International Journal of Advanced Technology in Engineering and Science
Vol. No. 10, Issue No. 05, May 2022
www.ijates.com
ijates
ISSN 2348 - 7550

Optimization of Machining Parameters of Vetiver fiber reinforced Epoxy resin using Taguchi & RSM Techniques

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ABSTRACT

Organic fibre-reinforced epoxy composites saw a boom in use in a range of engineering applications in recent years. As a result, need for precise composite machining has skyrocketed. Different drilling-variables like as tool rotational speed, bit-diameter, and feed-rate are used to evaluate surface-roughness and-delamination in drilling-processes. Bisphenol-A epoxy resin is used for the epoxy, and Vetiver Fiber is used for the natural fibre reinforcing. The specimen is prepared using a hand layup process. The Taguchi method was used to design the experiment, and RSM was used to fine-tune the parameters (Response Surface Methodology). Following that, the outputs will be assessed

I INTRODUCTION

In a variety of technological applications, natural fibre composites are showing to be viable options to glass-reinforced composites and metals. Vetiver, a lingo-cellulosic fibre found in coconut palms, has been used as a fillers or reinforcement in a variety of composite products. The structure parameters of the fibre (including measurements, weight, electric resistance, ultimate tensile, initial modulus, and % elongation) were investigated. The fibres of vetiver are hirsute, glossy, non-sulky, and rigid. With just a tenacity of 2.11 grammes per denier, vetiver fibre is harder than wool but just not as strong as cotton. When the fibre is wet, its flexibility and toughness are reduced. The hardener was HY951 and the matrix was epoxy Bisphenol-A resin. The samples were produced comprised with 18 sheets of fibre utilising the hands lay-up technique and a hot press.

When it comes to producing composites, hand layup is indeed the earliest and most basic technique, which entails manually laying down layers of fabric or plies in a mould and then applying resin to the layers to make laminates. Typically, a hand layup manufacture can be separated into four essential steps: mould prep, gel coatings, layup, and curing. This procedure involves labor-intensive in which the lamination quality, resin blending, and lamination resin content are highly reliant on the operator's abilities, as in this approach not much fibre loading is possible. Using the Taguchi technique of quality control, engineers emphasise the importance of product design and research and development (R&D) in reducing the occurrence of manufacturing faults. Design parameters are optimised in the Taguchi method before output parameters are optimised to meet target values. With only a few experiments, the Taguchi technique studies all of the design elements. One of the most popular methods for studying and modelling processes where the response of interest is modified by multiple variables is called response surface methodology (RSM). Responses are called dependant 9 variables, whereas variables that influence the process are known as dependant variables.

Phani sai and Lokesh Considering hand-laying up a Vetiver fibre composite sheet 170 x 130 x 10 mm, composed of fibres that are irregularly arranged. Vetiver fibres were used in a bisphenol-a epoxy resin mixture at a weight ratio of 1:3 to create the composite material. They used Taguchi's method to conduct-drilling study on Vetiver fibre-reinforced polyester composites to determine the best parameters for achieving surface-roughness and -Delamination. According to a close look at their results, the values stated in the L9 orthogonal array differ from the levels at which process parameters were assigned in their analyses. The cutting parameters recommended by them are based on the assigned levels of process factors. The test runs don't even use Taguchi's L9 orthogonal array in process variable definitions. Surface-roughness and-delamination have been found to be inaccurately predicted by mathematical models based on process variables (drill-bit size, rotational speeds, and feed----rate). As a result, it's time to revisit this intriguing subject and show how Taguchi's design of experiments can be used to track down the optimal process parameters that lead to the desired output reaction. According to the Taguchi method, these experimental data by Lokesh and Phani sai have been rearranged in an orthogonal array. The surface-roughness, and delamination-of the optimum process parameters can be predicted using a simple and effective approach. A comparison of test data confirms the optimal drilling-variables for achieving surface-roughness &-delamination in a randomly distributed coir fibre composite.

II PROCEDURE

• Acquire the fiber and epoxy resin
• Manufacture using hand layup
• Determine the input factor, responses and level
• Design of experiment using Taguchi
• Identify the machine (Drilling)
• Conduction of experiment
• Measurement of responses
• Factor interaction using Taguchi
• Optimization of parameters using RSM
• Result and discussion
• Conclusion
• Conference Paper Presentation

III DESIGN OF EXPERIMENT

DOE is a technique used to examine the impact of various factors on output characteristics. Once we have a number of input variables, we use the DOE table to construct a number of levels. These levels are determined by the number of experiments that need to be carried out. In this context, "levels" refers to the number of possible values that can be derived from a given set of input data.

IV RESPONSE SURFACE METHODOLOGY

In this project, Response surface method RSM is used to optimise the output parameters based on the stated input variables. Evaluation and optimisation of response to various input variables can indeed be done using this statistical and mathematical method.

Delamination-factors, for example, can be affected by the tool's X1 and X2 feed speeds, as well as the speed at which the workpiece is Drilled. It is possible to alter the workpiece Delamination factor with any combination of X1 and X2. There are no limits on how fast or how much you can feed. The Delamination factor of the workpiece is a function of speed and feed, and RSM can be used to optimise this response variable. As demonstrated in equation 3.4.1, the dependent variable, y, is related to the independent variables, X1 and X2.

$$Y = f(X_1) + f(X_2) + e \quad \text{Eq 3.4.1}$$

Here, e is the error in the response

V EXPERIMENTAL PROCEDURE

SPECIMEN PREPARATION

This study made use of vetiver fibre. Ethylene bisphenol A epoxy resin and hardener were used in the composition of matrix (HY951). The epoxy resin samples had a fibre weight ratio of 1:3 and were manufactured up of 18 layers utilising a hot press and hand lay-up process. A zig zag machine was used to do the curing procedure, which resulted in a specimen of 170x130mm.

