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Optimization of Surface Roughness of Turned Nano-Khorasan Based Madar Fiber Composites Using Response Surface Methodology

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Abstract*: *Now a day Nano based Natural Fiber Reinforced Polymer (NFRP) composite is important alternative material to conventional materials because of its superior characteristics. In general composite products are manufactured nearer to the required shape, but secondary operations like machining is necessary to obtain the required surface finish. Machining of NFRP composites is different than the machining of traditional materials. This paper focuses on the behavior and optimization of machining parameters on turning of Nano-Khorasan based madar fiber reinforced composites by using Response Surface Methodology (RSM) technique. The input factors studied are speed, feed, depth of cut and Nano-Khorasan mixing. The investigated output response was Average Surface Roughness (Ra). A Box- Behnken approach was employed to evaluate the optimum parameters to attain the minimum Ra. Based on this approach, a second order polynomial modal equation was generated for predicting response Ra. Also the relative effect of parameters on response Ra was studied by using ANOVA. The experimental result shows some interesting factors in context to the turning of Nano Khorasan based Madarfiber reinforced polymer composites.

Index Terms*: *Madar fiber, Nano Khorasan powder, turning, Response Surface Methodology.

I. INTRODUCTION

The development of bio-composites or Natural Fiber Reinforced Polymer (NFRP) composite materials has been a hot issue recently due to the growing environmental awareness. The application of NFRP composites and bio-based resins for substituting the present glass fiber reinforced composite materials in massive. High specific properties with lesser prices of natural fiber composites are making it eye-catching for various applications. Bio fillers and Nano-clay bio fillers are being used nowadays to extremely enhance the properties of composites. These composites have many applications like automobile interior and exterior body parts, partitions, heaters, electrodes [1-3]. Addition of Nano-clay play important role in the enhancement of characteristics of the composites [4]. Nano composite are difficult to machine due to their in-homogeneity and anisotropy. Manufacturing industries put great interest on surface quality of the products because the quality of the product depends on the surface roughness [5]. There is a wide range of research is going on in the area of surface roughness analysis and machining induced delamitions of synthetic fiber composites. Some of the important research literatures are given below:

Rajasekaran et al. [6] conducted the machining experiments to study the significance of metal cutting variables on surface quality for carbon fiber composites. The significance of metal cutting variables such as speed, feed and depth of cut in determining the response surface quality Ra were studied. Among the various metal cutting variables feed is the parameter to play a major role in deciding the surface quality Ra followed by speed. DilliBabu et al. [7] investigated the milling of NFRP composites and concluded that, design of experiment approach provides significant and systematic approach for the selection of optimum cutting variables resulting in the quality machining. The machining quality of NFRP composites was in some cases better than those of synthetic fiber composite. The metal cutting variables speed and feed are seen to make major contribution on average roughness Ra and delamination of milled NFRP composites. Generally, the selection of high speed and low feed improves the surface quality of the machined composites.

Vivek et al. [8] conducted the experimental examination on machining of aluminum and silicon carbide Nano composites using RSM methodology. Polycrystalline Diamond Tool (PCD) is used for Turning, which is four times harder than Al/Sic composites, and has better life period and reduced tool wear. Feed and speed was recognized as the major influencing parameters on tool wear. Regression equation is formed for predicting the output response and response surface method (RSM) is implemented to optimize the result. Kumar et al. [9] studied the machining performance of Glass fiber polymer composites. The influence of drill parameters like drill bit geometry, speed and the feed on the surface quality of drilled hole was investigated by using design of experiments and ANOVA analysis. The thrust force recorded for composites made up of with fillers was lower than composites without fillers.

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This investigation mainly focuses on the determination of machining parameters and their combination for better surface quality in turning Nano-Khorasan based NFRP composites. This study uses response surface methodology for carry out experimentation to identify the trend of process parameters and highly influential parameter.

II. EXPERIMENTAL INVESTIGATION

A. Fabrication of composites

The natural fiber, which is extracted from Madar tree stem, as shown in figure (1a), is used as reinforcing material in the composite fabrication process. The Pineapple plant is abundantly available in India, especially in Tamilnadu and Andhra Pradesh. Polyester resin is used as matrix material for the current study. Density and modulus of the polyester resin used is 1300kg/m3 and 3.28Gpa respectively.

1(a) 1(b)

Fig 1.(a). Madar tree and fiber. (b). Nano-Khorasan based Madar fiber composites for turning experiments.

