

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

G Dilli Babu, B Jagadish Babu, K Sivaji Babu

**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

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**G Dilli Babu**, Department of Mechanical Engineering, V R Siddhartha Engineering College, Vijayawada, Andhra Pradesh, India.

**B Jagadish Babu**, Department of Mechanical Engineering, V R Siddhartha Engineering College, Vijayawada, Andhra Pradesh, India.

**K Sivaji Babu**, Department of Mechanical Engineering, P V P Siddhartha Institute of Technology, Vijayawada, Andhra Pradesh, India.

range of research is going on in the area of surface roughness analysis and machining induced delaminations 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.

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.



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## 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/m<sup>3</sup> and 3.28Gpa respectively.



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 <sup>2</sup>  | 123                    | 235                                                    |
| Tensile Modules in GPa                 | 8.03                   | 9.42                                                   |
| Flexural Strength in N/mm <sup>2</sup> | 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).

$$N = f(x_1, x_2, X_3, \dots, x_n) + \epsilon \quad (1)$$

Where N is the output, x<sub>1</sub>, x<sub>2</sub>, x<sub>3</sub>...,x<sub>n</sub> 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<sub>a</sub> was calculated by standard stylus surf test, Mitutoyo SJ-210 series instrument. The stylus instrument was calibrated using reference specimen having R<sub>a</sub> value of 3.0μm. The surface roughness measurement setup is shown in Figure (2b).

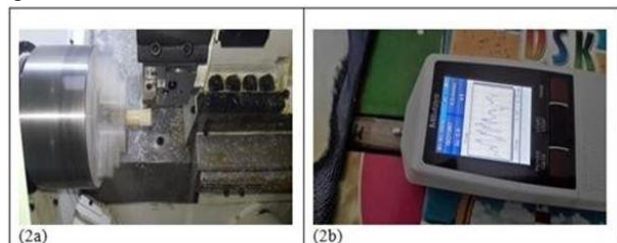


Fig.2. (a). Turning of composites on CNC lathe. (b). Surface roughness measurement using stylus surf test.

## 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<sub>a</sub> 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. Since the model had three machining parameters, a total of three surface graphs were created for the output response (R<sub>a</sub>), shown in the figures (3a-3c). 3D surface graphs show that, the output response R<sub>a</sub> decrease with decrease in feed and depth of cut. Also it is identified that R<sub>a</sub> 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 $R_a$ [ $\mu$ m] |
|-----|-----|-----------------------|----------------------|---------------------|-----------|----------------------------|
| 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  $R_a$ . ANOVA table shows contribution of parameters on the output response ( $R_a$ ). The regression modal values are also performed. The present modal  $R^2$  value is 0.9328 which indicates the modal is good for analysis.

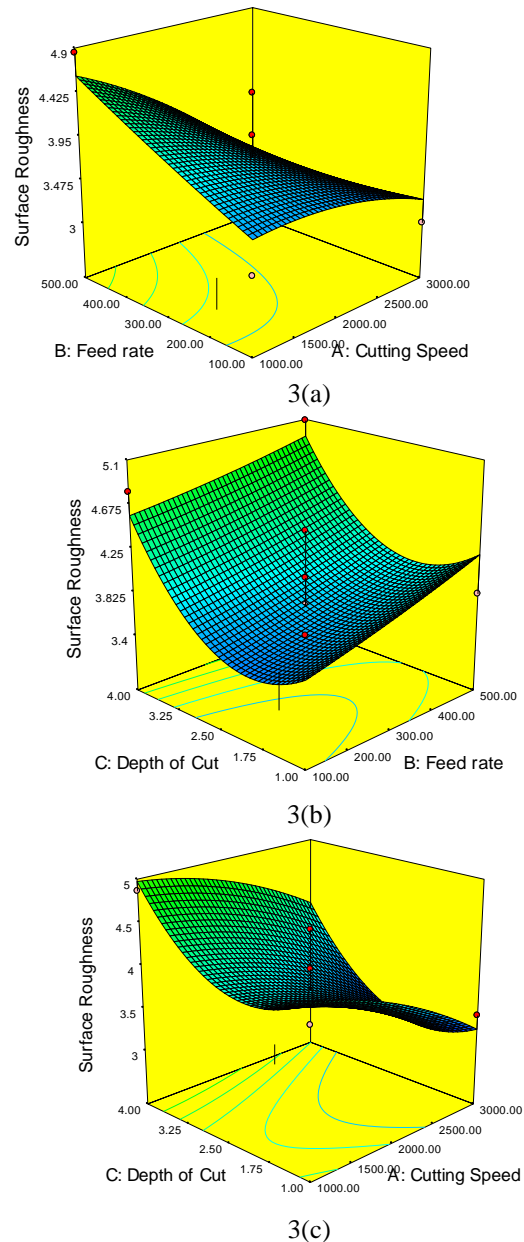


Fig.3. (a). 3D surface graphs for feed and speed. (b). 3D surface graphs for depth of cut and speed. (c). 3D surface graphs for depth of cut and feed.

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  $R_a$  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



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response.

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

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 <sup>2</sup>              | 0.16           | 1  | 0.16           | 1.21       | 0.2841           | 0.57   |
| B <sup>2</sup>              | 5.695E-003     | 1  | 5.695E-003     | 0.043      | 0.8370           | 0.002  |
| C <sup>2</sup>              | 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 |                |            |                  |        |
| <b>R<sup>2</sup> Values</b> |                |    |                |            |                  |        |
| 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 (Ra) |
|-------|---------------------|------------|--------|--------------------------------------|-----------------------|
|       | A (rpm)             | B (mm/min) | C (mm) |                                      |                       |
| 1     | 3000                | 100        | 2.50   | experimental<br>Predicted<br>Error % | 3.05<br>3.27<br>6.72  |
| 2     | 1000                | 300        | 1.00   | experimental<br>Predicted<br>Error % | 5.92<br>5.60<br>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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## AUTHORS PROFILE



**Dr. G Dilli Babu** completed a Doctorial degree from J N T University, Anantapur, in the area of Composite Machining. He published more than 20 research papers in the reputed journals and conferences. Area of research interest is natural fiber composites characterization, Machining of composites, Nanomaterials, etc. Currently working as Associate Professor in the Department of Mechanical Engineering, V R Siddhartha

Engineering College, Vijayawada



**Mr. B Jagadish Babu** completed his Master's degree from J N T University, Kakinada, in the area of Composite Machining.. Area of research interest is natural fiber composites characterization, Machining of composites, Nanomaterials, etc.



**Dr. K Sivaji Babu** completed a Doctorial degree from J N T University, Hyderabad, in the area of Natural Fiber Reinforced Composite. He published more than 25 research papers in the reputed journals and conferences. Area of research interest is natural fiber composites characterization, Machining of composites, Nanomaterials, etc. Currently working as Professor and principal, P V P Siddhartha Institute of Technology, Vijayawada