International Journal of Engineering Research and Development
e-ISSN: 2278-067X, p-ISSN: 2278-800X, www.ijerd.com
Volume 11, Issue 02 (February 2015), PP.08-14

Implementation of Response Surface Methodology for Analysis of Plain Turning Process Using Single Point Cutting Tool.

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Abstract:- This paper investigates the effect of cutting speed, feed rate and depth of cut on the surface roughness of mild steel material with turning process. The response surface methodology (RSM) was employed in the experiment. The investigated turning parameters were cutting speed (CS) (1150, 850m/min), feed rate (FR) (1 and 0.5 mm/rev) and depth of cut (DOC) (1.0 and 0.5 mm) and no. of cuts(NOC) (2 and 1). The results showed that the interaction between the feed and depth of cut, was the primary factor controlling surface roughness. The responses of various factors were plotted using a three-dimensional surface graph. The optimum condition required for minimum surface roughness(SR) include cutting speed of 1150 m/min, feed rate of 1 mm/rev, axial depth of cut of 0.5 mm and no. of cut 1. With this optimum condition, a surface roughness of 0.280μm was obtained. The methodology for above experimentation is presented in this paper along with results and interpretation.

Keywords:- High-speed machining, Surface roughness, Response surface method, etc.

I. INTRODUCTION

Surface roughness is generally known to be highly affected by feed rate, followed by cutting speed and axial depth of cut. The geometrical shape of the insert is another factor considered in studies on surface roughness. Surface roughness is used to assess the performance of cutting tools under various conditions. This study aims to determine the cutting conditions that will result in the lowest value of surface roughness.

Surface roughness is one of the most important requirementsin machining process, as it is considered as one of the index of product quality. It measures the finer irregularities of thesurface texture. Achieving the desired surface quality iscritical for the functional behaviour of a part. Surfaceroughness influences the performance of mechanical partsand their production costs because it affects factors, suchas friction, ease of holding lubricant, electrical and thermalconductivity, geometric tolerances and more. The ability ofa manufacturing operation to produce a desired surfaceroughness depends on various parameters. The factors thatinfluence surface roughness are machining parameters,tool and work piece material properties and cuttingconditions. For example, in turning operation the surfaceroughness depends on cutting speed, feed rate, depth ofcut, tool nose radius, lubrication of the cutting tool, machinevibrations, tool wear and on the mechanical andother properties of the material being machined. Evensmall changes in any of the mentioned factors may havea significant effect on the produced surface [1].Therefore, it is important for the researchers to modeland quantify the relationship between roughness and theparameters affecting its value. The determination of thisrelationship remains an open field of research, mainlybecause of the advances in machining and materials technology and the available modeling techniques. In machinabilitystudies investigations, statistical design ofexperiments is used quite extensively. Statistical designof experiments refers to the process of planning the experimentsso that the appropriate data can be analysed bystatistical methods, resulting in valid and objective conclusions[2]. Design methods such as factorial designs,response surface methodology (RSM) and taguchi methodsare now widely use in place of one factor at a timeexperimental approach which is time consuming andexorbitant in cost.

II. METHODOLOGY

To carryout RSM analysis, we had to carry out simple turning process. We selected the automatic lathe machine, ALFA model made by Panther Engineering Co. The steps followed are as follows

1] We got the raw material job having required initial dimensions of M.S. Bar
2] We adjusted the speed of lathe at level one and depth of cut also at level one.
3] First mounted the job in spindle and carry out simple turning operation for one cut.
4] Measured the time required for operation
5] Measured the initial and final dimensions of the diameter of the job.
6] Labelled it with specific no.
7] Took the second job.

8] Carried out simple turning operations for 2 cuts.
9] Repeat steps 4, 5, and 6.
10] With the speed at level one and DOC at level 2, repeat steps 3 to 9.
11] In this way we carried out simple turning operation on 16 different jobs and collected data about time required, initial and final dimensions, by changing DOC, feed and speed.
12] Compiled all the collected data in tabular format.
13] Carried out RSM analysis.
14] Find the correct fitting equation for Surface finish and Diameter.