DRILLING-PROCESS

A vertically CNC milling with a maximum tool rotational speed, feedrate, & drill-bit diameter was used to drill-vetiver fibre reinforced epoxy resin. In all experiments, coolant was not used because the cutting conditions were dry. For the epoxy resin to be properly positioned and held, an appropriate & adjustable fixture was required. Using a fixture and dynamometer mounted on the CNC machine table, the specimen was tested. A DAQ-System Type 5697A was used to quantify the thrust force caused during the drilling of vetiver fibre reinforced epoxy resin composites. A Kistler5697A DAQ device with an A/D converters transmitted signals to a computer through connected wires. The data was collected and analysed using the DynoWare Kistler programme.

DESIGN OF EXPERIMENT

The design of experiment DOE is a method for identifying the parts of the production process that contribute to the best possible product properties. Factorial tests are the best method for studying the effects of several variables.

International Journal of Advanced Technology in Engineering and Science
Vol. No. 10, Issue No. 05, May 2022
www.ijates.com
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Table 4.2.1: Drilling parameters in three levels

Levels	Rotational speed (RPM)	Feed Rate(mm/revo)	Drill-bit dia (mm)
1	600	0.05	9
2	1200	0.35	11
3	1800	0.2	10

Drilling experiments were designed using the Taguchi's L 9 orthogonal array in this investigation. Minitab program was used to design the experiment, which included three levels of tool rotational speed, feeds, & drill-bit diameter as input factors (see Table). There were a total of nine trial runs. Taguchi was used to ensure the validity of each run's results. As a result, nine separate tests were performed. Each run's-delamination size & surface-roughness were recorded as response variables.

Table4.2.2: L9 DOE orthogonal array table

S.NO	A	B	C
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	3
5	2	2	1
6	2	3	2
7	3	1	2
8	3	2	3
9	3	3	1

Here A, B, C are the input parameters which you define. Using the above table Drilling experimental values are generated.

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Table 4.2.3: Drilling DOE values

S.NO	Rotational speed(rpm)	Feed (mm/revo)	Drill-bit dia (mm)
1	600	0.05	9
2	1200	0.35	9
3	1800	0.2	9
4	1200	0.2	11
5	1800	0.05	11
6	600	0.35	11
7	1800	0.35	10
8	600	0.2	10
9	1200	0.05	10

WORKSHEET 1

Taguchi Analysis: Surface rougness, Delamination versus Drill bit diameter, Spindle speed, Feed rate

Response Table for Signal to Noise Ratios

Smaller is better

Level	Drill bit diameter	Spindle speed	Feed rate
1	-8.390	-8.594	-11.558
2	-16.552	-15.474	-14.241
3	-13.046	-13.919	-12.188
Delta	8.162	6.880	2.683
Rank	1	2	3

Response Table for Means

Level	Drill bit diameter	Spindle speed	Feed rate
1	2.651	3.025	4.013
2	5.281	4.716	4.345
3	3.962	4.153	3.536
Delta	2.629	1.691	0.808
Rank	1	2	3

MEASUREMENTS

Surface-roughness&-Delamination were tested with in lab after the Drilling process and documented.

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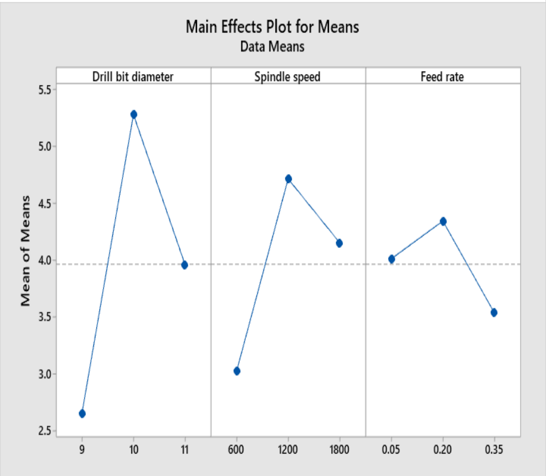
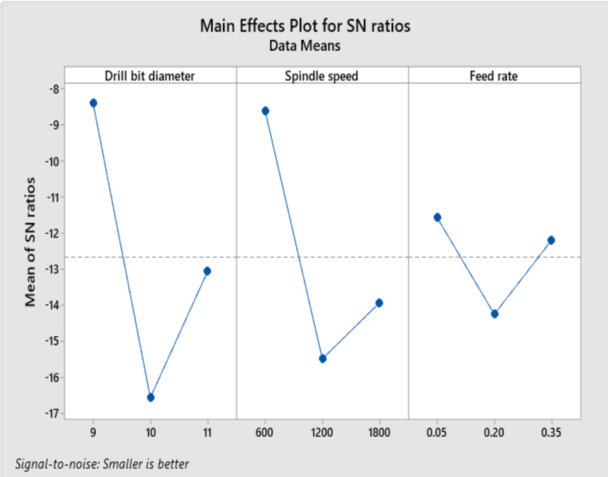
ISSN 2348 - 7550





