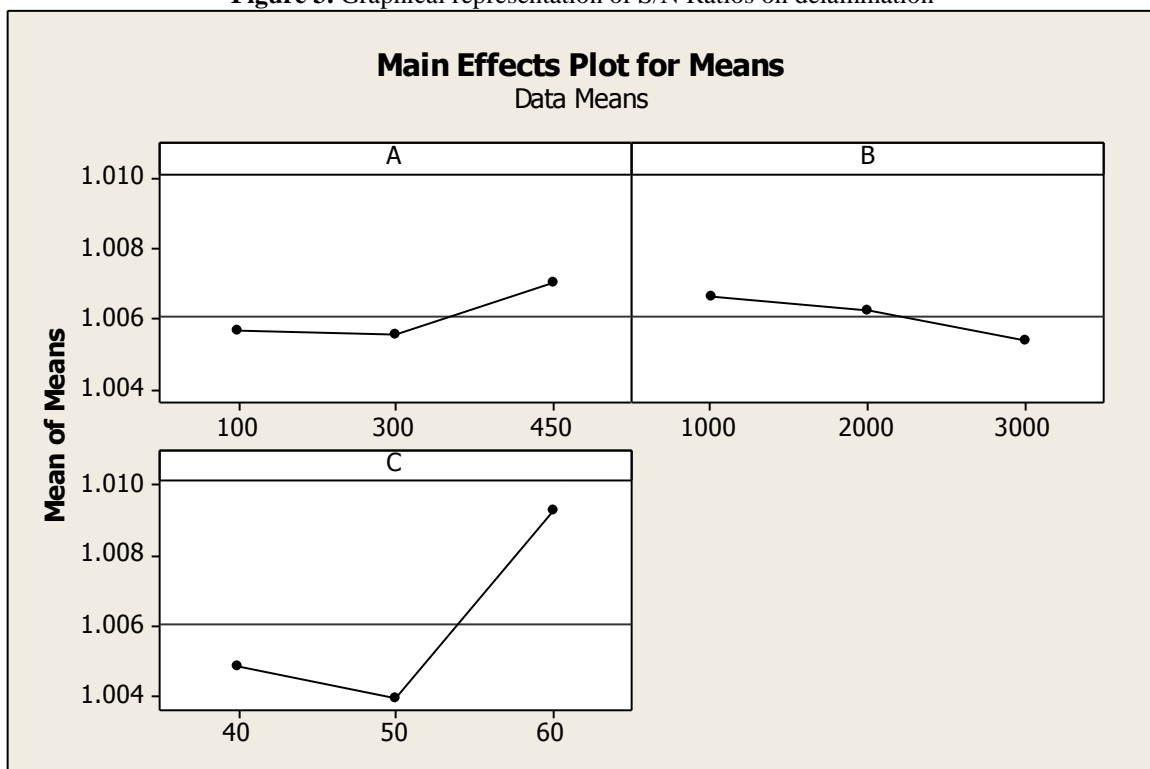


Figure 4. Graphical representation of factor effects on delamination

Analysis of Variance

Analysis of variance (ANOVA) is a procedure used to distribute the fluctuation of an output to numerous inputs. The percentage contribution by each drilling variable indicates its importance. The significance level is set at 5% (confidence level is 95%). From the Table 5, it is recognized that speed (Percentage contribution, P = 90.85 %) is the most significant drilling parameter.

Table 5. Results of ANOVA analysis

Source	Degree of Freedom	Sum of squares	Mean square	F-Value	% contribution
Feed	2	0.00000403	0.00000201	0.13	5.6
Speed	2	0.00006440	0.00001610	0.17	90.85
Volume fraction	2	0.00000238	0.00000119	0.04	3.35
Error	2	0.00000008	0.00000041	-	0.2
Total	8	0.00007088	-	-	100
S=0.0007711 R-sq=96.36% R-sq(adj)=95.26%					

5. Conclusion

As per the experimental outcome, the ensuing conclusions are perceived through drilling of Hybrid Fibre Reinforced epoxy composite using HSS drill bit with Tungsten Carbide coating. The set of optimized input parameters is:- Feed rate: 300 mm/min, Cutting Speed: 3000 rpm and Volume fraction of 60%. Through ANOVA analysis, we find out that the Speed (contribution =90.85%) is the dominating parameter in the case of delamination factor.

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