The characteristics of the Madar fiber composites with and without addition Nano- Khorasan are described in Table 1. Nano based specimens are fabricated by mixing the Nano Khorasan powder in the polyester resin by using the sonicator. Hand Lay-up method is used to fabricating the round cylindrical shaped specimens. The time of solidification process depends on the type of matrix used for NFRP composites fabrication. For polyester resin, curing time is 24- 48 hours at room temperature. The size of the test specimens are 25mm diameter and 60mm length, sample specimens are shown in figure (1b). The percentage of volume fraction of the composite material is 60% of resin and 40% of fiber. For the Nano particulate components 10% of Khorasan powder added of the resin weight.

TABLE I. MECHANICAL CHARACTERISTICS OF COMPOSITES WITH AND WITHOUT KHORASAN NANO PARTICULATES.

Properties	**Madar fiber composites**	**Madar fiber composites with Khorasan Nano particulates**
Volume Fraction of fiber	0.35	0.35
Density in g/cc	1.01	1.16
Tensile strength in N/mm^2	123	235
Tensile Modules in GPa	8.03	9.42
Flexural Strength in N/mm^2	326	424
Flexural Modules in GPa	8.864	9.88
Impact strength in J/m	280	371

B. Response Surface Methodology (RSM)

RSM is a scientific approach to analyze the connections between the output and the input variables. This methodology consists of a statistical design with the aim of obtaining results in a systematic way in order to obtain the output response about the performance of a process. The correlation between the output and the input is given in the equation (1).

$N = f(x1, x2, X3\ldots\ldots, xn) + \varepsilon$ ……. (1)

Where N is the output, x1, x2, x3...,xn represents the independent process variables, n is the no. of the independent process variables and ε is error. For the embellishment of experimental design we used the RSM methodology for three machining variable with three levels and one categorical factor (Nano-Khorasan mixing). The detailed factors and their assigned corresponding levels are shown in the table 2.you submit your final version, after your paper has been accepted, prepare it in two-column format, including figures and tables.

TABLE II. RSM DESIGN INPUT FACTORS AND THEIR CORRESPONDING LEVELS.

Factors	**Notation**	**Limits**		
		-1	0	1
Speed in rpm	A	1000	2000	3000
Feed in mm/min	B	100	300	500
Depth of cut in mm	C	1	2.5	4

C. Experimental Details:

LMW Smarturn CNC Turning Machine, supplied by Lakshmi Machine Works Limited, Coimbatore is used for the turning process. The cutting tool used for turning operations was CNMG 1204 tungsten carbide tool. The experiments are performed as per the RSM design. The detailed experimental setup of turning of Madar fiber reinforced polymer composite is shown in figure (2a).

Output response R_a was calculated by standard stylus surf test, Mitutoyo SJ-210 series instrument. The stylus instrument was calibrated using reference specimen having R_a value of 3.0µm. The surface roughness measurement setup is shown in Figure (2b).

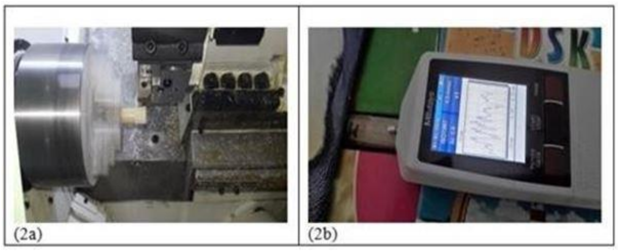

Fig.2. (a). Turning of composites on CNC lathe. (b). Surface roughness measurement using stylus surf test.

III. EXPERIMENTAL RESULTS AND DISCUSSION

The detailed RSM table and the response values are presented in the table 3. The effect of turning parameters and Nano Khorasan powder mixing on output response R_a of turned Madar fiber polymer composite was studied by using regression analysis and ANOVA. To investigate the interaction effect of turning parameters on output response Ra, 3D graphs for the output responses were drawn based on the regression model equation.

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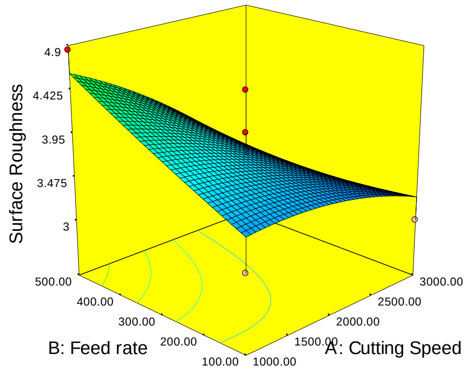
Since the model had three machining parameters, a total of three surface graphs were created for the output response (R_a), shown in the figures (3a-3c). 3D surface graphs show that, the output response R_a decrease with decrease in feed and depth of cut. Also it is identified that R_a is decreasing when the speed approaches to the higher level. So, the machining parameters for reduced R_a should consist of middle level of depth of cut, low level feed rate and higher level of speed for turned Madar fiber reinforced polymer composite made with addition of Nano- Khorasan.