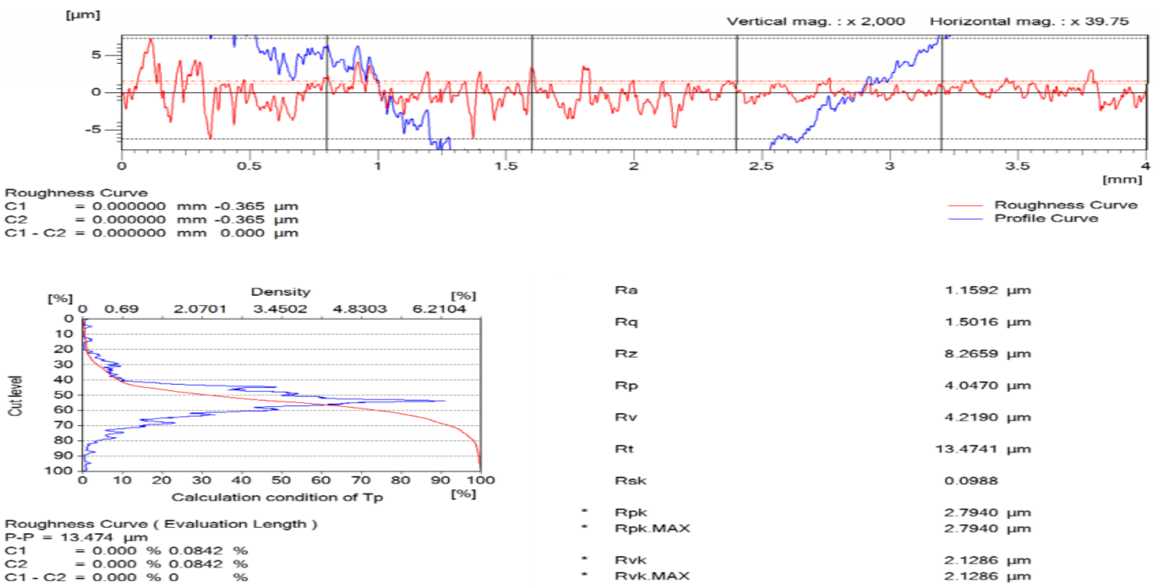
SURFACE-ROUGHNESS

The SURFCOM 1400G machine was used to assess surface-roughness (Ra) from the hollow wall surfaces using an ANSI standard cut-off value and traversal length of 4 mm. By using average of four measurements taken at 4 distinct points along hollow plane, surface- roughness values may be calculated for each hole.

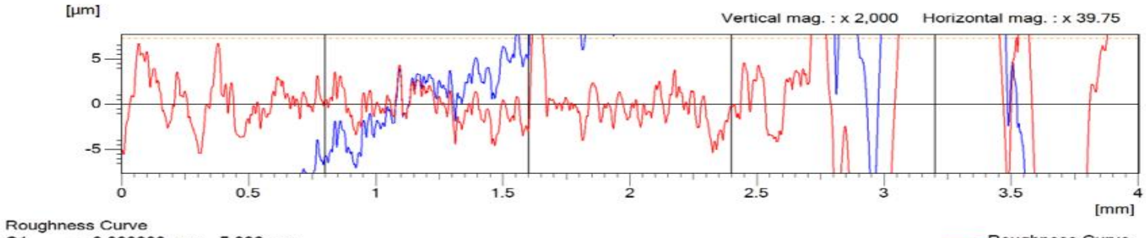
Surface-roughness was measured after Drilling, it was done with SURFCOM Profilometer.

Surface-roughness

H1

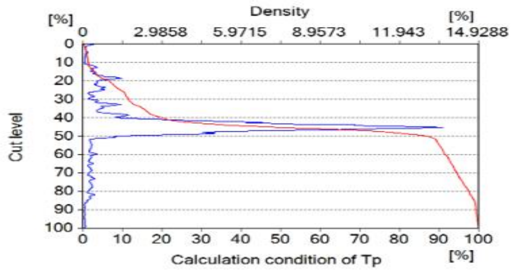


H 2



Roughness Curve
C1 = 0.000000 mm -5.006 µm
C2 = 0.000000 mm -5.006 µm
C1 - C2 = 0.000000 mm 0.000 µm

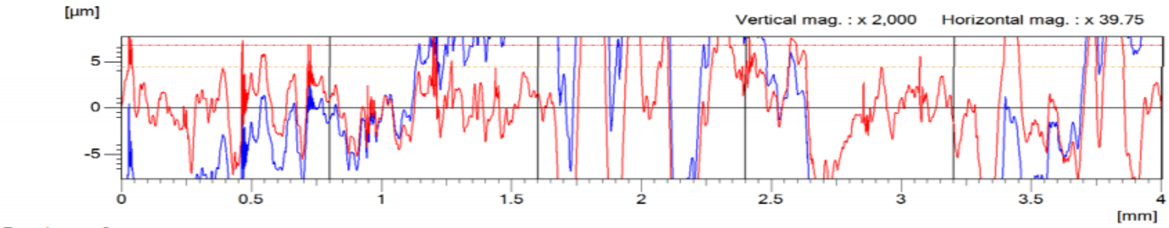
Roughness Curve
Profile Curve



Ra	7.3163 µm
Rq	9.2704 µm
Rz	39.6184 µm
Rp	19.0055 µm
Rv	20.6129 µm
Rt	91.7579 µm
Rsk	0.3587
* Rpk	26.1321 µm
* Rpk.MAX	26.1321 µm
* Rvk	29.6748 µm
* Rvk.MAX	29.6748 µm