2. Experimental work

In this study, cutting experiments are planned using 2 level full factorial experimental design. Machining testsare conducted by considering four cutting parameters: cuttingspeed (v), feed rate (f), depth of cut (d), and tool no. of cuts (n). Total 2^4= 16 cutting experiments are carriedout. Low-middle-high level of cutting parameters in cutting space of two level full factorial experimental designare shown in Table 2. Ranges of cutting parameters are selected based on shop floor. All the experiments were carriedout on ALFA model made by Panther Engineering Co., lathe machine with variable spindle speed 45 to 938 RPM and 1.5 KW motor drive was used for machining tests. Surfacefinish of the work piece material was measured bySurf tester.The surfaceroughness was measured at three equally spaced locationsaround the circumference of the work pieces to obtain thestatistically significant data for the test. In the presentwork, the work piece material was the mild steel. Thismaterial has good wear and corrosion resistance. A mechanical property of the material

Table 1 Input parameters and their levels.

Sr.No.	Parameters	Level 1	Level 2
1	Cutting speed (v), m/min	1150	850
2	Feed (f), mm/rev	1	0.5
3	Depth of cut (d), mm	2	1
4	No.of cuts	2	1

Table 2

Natural Variables				Coded Variables				Responses	
N	F	DOC	No. of cuts	A	B	C	D	Diameter	Surface finish
800	0.5	1	1	-1	-1	-1	-1	14.10	8.57
800	0.5	1	2	-1	-1	-1	1	13.20	8.68
800	0.5	2	1	-1	-1	1	-1	13	16.2
800	0.5	2	2	-1	-1	1	1	10.26	2.80
800	1	1	1	-1	1	-1	-1	13.10	16.68
800	1	1	2	-1	1	-1	1	11.70	13.28
800	1	2	1	-1	1	1	-1	13.20	12.68
800	1	2	2	-1	1	1	1	10.96	11.50
1150	0.5	1	1	1	-1	-1	-1	13.96	20.13
1150	0.5	1	2	1	-1	-1	1	13.12	14.87
1150	0.5	2	1	1	-1	1	-1	13.14	16.2
1150	0.5	2	2	1	-1	1	1	11.10	15.2
1150	1	1	1	1	1	-1	-1	13.98	6.13
1150	1	1	2	1	1	-1	1	13.10	5.76
1150	1	2	1	1	1	1	-1	13.72	12.22
1150	1	2	2	1	1	1	1	13.64	12.7

