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Study of Surface Roughness measurement in turning of EN 18 steel

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Abstract – *Increasing the productivity with quality is the main key areas focused in the present scenario of manufacturing. Various techniques have been implemented to improve the machining processes to increase the productivity. And Turning is one of the most important manufacturing techniques because of its simplicity and effectiveness. The main aim of this study is to optimize the understudy parameter specially the surface roughness (Ra) in turning of EN 18 Steel work piece by using three input parameters i.e. spindle speed, feed rate and depth of cut. Experimental work was done using Design Expert 7.0.0 (dx7) software with Central Composite Design (CCD) approach. The input parameters were varied at three different levels. And turning was done using CNC lathe machine and surface roughness was measured with the help of portable Mitotoyo Surftest-4 tester. This study uses Response surface methodology to find the optimum machining parameters to produce minimum surface roughness possible in turning process. Regression Equations were developed for Surface Roughness. Confirmation experiments were conducted in end to validate the results of experimental work.*

Key Words: **HMT HS CNC lathe, EN 18 steel, Response surface methodology (RSM), Surface roughness, CCD central composite design.**

1. INTRODUCTION

Since ages, Lathe has been revolutionary in industrial sector. Since that time there have been many drastic improvements, whether it is in manufacturing of Lathe machine or is it in processes done on it. The increased demand of manufacturing components of higher accuracy and in large quantities has also added importance to value of Lathe. Nowadays, Lathes have been attached with computers to increase its efficiency to generate parts of higher accuracy in very short span of time. These machines are named as CNC machines, i.e. Computer Numerical Control Machines. These CNC's help to generate designs of high complexities with ease. In this study, CNC was used namely HMT Stallion HS CNC Lathe Machine to process the workpiece. On the other hand, turning process used in this investigation is one of the most commonly used processes of manufacturing. Whereas, EN 18 is an alloyed medium carbon steel which finds applications in manufacturing of shafts, stressed pins, studs, keys etc. These components are manufactured by process i.e. turning. And Minimizing surface roughness has been the main aim of this study.

2. EXPERIMENTAL PROCEDURE

In this study, Design Expert 7.0.0 (dx7) software was used and by using Central Composite Design (CCD) approach the experimental plan was developed for single response optimization. In this study, Response Surface Methodology was used to optimize the Surface Roughness. Response surface methodology (RSM) is a collection of mathematical and statistical techniques used for empirical model building. Where a response of interest is influenced by several variables and the objective is to optimize the response. To find relation between input and response variable, usually first order model is used, as given in equation below

$$y = \beta_0 + \beta_i x_i + \beta_{ii} x_{ii} + \ldots\ldots \beta k x_{ik} + \varepsilon$$

Where, y is the response understudy, β is regression coefficient and ε is error. If the result can still be improved, then the Second order model is applied, as given below

$$y = \beta_0 + \sum_{i=1}^{k} \beta_i x_i + \sum_{i=1}^{k} \beta_{ii} x_i^2 + \sum_{i<j} \beta_{ij} x_i x_j + \varepsilon$$

The values of regression coefficients are obtained by regression analysis of 2^3 factorial designs. The experimentation work was conducted using a HMT Stallion CNC lathe machine and Mitotoyo Surftest-4 tester was used to measure the surface roughness. The study used speed, feed and depth of cut as input process parameters varied at three different levels. Design Expert was used for collected data analysis. And overall Desirability was found by numerical optimization. At the end analyzed result was validated by conducting confirmation experiments.

2.1 Workpiece Material

In Present work, EN 18 alloyed medium carbon steel is used which is quite responsive to mechanical and heat treatments. This offers more strength and toughness than mild steel. It finds application in automobiles, shafts, pins, couplings, rolls, keys parts.

Table 1: Chemical Composition of EN-18

Element	C	Si	Cr	S	P	Mn
Percentage (%)	0.35-0.45	0.10-0.35	0.85-1.15	0.050	0.050	0.60-0.95