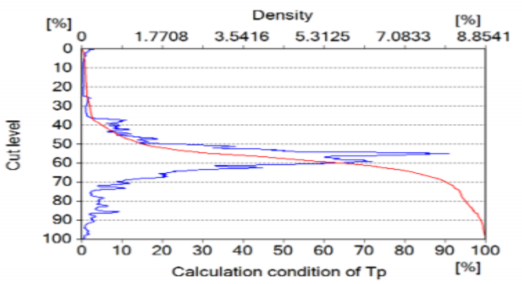
Roughness Curve (Evaluation Length)
P-P = 91.758 µm
C1 = 0.000 % 0.4138 %
C2 = 0.000 % 0.4138 %
C1 - C2 = 0.000 % 0 %

H 3



Roughness Curve
C1 = 0.000000 mm 0.206 µm
C2 = 0.000000 mm 0.206 µm
C1 - C2 = 0.000000 mm 0.000 µm

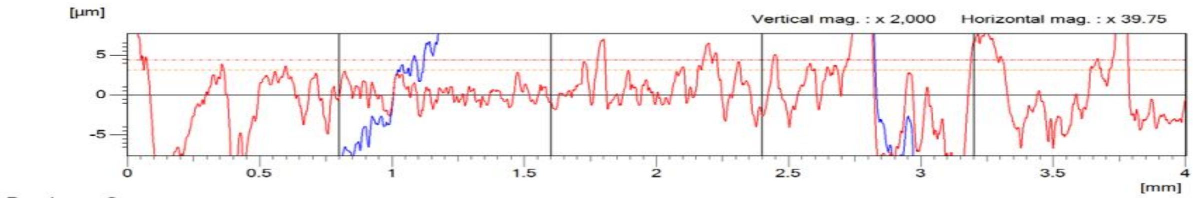
Roughness Curve
Profile Curve



Ra	4.4177 µm
Rq	5.6362 µm
Rz	27.6701 µm
Rp	15.1584 µm
Rv	12.5118 µm
Rt	57.0647 µm
Rsk	-0.1094
* Rpk	11.3147 µm
* Rpk.MAX	11.3147 µm
* Rvk	11.0522 µm
* Rvk.MAX	11.0522 µm

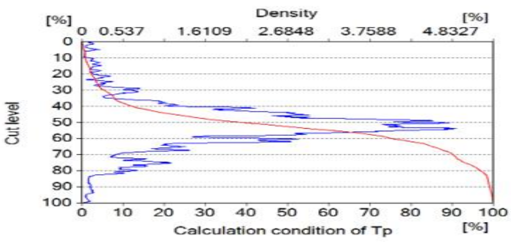
Roughness Curve (Evaluation Length)
P-P = 57.065 µm
C1 = 0.000 % 0.271 %
C2 = 0.000 % 0.271 %
C1 - C2 = 0.000 % 0 %

H4



Roughness Curve
C1 = 0.000000 mm 11.923 µm
C2 = 0.000000 mm 11.923 µm
C1 - C2 = 0.000000 mm 0.000 µm

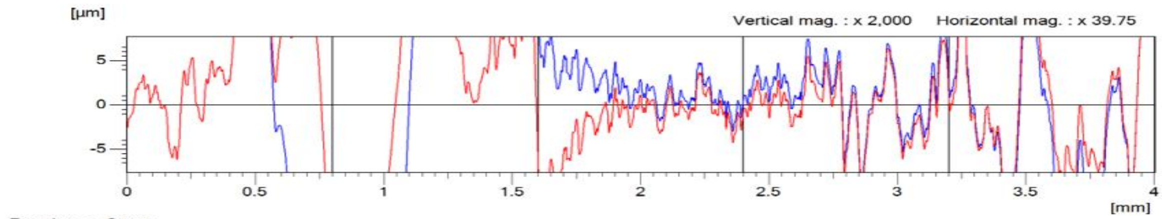
Roughness Curve
Profile Curve



Roughness Curve (Evaluation Length)
P-P = 31.807 µm
C1 = 0.000 % 0.1208 %
C2 = 0.000 % 0.1208 %
C1 - C2 = 0.000 % 0 %

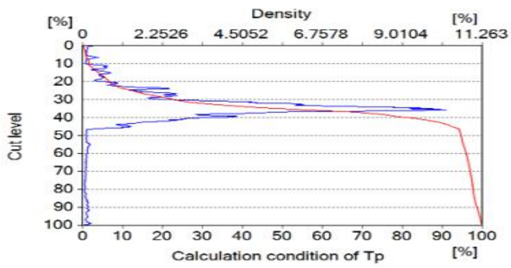
	Ra	3.1523 µm
	Rq	4.0244 µm
	Rz	18.8171 µm
	Rp	10.4278 µm
	Rv	8.3893 µm
	Rt	31.8069 µm
	Rsk	0.5055
*	Rpk	7.1890 µm
*	Rpk.MAX	7.1890 µm
*	Rvk	6.4598 µm
*	Rvk.MAX	6.4598 µm