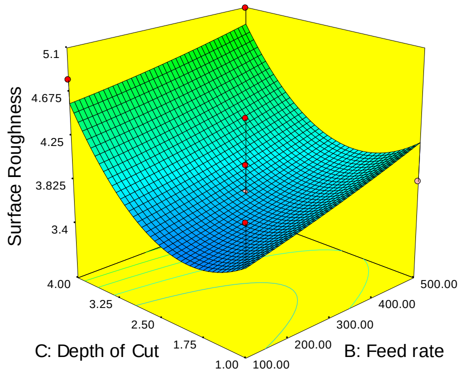
TABLE III. RSM DESIGN WITH OUTPUT RESPONSE (R_A).

std	Run	A:cutting speed [Rpm]	B:feed rate [Mm/min]	C:depth of cut [mm]	D: filler	Roughness R_a [µm]
1	34	1000	100	2.50	with	3.2105
2	29	3000	100	2.50	with	3.002
3	9	1000	500	2.50	with	4.85
4	10	3000	500	2.50	with	3.092
5	26	1000	300	1.00	with	4.043
6	5	3000	300	1.00	with	3.4225
7	14	1000	300	4.00	with	4.866
8	19	3000	300	4.00	with	3.8625
9	25	2000	100	1.00	with	4.0585
10	17	2000	500	1.00	with	3.815
11	31	2000	100	4.00	with	4.799
12	15	2000	500	4.00	with	5.089
13	28	2000	300	2.50	with	4.431
14	12	2000	300	2.50	with	3.9725
15	2	2000	300	2.50	with	3.7025
16	21	2000	300	2.50	with	3.672
17	18	2000	300	2.50	with	3.5455
18	4	1000	100	2.50	without	4.138
19	22	3000	100	2.50	without	4.0475
20	7	1000	500	2.50	without	6.014
21	11	3000	500	2.50	without	5.1195
22	24	1000	300	1.00	without	5.986
23	13	3000	300	1.00	without	4.289
24	1	1000	300	4.00	without	6.0495
25	30	3000	300	4.00	without	5.2355
26	20	2000	100	1.00	without	3.967
27	6	2000	500	1.00	without	6.5515
28	33	2000	100	4.00	without	4.553
29	3	2000	500	4.00	without	6.228
30	8	2000	300	2.50	without	4.4235
31	23	2000	300	2.50	without	4.6425
32	16	2000	300	2.50	without	4.8805
33	27	2000	300	2.50	without	4.777
34	32	2000	300	2.50	without	4.9085

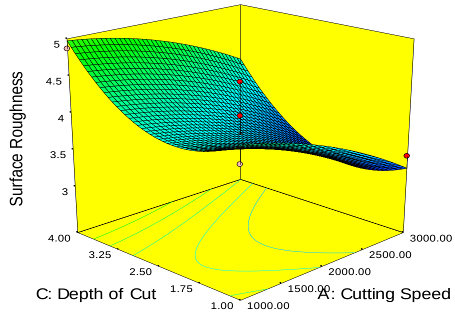
ANOVA findings are summarized in table 4. ANOVA analysis provides information regarding influence of input factors (speed, feed, depth of cut and Nano Khorasan addition) on the output Ra. ANOVA table shows contribution of parameters on the output response (R_a). The regression modal values are also performed. The present modal R^2value is 0.9328 which indicates the modal is good for analysis.



3(a)



3(b)



3(c)

Fig.3. (a). 3D surface graphs for feed and speed. (b). 3D surface graphs for depth of cut and speed. (c). 3D surface graphs for depth of cut and feed.

The present ANOVA modal F-value is 14.67 it shows that the modal is significant. P-values of this model are less than 0.05 it represents that the parameters are highly significant. The result shows that the machining parameters selected are highly significant at 95% confidence interval. In this case A, B, C, D, AB, BD, C^2 are significant model terms that affects the output response Ra because this combination has a P-value less than 0.05. In the ANOVA table, % C represents the percentage contribution of parameters on the output response R_a. The Nano Khorasan mixing (35.92%) is the major parameter which influences the output response R_a, followed by feed (18.2%), speed (11.3%) and depth of cut (4.66%). Regression modal equations were generated to relate the correlation among the input parameters on the output response (R_a). The following modal equation representing the relation in between input parameters verses output response.