2.2 Flow Process Chart

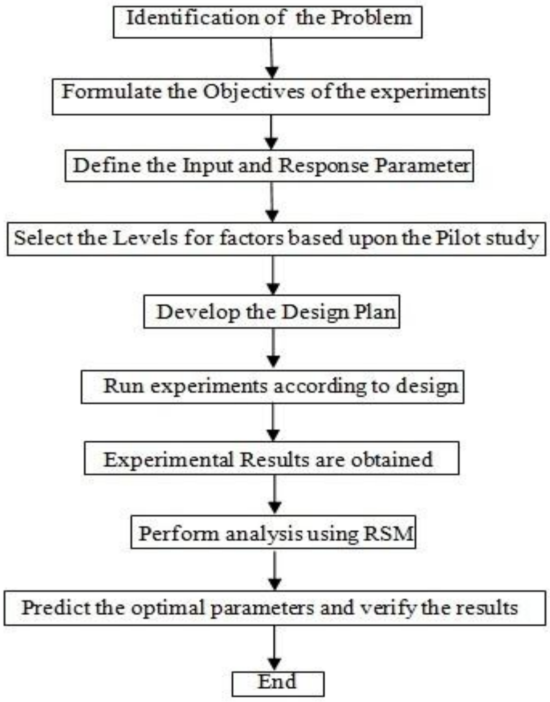


Fig. 1 Flow chart

2.3 Process Variables and their levels

The process variables working ranges was selected by performing pilot study. In the present experimental study spindle speed, feed rate and depth of cut has been considered as process variables. The process variables with their units (and notations) are listed in Table 2

Table 2: Process Variables

Factors	Units	Level 1	Level 2	Level 3
Spindle Speed (N)	rpm	1500	2500	3500
Feed (F)	mm/min	0.81	0.91	1.02
Depth of Cut	mm	1.20	1.85	2.50

2.4 Experimental Results for Surface Roughness

The experiment results obtained for average Surface Roughness are shown in Table 3. Here input factors are Speed, Feed and DOC (depth of cut) and Response under study is Surface Roughness (Ra).

Table 3: Results of main experiments for average Ra

Run	Factor 1 A: Speed rpm	Factor 2 B: Feed mm/min	Factor 3 C: DOC mm	Response Surface Roughness Ra
1	1500	1.02	2.5	3.02
2	2500	0.915	1.85	1.4
3	2500	0.915	1.85	1.98
4	2500	0.915	2.5	2.01
5	3500	0.81	2.5	2.97
6	2500	1.02	1.85	2.4
7	2500	0.915	1.2	1.24
8	3500	0.915	1.85	3.05
9	2500	0.915	1.85	1.99
10	2500	0.81	1.85	0.18
11	1500	0.81	1.2	0.15
12	2500	0.915	1.85	1.51
13	1500	0.915	1.85	1.58
14	3500	1.02	1.2	2.84
15	2500	0.915	1.85	1.86

3. RESULTS ANALYSIS AND DISCUSSIONS

3.1 ANOVA table for Surface Roughness

Table 4: ANOVA for Ra

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	Remarks
Model	10.80	4	2.70	26.10	< 0.0001	significant
A-Speed	2.82	1	2.82	27.20	0.0004	
B-Feed	4.10	1	4.10	39.62	< 0.0001	
C-DOC	2.37	1	2.37	22.89	0.0007	
A^2	1.52	1	1.52	14.67	0.0033	
Residual	1.03	10	0.10			
Lack of Fit	0.73	6	0.12	1.61	0.3350	not significant
Pure Error	0.30	4	0.076			
Cor Total	11.84	14				
Std. Dev.	0.32		C.V. %	17.12		
R-Squared	0.9126		Pred R-Squared	0.7671		
Mean	1.88		PRESS	2.76		
Adj R-Squared	0.8776		Adeq Precision	16.2776		

ANOVA (Analysis of Variance) is generally used to summarize the performed experimental work. ANOVA table indicates the significance of the proposed model. Accordingly, If "Prob.>F" value is less than 0.05, then this shows that model is significant, which is desirable and this also indicates that the model shows a significant effect on the response variables. Lack of Fit in ANOVA shows whether the model is ready to fit or not. And insignificant value of Lack of Fit is desirable as we want the model to fit. Here for, Surface roughness the least significant terms are eliminated to improve the model.

Table 4 shows ANOVA table for Surface roughness. And it is quite visible that Prob.>F value is less than 0.05, which shows that model is significant and model fits well as it has insignificant Lack of Fit. ANOVA table also shows the R-squared value to be high and close to one, which is desirable. And there is close agreement within R-squared value and Adj. R-squared value. "Adeq Precision" measures the signal to noise ratio. A ratio greater than 4 is desirable. Here the ratio obtained in Table 4 indicates an adequate signal. This model can be used to navigate the design space. And hence we conclude that the developed model is fit.