H5



Roughness Curve
C1 = 0.000000 mm -2.586 µm
C2 = 0.000000 mm -2.586 µm
C1 - C2 = 0.000000 mm 0.000 µm

Roughness Curve
Profile Curve

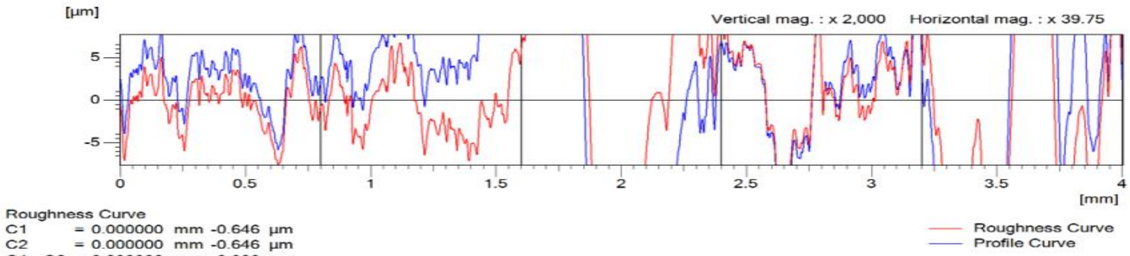


Roughness Curve (Evaluation Length)
P-P = 106.021 µm
C1 = 0.000 % 0.2856 %
C2 = 0.000 % 0.2856 %
C1 - C2 = 0.000 % 0 %

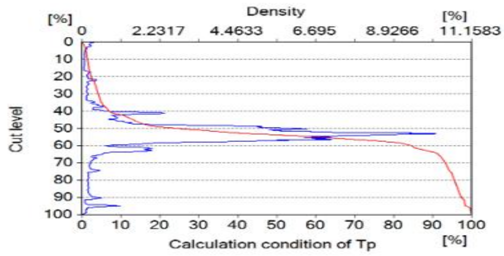
	Ra	7.7222 µm
	Rq	10.3413 µm
	Rz	44.2307 µm
	Rp	19.3518 µm
	Rv	24.8788 µm
	Rt	106.0209 µm
	Rsk	-0.2348
*	Rpk	15.8267 µm
*	Rpk.MAX	15.8267 µm
*	Rvk	28.5457 µm
*	Rvk.MAX	28.5457 µm

International Journal of Advanced Technology in Engineering and Science
Vol. No. 10, Issue No. 05, May 2022
www.ijates.com
ijates
ISSN 2348 - 7550

H6



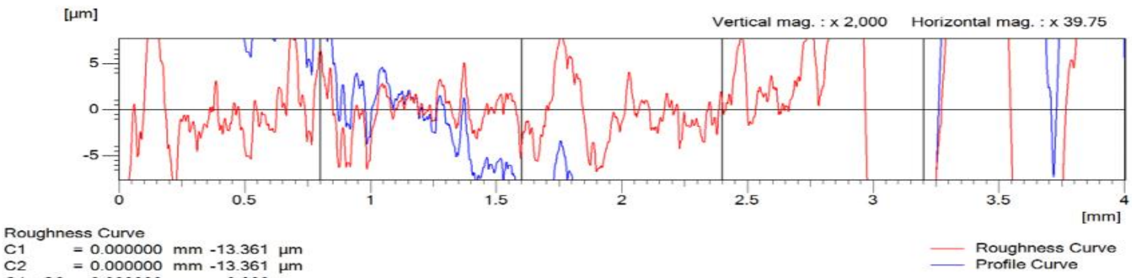
Roughness Curve
C1 = 0.000000 mm -0.646 µm
C2 = 0.000000 mm -0.646 µm
C1 - C2 = 0.000000 mm 0.000 µm



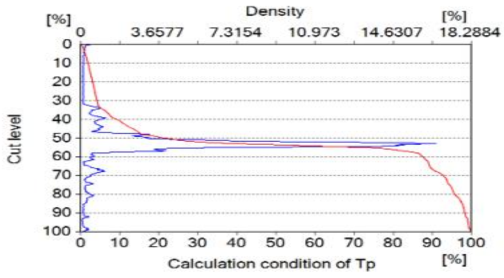
Roughness Curve (Evaluation Length)
P-P = 127.639 µm
C1 = 0.000 % 0.3369 %
C2 = 0.000 % 0.3369 %
C1 - C2 = 0.000 % 0 %

	Ra	9.7632 µm
	Rq	12.9151 µm
	Rz	57.3076 µm
	Rp	30.5696 µm
	Rv	26.7379 µm
	Rt	127.6391 µm
	Rsk	0.1117
*	Rpk	32.5670 µm
*	Rpk.MAX	32.5670 µm
*	Rvk	33.1842 µm
*	Rvk.MAX	33.1842 µm

