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MODELING AND PARAMETRIC ANALYSIS OF SURFACE ROUGHNESS IN HOT TURNING OF EN 36 STEEL

Bhargav Patel, Vipul Patel, Narendra Makvana, Kamlesh Thakkar, Rakesh Oza and Dr. N. A. Patel
Assistant Professor, Government Engineering College, Patan, Gujarat, India

ABSTRACT

The present research investigation aims at optimization of machining parameters such as spindle speed, surface temperature and feed rate on surface roughness produced on the machined component. Achieving high production responsiveness—which offers a first line of defense against the volatile market conditions of today requires optimizing machining procedures. The experiments were conducted on the EN 36 Steel specimens heated with gas flame were machined on a lathe under different cutting conditions of Surface temperatures ranging from 200^0C to 600^0C at constant depth of cut 0.8 mm. Taguchi technique is utilized to find the optimized machining parameters. After experimentation, it is found that the influence of feed rate is significantly high on surface roughness of the turned component compared to other parameters. This paper highlights the development of a comprehensive mathematical model for correlating the interactive and higher order influences of various machining parameters, utilizing relevant experimental data as obtained through experimentation of surface roughness. The adequacies of the above proposed model have been tested through the analysis of variance (ANOVA).

Keywords: Hot turning, Taguchi, RSM

INTRODUCTION

Turning is a secondary manufacturing operation that removes extra material from work material to give the product the desired size, shape, and finish as shown in fig. 1 [1]. A procedure known as "hard turning" involves using single-point cutting tools to machine a hardened condition material (between 50 and 70 HRC) [2]. Turning operations are typically carried out on both CNC and manual center lathe machines. Preparing a finished product from hard metals with the necessary surface finish, MRR, precise tolerances, and dimensional accuracy is an important challenge. Many machining parameters affect quality and productivity [3]. Surface roughness is one of the main factors in evaluating the quality of a component as it affects all the dimensions of quality. Since it is an important factor of quality for many years. In numerous situations, including parts exposed to fatigue loads, precise fits, fastening, and aesthetic requirements, it has developed an essential design element [4]. Since its invention in 1889, Tigham's hot machining process has piqued the interest of numerous researchers [5]. Surface roughness is one of the most significant constraint when choosing cutting parameters. The choice of different process parameters, such as feed, depth of cut, and cutting speed, determines the proper surface finish. In the current study, surface temperature, feed rate, and cutting speed are chosen to measure surface roughness during hard turning of EN 9 steel.

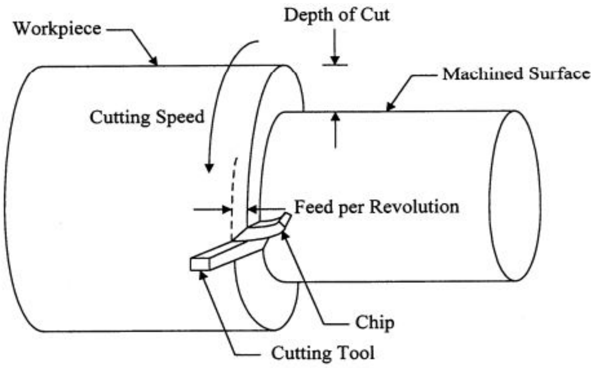

Figure 1: Turning process [1]

EXPERIMENTAL PROCEDURE:

Low carbon and high alloy content alloy steel is EN 36 studied in this work. The chemical composition of workpiece material is shown in Table 1. Steel is known for its toughness, which comes from the use of nickel, and its more uniform hardness, which comes from the use of chromium. It is made especially for carburizing, which produces an extremely strong core and robust case. It is frequently used for big cross-section components that need to be extremely robust and strong, like heavy-duty gear shafts, crane shafts, and gears, in the mechanical engineering, aerospace, and vehicle construction industries [6].

Table I: Chemical Compositions of En 36 Steel

	C	Ni	Cr	Si	Mn	S	P	Mb
%	0.7	3.2	1.05	0.25	0.42	0.01	0.01	0.14

The Taguchi technique was created by Taguchi. He suggested that the engineering optimization of a product or process should be done in three steps: tolerance design, system design, and parameter design [7].The Taguchi approach is successful because it enables the rapid optimization of 70–90% of the target parameters; the remaining 10–30% can be attained with one or two complementing tests; and it is confined to 2-4 parameters that are thought to be the most relevant [8]. The three control variables type of Cutting speed (m/min), Feed Rate (mm/rev) and Temperature (^{0}C) are selected with five levels and the corresponding orthogonal array L25 (53) is chosen for experimentation, while depth of cut remain constant as 0.8 mm. Tungsten carbide tool is used for the experimentation. The taken control variables with their levels are depicted in Table No. 2.