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$$\text{Average surface Roughness } (R_a) = +4.30 - 0.47*A+0.60*B-0.28*C+0.55*D-0.062*A*B-0.05*A*C-0.093*A*D-0.016*B*C+0.46*B*D-0.063*C*D-0.3*A2+0.04*B2 +0.69*C2 \quad (2)$$

Where A = Cutting speed in rpm, B = Feed rate in mm/min, C = Depth of cut in mm, D = Nano Khorasan (for categorical factor, with Nano Khorasan mixing is 1, without mixing is 0.) Based on the Box-Behnken approach the optimum machining conditions for turning of Madar fiber reinforced composites were identified. High cutting speed, low feed rate, medium depth of cut and Nano-Khorasan powder mixing improves the output response (Ra).

TABLE IV. DETAILED ANOVA RESULTS

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	% of C
Model	25.02	13	1.92	14.67	< 0.0001	
A-Cutting Speed	3.14	1	3.14	23.93	< 0.0001	11.3
B-Feed rate	5.04	1	5.04	38.46	< 0.0001	18.2
C-Depth of Cut	1.29	1	1.29	9.87	0.0051	4.66
D-filler	9.93	1	9.93	75.74	< 0.0001	35.92
AB	0.69	1	0.69	5.28	0.0325	2.49
AC	0.031	1	0.031	0.24	0.6307	0.11
AD	5.581E-004	1	5.581E-004	4.256E-003	0.9486	0.002
BC	0.018	1	0.018	0.13	0.7174	0.06
BD	1.84	1	1.84	14.06	0.0013	6.65
CD	0.25	1	0.25	1.92	0.1816	0.9
A^2	0.16	1	0.16	1.21	0.2841	0.57
B^2	5.695E-003	1	5.695E-003	0.043	0.8370	0.002
C^2	2.65	1	2.65	20.22	0.0002	9.58
Residual	2.62	20	0.13			
Lack of Fit	1.97	12	0.16	2.00	0.1659	
Pure Error	0.66	8	0.082			
Cor Total	27.64	33				

R^2 Values			
Std. Dev.	0.36	R-Squared	0.9051
Mean	4.51	Adj R-Squared	0.8434
C.V. %	8.03	Pred R-Squared	0.6613
PRESS	9.36	Adeq Precision	14.259

IV. CONFIRMATION TEST

Confirmation tests were conducted to validate the model equations generated in this study. Table 5 shows confirmation test results for predicted and experimental values. Maximum error obtained in the confirmation test was below 5%. Thus the model equation can be successfully used to predict the output response (Ra).

TABLE V. CONFIRMATION TEST RESULTS FOR PREDICTED VERSES EXPERIMENTAL RESPONSE RA.

S. no	Machinig parameters				Surface response (R_a)
	A (rpm)	B (mm/min)	C (mm)		
1	3000	100	2.50	experimental Predicted Error %	3.05 3.27 6.72
2	1000	300	1.00	experimental Predicted Error %	5.92 5.60 5.40

V. CONCLUSION

From the experimental investigation on turning of Madar fiber reinforced Nano Khorasan composites, the following points were observed,

- From the ANOVA and Box-Behnken approach, the optimum turning condition for surface roughness (Ra) of Madar fibre reinforced composites are, speed at 3000 RPM, feed rate at 100 mm/min, depth of cut at 2.50 mm and with addition of Nano Khorasan powder.
- The investigated parameters, Nano Khorasan powder mixing, speed, feed and depth of cut are highly influencing the output response (Ra).
- The roughness (Ra) recorded for Madar fibre reinforced polymer composites with Nano Khorasan powder mixing was lower than that of composites made without Nano Khorasan powder.
- For both with and without Nano Khorasan powder mixing composites, the parameters speed and feed are highly influencing the roughness (Ra). Therefore, these parameters appear to be the significant machining parameters to achieve high quality surface quality in turning of Madar fiber composites.
- The experimental results were verified by conducting the confirmation experiments. The conformational result shows that, the error related to average surface roughness (Ra) of the turned composites varies by ±5%. It shows good relation between the modal equation results and experimental results. So the modal equation can be used successfully for finding the Ra.

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