H 7



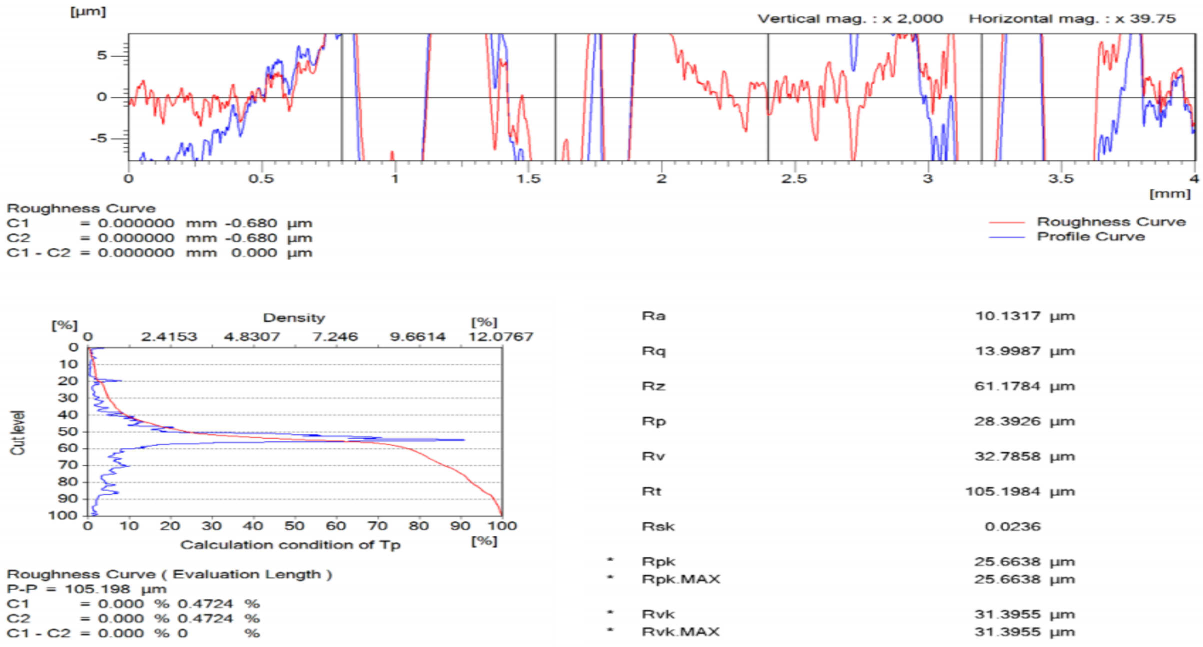
Roughness Curve
C1 = 0.000000 mm -13.361 µm
C2 = 0.000000 mm -13.361 µm
C1 - C2 = 0.000000 mm 0.000 µm



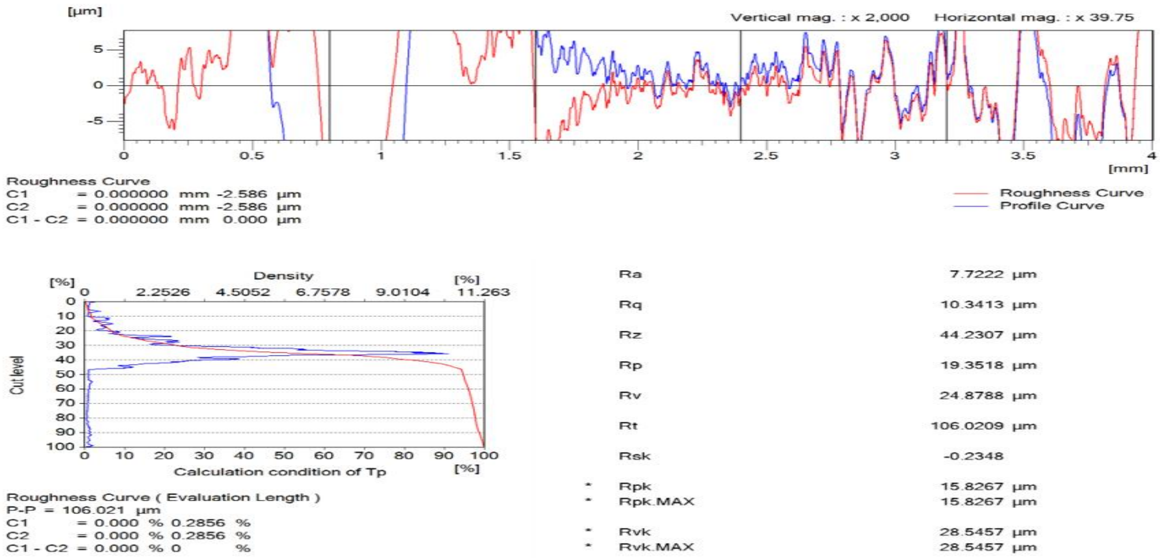
Roughness Curve (Evaluation Length)
P-P = 150.753 µm
C1 = 0.000 % 0.4394 %
C2 = 0.000 % 0.4394 %
C1 - C2 = 0.000 % 0 %

	Ra	10.7936 µm
	Rq	14.5255 µm
	Rz	55.4447 µm
	Rp	28.2702 µm
	Rv	27.1745 µm
	Rt	150.7526 µm
	Rsk	-0.0849
*	Rpk	36.8642 µm
*	Rpk.MAX	36.8642 µm
*	Rvk	40.3405 µm
*	Rvk.MAX	40.3405 µm

H 8



H 9



DELAMINATION FACTOR

A Profiles Projection machine was used to measure both nominal diameter & optimum size of the drilled holes just on screening bed of the scanner. The measurements were then obtained using the-delamination!factor formula.