3.2 Regression Equation for Surface Roughness

The regression equations are given below in both coded and actual factors. The insignificant coefficients are omitted from the equations. The developed statistical model for Surface roughness is-

Surface Roughness (coded form) =

$$+1.62 + 0.68 * A + 0.83 * B + 0.63 * C + 0.65 * A^2$$

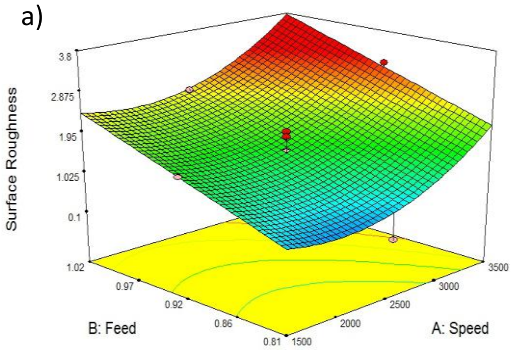
Surface Roughness (actual form) =

$$-5.02673-2.56222E-003* \text{Speed}+7.87302* \text{Feed}+0.96667* \text{DOC}+6.49444E-007* \text{Speed}^2$$

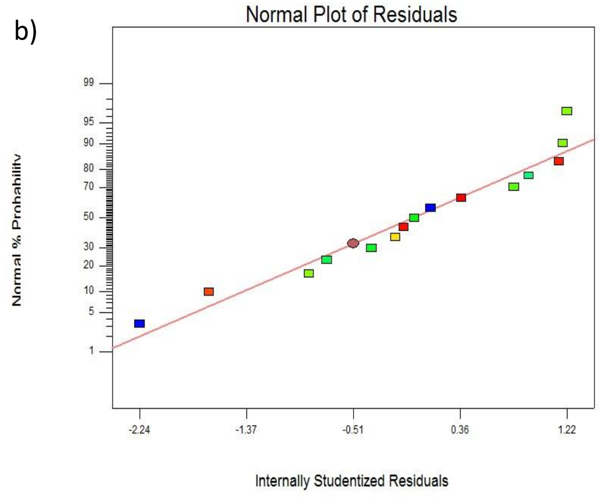
The above mentioned Regression Equations can be used to find the desired results of Surface Roughness while turning EN 18 steel.

3.3 Response Surface Diagram and Normal Plot of Residuals

a)



b)



c)

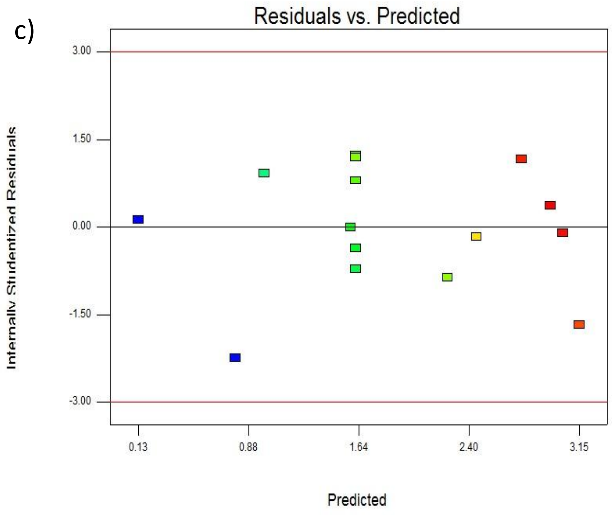


Fig. 2 (a) Response surface diagram b) Normal plot of residuals and c) Residuals Vs Predicted for Surface Roughness (Ra).

The response surface diagram for Surface Roughness (Ra) is shown in Fig. 2 (a) which indicates that Ra value shows a considerable increase with increased value of Feed. The adequacy of model was examined by using residual plots. And if the model is adequate, the points on the normal probability plots of the residuals will follow along a straight line.

On the other hand, the plots of the residuals versus the predicted should be structure less, that is, there would be no obvious pattern but all the points must lie between the red lines. Here, it is be clearly visible that proposed model is adequate and fits the data well. The normal probability plots of the residuals and the plots of the residuals versus the predicted for surface roughness are as shown in Fig. 2(b, c).