A=N-975\175, B=F-0.75/0.25, C=DOC-1.5/0.5, D=T-1.5/0.5

Image.No.1- Surface Roughness measurement Instrument

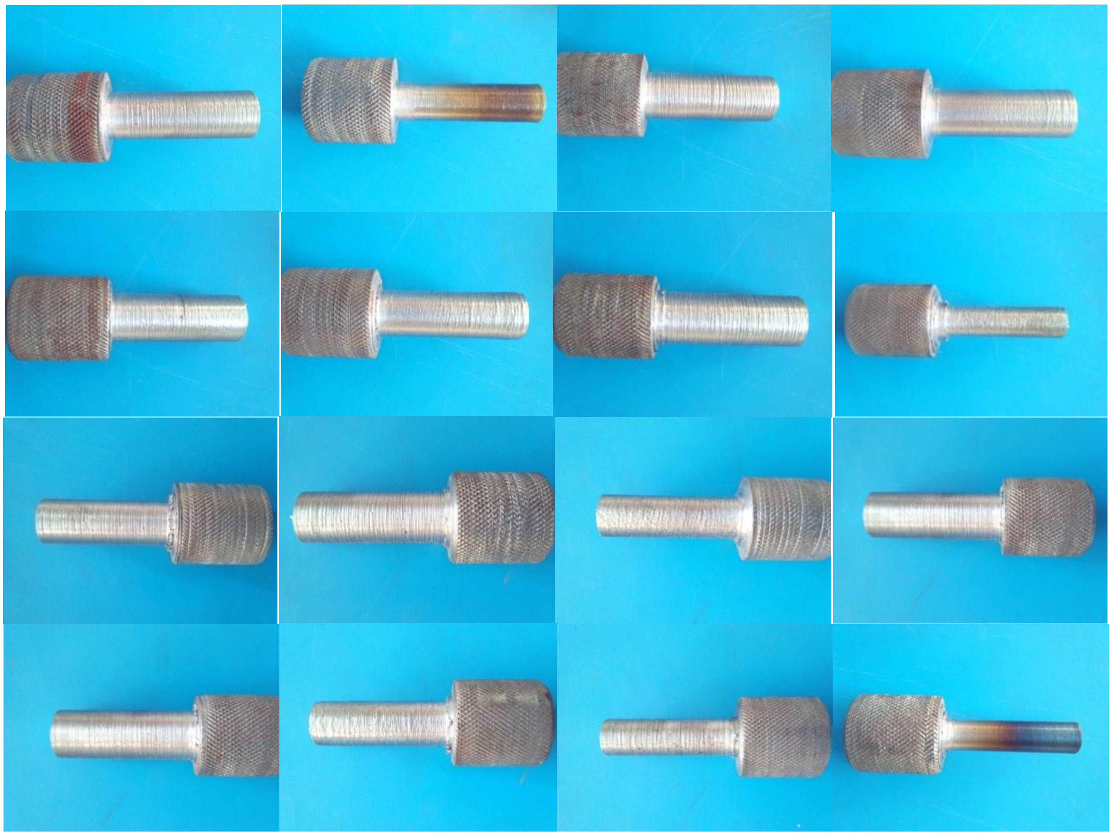

Image No.2- Surface Roughness images of all components

$$X = \begin{vmatrix} 1. & -1. & -1. & -1. & -1. \\ 1. & -1. & -1. & -1. & 1. \\ 1. & -1. & -1. & 1. & -1. \\ 1. & -1. & -1. & 1. & 1. \\ 1. & -1. & 1. & -1. & -1. \\ 1. & -1. & 1. & -1. & 1. \\ 1. & -1. & 1. & 1. & -1. \\ 1. & -1. & 1. & 1. & 1. \\ 1. & 1. & -1. & -1. & -1. \\ 1. & 1. & -1. & -1. & 1. \\ 1. & 1. & -1. & 1. & -1. \\ 1. & 1. & -1. & 1. & 1. \\ 1. & 1. & 1. & -1. & -1. \\ 1. & 1. & 1. & -1. & 1. \\ 1. & 1. & 1. & 1. & -1. \\ 1. & 1. & 1. & 1. & 1. \end{vmatrix}$$

$$Z = \begin{vmatrix} 12.83 \\ 0.39 \\ 0.095 \\ -0.4525 \\ -0.695 \end{vmatrix}$$

The fitted regression model for diameter is

Y_{dia}= 12.83+0.39A+0.095B-0.4525C-0.695D

$$X'{*}X = \begin{vmatrix} 16. & 0. & 0. & 0. & 0. \\ 0. & 16. & 0. & 0. & 0. \\ 0. & 0. & 16. & 0. & 0. \\ 0. & 0. & 0. & 16. & 0. \\ 0. & 0. & 0. & 0. & 16. \end{vmatrix}$$

$$X' = \begin{vmatrix} 1. & 1. & 1. & 1. & 1. & 1. & 1. & 1. & 1. & 1. & 1. & 1. & 1. & 1. & 1. & 1. \\ -1. & -1. & -1. & -1. & -1. & -1. & -1. & -1. & 1. & 1. & 1. & 1. & 1. & 1. & 1. & 1. \\ -1. & -1. & -1. & -1. & 1. & 1. & 1. & 1. & -1. & -1. & -1. & -1. & 1. & 1. & 1. & 1. \\ -1. & -1. & 1. & 1. & -1. & -1. & 1. & 1. & -1. & -1. & 1. & 1. & -1. & -1. & 1. & 1. \\ -1. & 1. & -1. & 1. & -1. & 1. & -1. & 1. & -1. & 1. & -1. & 1. & -1. & 1. & -1. & 1. \end{vmatrix}$$

$$(X'{*}X)^{\wedge}{-1} = \begin{vmatrix} 0.0625 & 0. & 0. & 0. & 0. \\ 0. & 0.0625 & 0. & 0. & 0. \\ 0. & 0. & 0.0625 & 0. & 0. \\ 0. & 0. & 0. & 0.0625 & 0. \\ 0. & 0. & 0. & 0. & 0.0625 \end{vmatrix}$$

$$Y = \begin{vmatrix} 14.1 \\ 13.2 \\ 13. \\ 10.26 \\ 13.1 \\ 11.7 \\ 13.2 \\ 10.96 \\ 13.96 \\ 13.12 \\ 13.14 \\ 11.1 \\ 13.98 \\ 13.1 \\ 13.72 \\ 13.64 \end{vmatrix}$$

Z=((X'*X)^-1)*X'*Y

$$S = \begin{vmatrix} 8.57 \\ 8.68 \\ 16.2 \\ 2.8 \\ 16.68 \\ 13.28 \\ 12.68 \\ 11.5 \\ 20.13 \\ 14.87 \\ 16.2 \\ 15.2 \\ 6.13 \\ 5.76 \\ 12.22 \\ 12.7 \end{vmatrix}$$