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Vol. No. 10, Issue No. 05, May 2022
www.ijates.com
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Table 4.3.4: Drilling results

S.NO	Rotational Speed (Rpm)	Feed (mm/rev)	Drill-bit diameter (mm)	Surfaces Roughness (R)	-Delamination! factor
1	600	0.05	9	1.1592	1.003
2	1200	0.35	9	7.3163	1.01
3	1800	0.2	9	4.4177	1.001
4	1200	0.2	11	3.1523	1.014
5	1800	0.05	11	7.8133	1.015
6	600	0.35	11	9.7632	1.012
7	1800	0.35	10	10.7936	1.027
8	600	0.2	10	10.1317	1.007
9	1200	0.05	10	7.7222	1.002

WORKSHEET 1

Response Surface Regression: Surface roughness versus Drill bit diameter, Spindle speed, Feed rate

Coded Coefficients

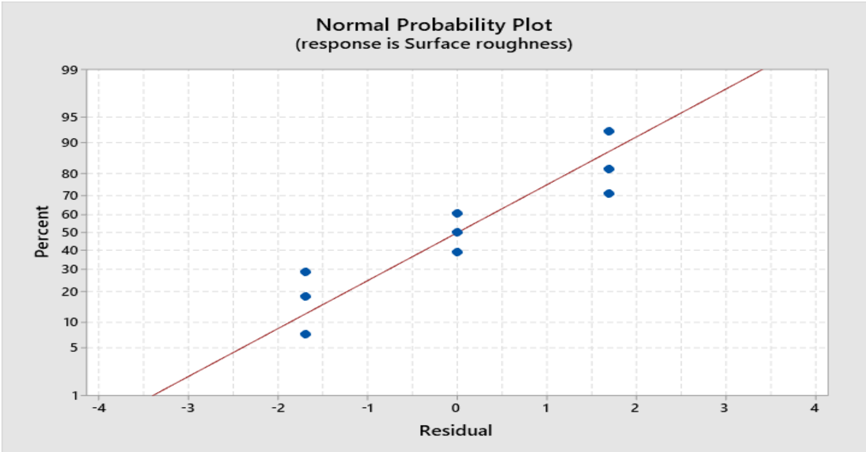
Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	8.69	3.09	2.81	0.217	
Drill bit diameter	1.31	1.69	0.77	0.582	1.00
Spindle speed	0.33	1.69	0.19	0.878	1.00
Feed rate					
0.05	-0.97	2.76	-0.35	0.785	2.67
0.20	-1.21	2.19	-0.55	0.678	1.67
Drill bit diameter*Drill bit diameter	-3.95	2.93	-1.35	0.407	1.00
Spindle speed*Spindle speed	1.28	2.93	0.44	0.737	1.00
Drill bit diameter*Spindle speed	-0.57	2.93	-0.20	0.877	2.00

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	7	71.4546	10.2078	0.59	0.765
Linear	4	30.2474	7.5619	0.44	0.794
Drill bit diameter	1	10.2328	10.2328	0.60	0.582
Spindle speed	1	0.6471	0.6471	0.04	0.878
Feed rate	2	19.3675	9.6837	0.56	0.686
Square	2	34.4253	17.2127	1.00	0.577
Drill bit diameter*Drill bit diameter	1	31.1339	31.1339	1.81	0.407
Spindle speed*Spindle speed	1	3.2914	3.2914	0.19	0.737
2-Way Interaction	1	0.6573	0.6573	0.04	0.877
Drill bit diameter*Spindle speed	1	0.6573	0.6573	0.04	0.877
Error	1	17.1914	17.1914		
Total	8	88.6460			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
4.14625	80.61%	0.00%	*



WORKSHEET 1

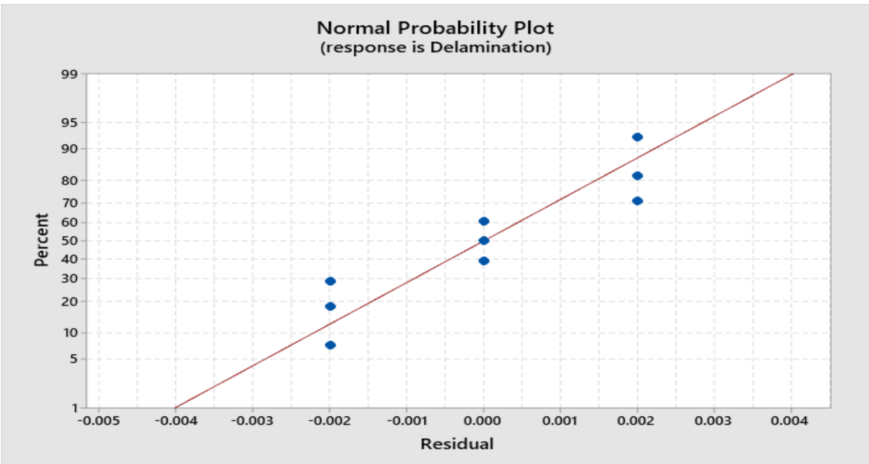
Response Surface Regression: Delamination versus Drill bit diameter, Spindle speed, Feed rate