3.4 Response Optimization for Minimum Surface Roughness Ra.

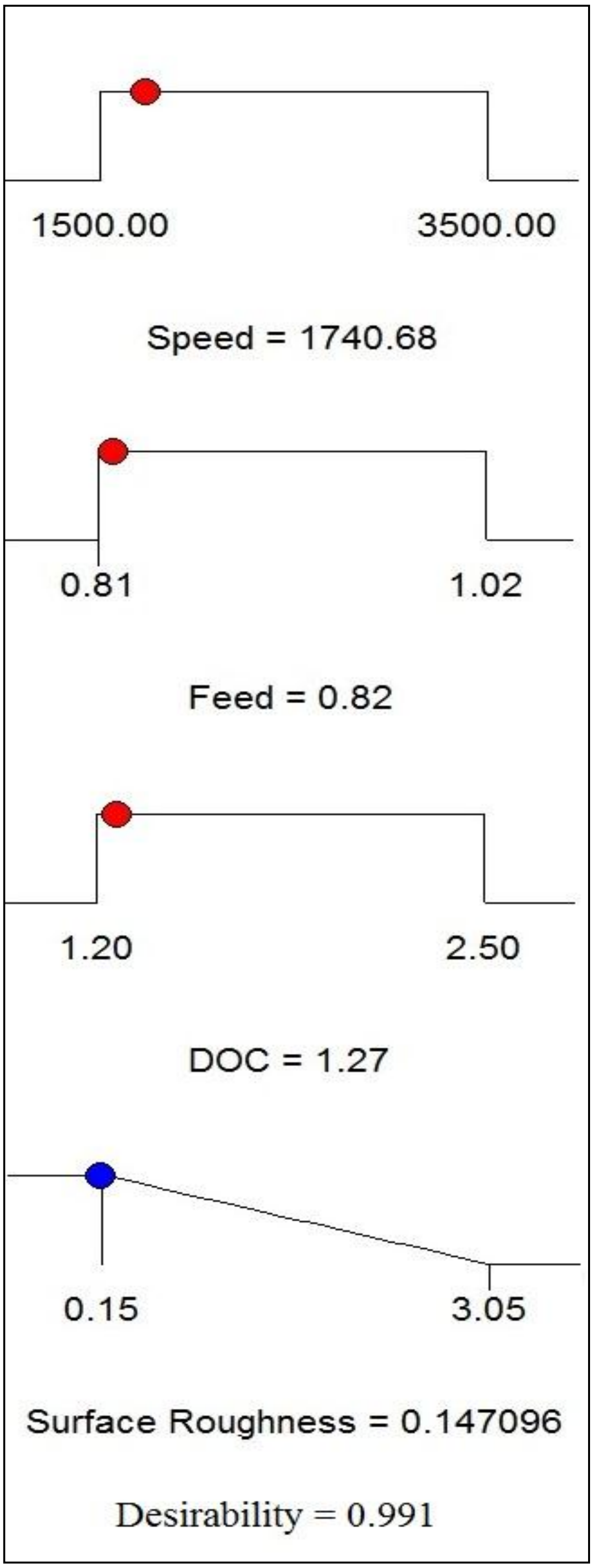


Fig. 3 Response optimization diagrams

Table 5: Optimal parameters for Surface Roughness (Ra)

Parameters	Units	Optimal Parameters
Speed	rpm	1740.68
Feed	mm/min	0.82
Depth of Cut	mm	1.27

Here, Fig. 3. Shows Response optimization diagrams and the value of Desirability comes out to be 0.991 and Table 5. Shows the optimum process parametric setting where spindle speed is 1740.68 RPM, feed rate is 0.82 mm/min. and depth of cut is 1.27 mm.

3.5 Validation of experiment

Table 6: Experimental comparison of developed model with optimal parametric settings

Response	Predicted	Experimental	Error %
Surface Roughness	0.147096	0.150512	2.32%

Now, the obtained result was validated at the end of experimental work and for this purpose confirmation experiment for the response variable i.e. Surface Roughness was performed at optimal levels of input variables. Then the experimentally obtained value is compared with the predicted value. The result is as shown in Table 6. This clearly indicates that predicted result are in accordance with experimental results obtained, as the percentage error is very low and which confirms the developed model to be satisfactory.

4. CONCLUSIONS

Here, in this work response understudy i.e. Surface roughness was optimized by using three parameters i.e. spindle speed, feed rate and depth of cut for EN 18 steel by using Response Surface Methodology. The main conclusions drawn are:-

1. ANOVA table analysis shows the “Pred R-Squared” to be reasonably in agreement with “Adj R-Squared” which indicates the absence of any problem in data or the model developed.
2. ANOVA table also shows the Lack of Fit value to be insignificant which is desirable, as it indicates the model fits the data well.
3. The adequacy of model was analyzed with the help of normal probability plots of residuals and plots of

   Residuals versus the predicted response for the Surface Roughness. This plot revealed the developed model to be adequate and fits data well.

4. By using response optimization, the optimal parametric settings obtained were spindle speed of 1740.68 RPM, feed rate 0.82 mm/min. and depth of cut 1.27 mm for achieving the required minimum surface roughness and maximum MRR.

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