SF=((X'*X)^-1)*X'*S

$$SF = \begin{vmatrix} 12.1 \\ 0.80125 \\ -0.73125 \\ 0.3375 \\ -1.50125 \end{vmatrix}$$

The fitted regression model for Surface Roughness is

Y_{dia}= 12.1+0.80125A-73125B+0.3375C-1.50125D

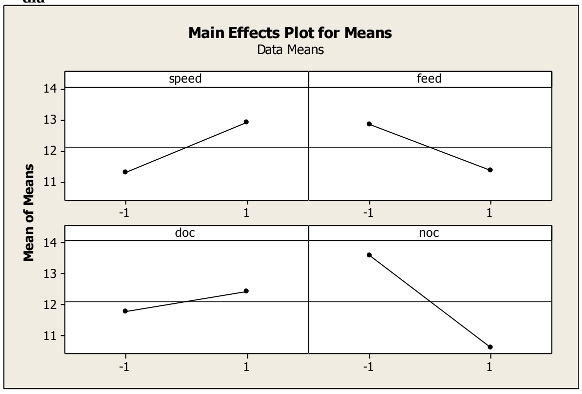

Fig. No.1.Main Effects plot for Means

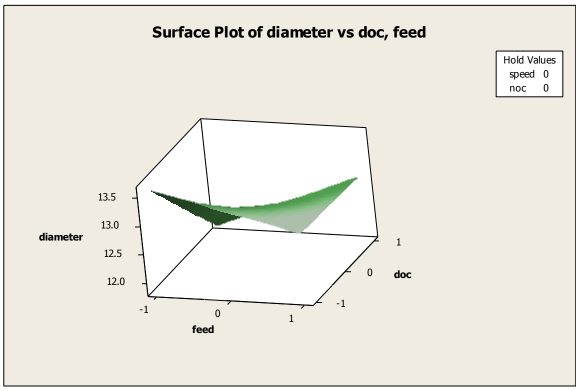

Fig. No.2.Surface plot of diameter Vs DOC,Feed

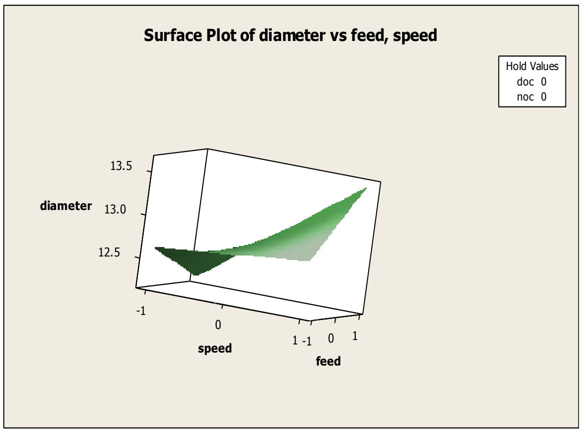

Fig. No. 3. Surface plot of diameter Vs feed, speed

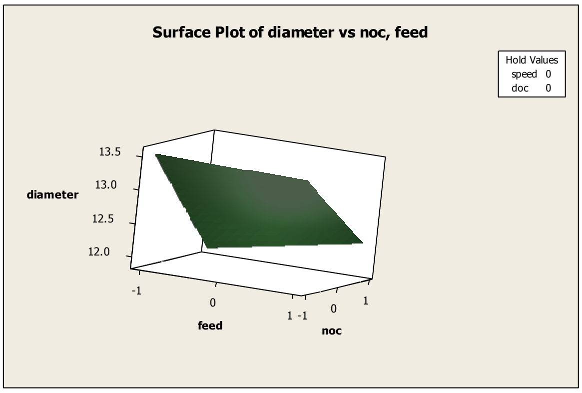

Fig. No. 4. Surface plot of diameter Vs DOC, speed

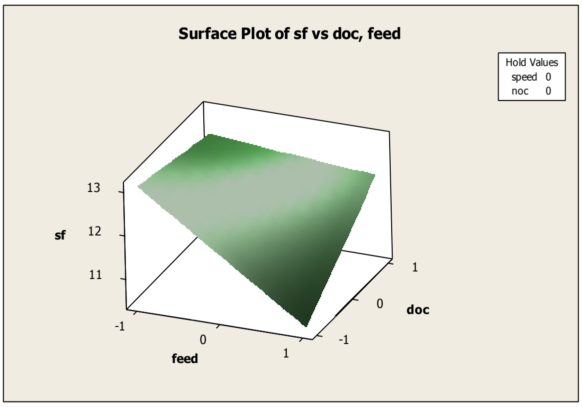

Fig. No. 5. Surface plot of SF Vs DOC, Feed

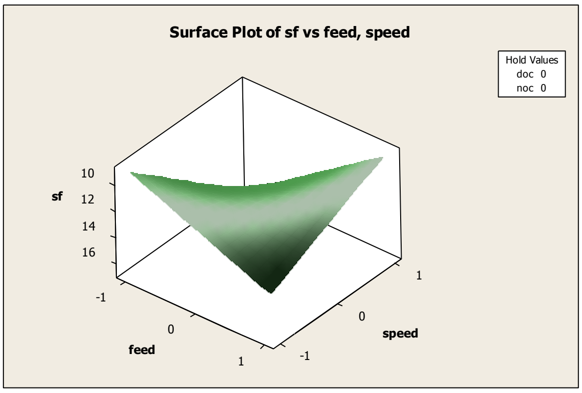

Fig. No.6. Surface plot of SF Vs feed, speed

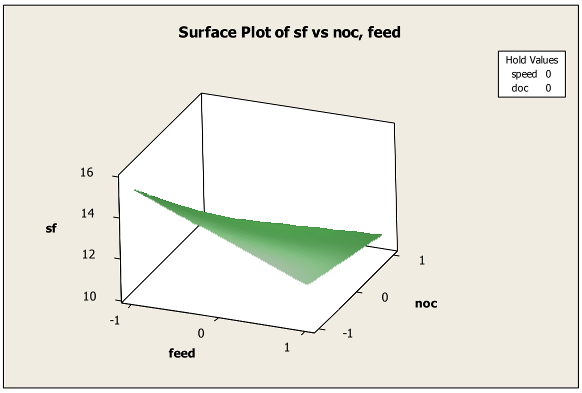

Fig. No. 7. Surface plot of SF Vs NOC, Feed

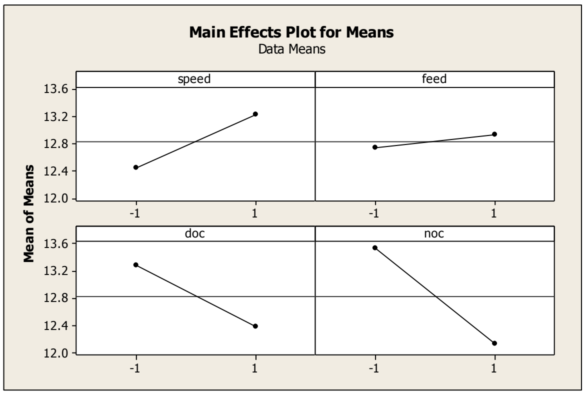

Fig. No. 8.Main Effects Plot For Means

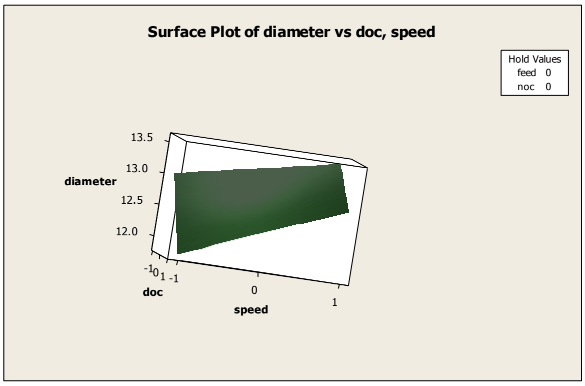