Coded Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	1.01056	0.00365	276.75	0.002	
Drill bit diameter	0.00450	0.00200	2.25	0.266	1.00
Spindle speed	0.00350	0.00200	1.75	0.330	1.00
Feed rate					
0.05	-0.00856	0.00327	-2.62	0.232	2.67
0.20	-0.00022	0.00258	-0.09	0.945	1.67
Drill bit diameter*Drill bit diameter	-0.00283	0.00346	-0.82	0.564	1.00
Spindle speed*Spindle speed	0.00217	0.00346	0.63	0.644	1.00
Drill bit diameter*Spindle speed	0.00767	0.00346	2.21	0.270	2.00

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	7	0.000513	0.000073	3.05	0.415
Linear	4	0.000481	0.000120	5.01	0.322
Drill bit diameter	1	0.000122	0.000122	5.06	0.266
Spindle speed	1	0.000074	0.000074	3.06	0.330
Feed rate	2	0.000286	0.000143	5.96	0.278
Square	2	0.000025	0.000013	0.53	0.697
Drill bit diameter*Drill bit diameter	1	0.000016	0.000016	0.67	0.564
Spindle speed*Spindle speed	1	0.000009	0.000009	0.39	0.644
2-Way Interaction	1	0.000118	0.000118	4.90	0.270
Drill bit diameter*Spindle speed	1	0.000118	0.000118	4.90	0.270
Error	1	0.000024	0.000024		
Total	8	0.000537			



EXPERIMENTATION

The CNC Drilling was used for the experimentation. To begin, the workpiece was drilled using input parameters of speed, feed, and drill-bit diameter as mentioned in the table 4.2.3 on the workpiece's surface. Surface-roughness and the-Delamination Factor were computed and tabulated at this point in the study. Minitab's Response Surface Methodology was used to calculate the best Drilling parameters.

MATHEMATICAL MODEL

Mathematical equations here are Regression equations, generated by using Minitab software for optimizing the results

For Drilling the input parameters were speed, feed and Drill-bit diameter and the output parameters are surface-roughness (Ra) and-Delamination factor

After Drilling, Regression equations are given for surface-roughness in eq 4.5.1 and for Delamination factor in eq 4.5.2:

Surface-roughness Ra,

Ra = -407 + 81.4 Drill bit diameter + 0.0016 Tool rotating speed - 3.95 Drill bit diameter * Drill bit diameter - 0.000004 Speed * Speed -0.00096 drill bit diameter * speed

Delamination-factor,

Delamination-factor= 0.829 + 0.0458 Drill bit diameter - 0.000136 Speed - 0.00283 rill bit diameter * Drill bit diameter + 0.000 Speed * Speed + 0.000013 Drill bit diameter * Speed

RESPONSE OPTIMIZATION

To get the best values, Minitab program utilizes Response surface methodology. Drilling process optimal values are 987.8788 rpm, 0.05 mm/rev feed rate, and Drill-bit diameter of 9.0 mm with a composite desirability factor of 0.9382.

It was determined by utilising regression equations to find the best values Drilling settings were refined using Minitab's response surface optimization module, which minimised surface-roughness and increased delamination-factor based on input parameter values. Optimized values of Drilling for surface-roughness

Ra = 0.88031 μm and

Delamination-factor =1.0000.

The response optimum plot is shown in Fig below

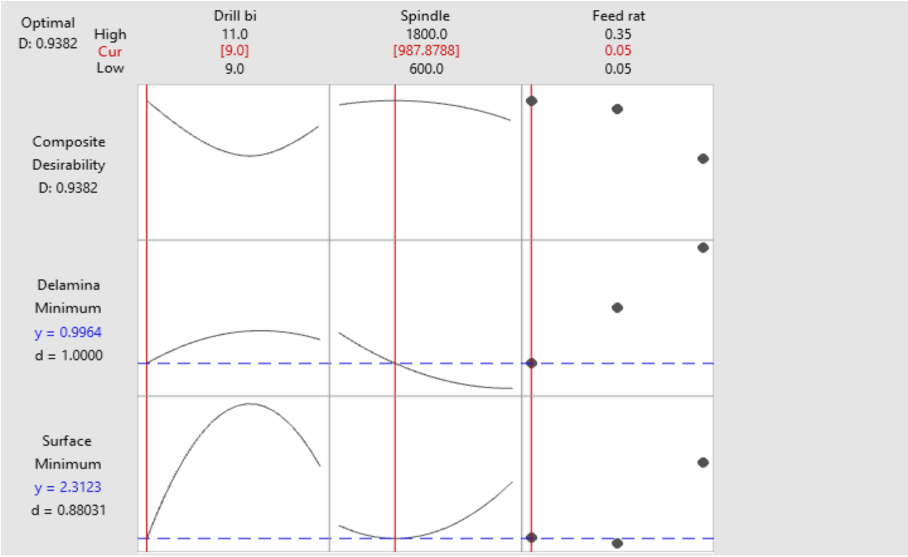


Fig 4.6.1: Response optimized plot of Drilling parameters

CONCLUSION

With the help of a Taguchi approach and RSM, ideal drilling settings for vetiver-reinforced epoxy resin were determined in this study The drill bit diameter and spindle speed were determined to be the most significant factors impacting surface-roughness and delamination in the Taguchi and RSM experimental trials. Drill bit diameter at 10, spindle speed at 1200, and feed rate at 0.2 were the best Taguchi control factors both for surface roughness &!delamination. Drill bit diameter at 9 mm, speed at 987.878 rpm, & feed rate at 0.05 using RSM were the best control parameters both for surface roughness and! delamination.