Fig. No. 9. Surface plot of diameter Vs DOC, speed

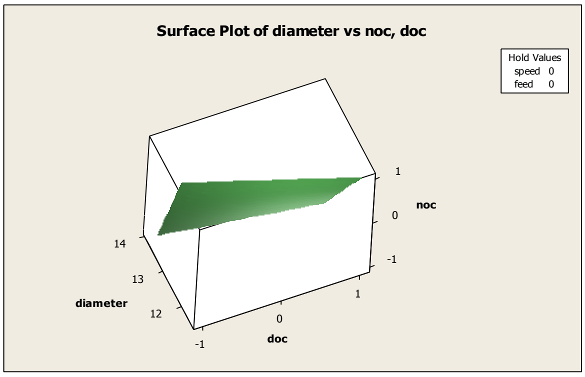

Fig. No.10. Surface plot of diameter Vs NOC, DOC

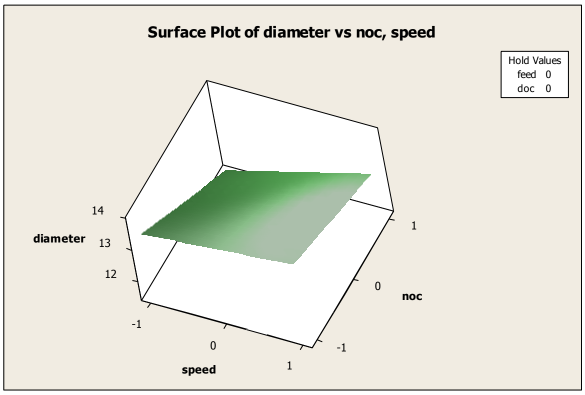

Fig. No. 11.Surface plot of diameter Vs NOC, speed

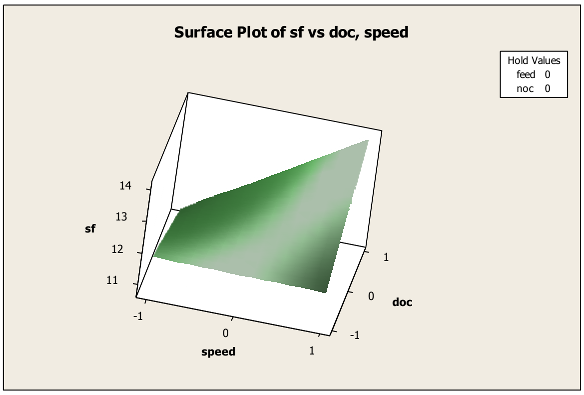

Fig. No. 12. Surface plot of SF Vs DOC, speed

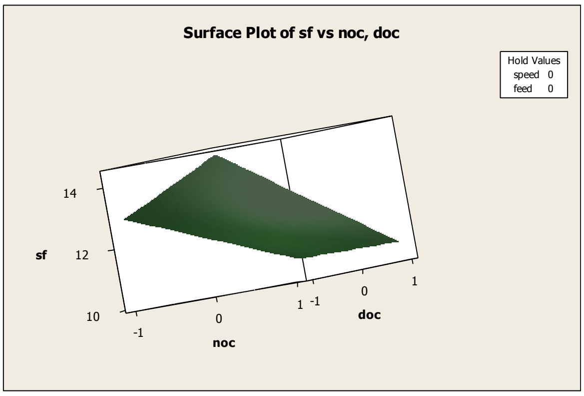

Fig. No.13. Surface plot of SF Vs NOC, DOC

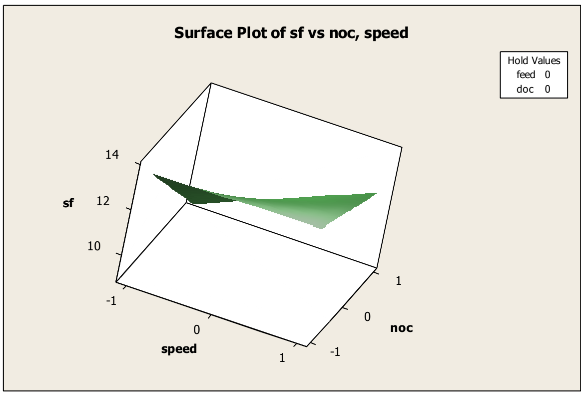

Fig. No. 14. Surface plot of SF Vs NOC, speed

III. RESULTS AND DISCUSSION

In this paper, application of RSM on the mild steel is carried out for turning operation. A quadratic model has been developed for surface roughness (Ra) to investigate the influence of machining parameters. The results are as follows:

(1) For the surface roughness, the feed rate is the main influencing factor on the roughness, followed by the tool nose radius and cutting speed. A depth of cut has no significant effect on the surface roughness.

(2) Except feed rate and toolnose radius which have the highest influence.

(3) Response surface optimisation shows that the optimal combination of machining parameters are(1150 m/min, 0.5 mm/rev, 1 mm, 1) for cutting speed, feed rate, depth of cut and tool no. of cuts respectively.

IV. CONCLUSIONS

A series of experiments using RSM were conducted to investigate the factors affecting the surface roughness of mild steel rod. The effect of spindle speed, feed rate, as well axial depth of cut and no. of cuts were studied. The following conclusions can be drawn:

The best surface finish was achieved when cutting at cutting speed of 1150 m/min, feed of 0.5 mm/, Depth of cut of 1 mm and no. of cuts 1.

This study shows the interrelation between depth of cut and feed rate to be the most dominant factor affecting the surface roughness.

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