Table II: Control Parameters and Their Levels

Process Parameters	Level 1	Level 2	Level 3	Level 4	Level 5
Cutting Speed (m/min)	21.35	33.91	51.11	78.50	121.20
Feed Rate (mm/rev)	0.245	0.287	0.344	0.382	0.430
Temperature (^{0}C)	200	300	400	500	600

RESULT AND DISCUSSION

Second order polynomial response surface mathematical models can be created in order to investigate the impact of the Turning operation parameters on the machining requirements that were previously discussed. In the typical scenario, an equation of the following kind characterizes the response surface [9], [10]. Where, Y is the estimated response, b's are the coefficients and xi's are the independent variables.

$$Y = b_0 + \sum_{i=1}^{k} b_i x_i + \sum_{i=1}^{k} b_{ii} x_i^2 + \sum_{i<j=2}^{k} b_{ij} x_i x_j + \varepsilon_r \qquad (1)$$

The Taguchi technique is used to arrange experiments for the development of second-order nonlinear polynomials. Table No. 3 contains the optimized 25 runs based on the Taguchi technique.

The experimental data shown in Table 4 is used to calculate the unknown coefficients. The "SE coef" column contains a tabulation of the standard errors on the coefficient estimations. F ratios are computed using a 95% confidence level. The regression model for surface roughness is formulated below.

Table III: Plan For Experimentation based on Taguchi

Sr. No.	**Temp**	**CS**	**Feed**	**SR**
1	200	21.35	0.245	3.2
2	200	33.91	0.287	3.14
3	200	51.11	0.344	3.43
4	200	78.5	0.382	3.52
5	200	121.2	0.43	3.42
6	300	21.35	0.287	3.15
7	300	33.91	0.344	3.18
8	300	51.11	0.382	3.25
9	300	78.5	0.43	3.39
10	300	121.2	0.245	2.98
11	400	21.35	0.344	2.81
12	400	33.91	0.382	3.05
13	400	51.11	0.43	3.12
14	400	78.5	0.245	2.39
15	400	121.2	0.287	2.35
16	500	21.35	0.382	2.97
17	500	33.91	0.43	2.79
18	500	51.11	0.245	2.15
19	500	78.5	0.287	2.16
20	500	121.2	0.344	2.11
21	600	21.35	0.43	1.96
22	600	33.91	0.245	1.67
23	600	51.11	0.287	1.71
24	600	78.5	0.344	1.79
25	600	121.2	0.382	1.75

Table IV: Estimated Regression Coefficients for Sr

Term	Coef	SE Coef	T	P
Constant	2.35324	1.1960	1.968	0.068
Temp	0.00141	0.0020	0.713	0.487
CS	0.00036	0.0072	0.049	0.961
Feed	3.23779	6.6616	0.486	0.634
Temp*Temp	-0.00001	0.0000	-1.658	0.118
CS*CS	0.00001	0.0001	0.220	0.829
Feed*Feed	2.52584	15.3690	0.164	0.872
Temp*CS	-0.00000	0.0000	-0.049	0.961
Temp*Feed	-0.00312	0.0111	-0.282	0.782
CS*Feed	-0.01430	0.0390	-0.367	0.719
S = 0.151326 PRESS = 1.51490 R-Sq = 96.32 % R-Sq(pred) = 83.76% R-Sq(adj) = 94.11%				

$$SR = 2.35324 + 0.00141 \times Temp + 0.00036 \times CS + 3.23779 \times Feed - 0.00001 \times Temp^2 + 0.00001 \times CS^2 + 2.52584 \times Feed^2 - 0.00312 \times Temp \times Feed - 0.0143 \times CS \times Feed$$

It is critical to assess the fitted model's suitability since an inaccurate or inadequately described model may produce misleading results. One can determine whether the model is underspecified by evaluating the model's fit. ANOVA is then used on the truncated model shown in Table 5 to perform the model suitability verification, which includes testing the regression model's significance, model coefficients, and lack of fit.

Table V: Analysis of Variance for Sr

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	9	8.98556	8.98556	0.998396	43.6	0.000
Linear	3	8.68581	0.01707	0.005689	0.25	0.861
Temp	1	7.55050	0.01163	0.011631	0.51	0.487
CS	1	0.26642	0.00006	0.000056	0.00	0.961
Feed	1	0.86888	0.00541	0.005410	0.24	0.634
Square	3	0.27846	0.14147	0.047157	2.06	0.149
Temp*Temp	1	0.27532	0.06291	0.062913	2.75	0.118
CS*CS	1	0.00002	0.00111	0.001107	0.05	0.829
Feed*Feed	1	0.00312	0.00062	0.000619	0.03	0.872
Interaction	3	0.02130	0.02130	0.007100	0.31	0.818
Temp*CS	1	0.01786	0.00006	0.000055	0.00	0.961
Temp*Feed	1	0.00036	0.00182	0.001823	0.08	0.782
CS*Feed	1	0.00308	0.00308	0.003082	0.13	0.719
Residual Error	15	0.34349	0.34349	0.022899		
Total	24	9.32906				

By conducting experiments as previously mentioned in the section, the impact of the machining parameters on the response variables (SR) has been assessed. Minitab software has been used for analysis. ANOVA is used to determine whether the second-order model is sufficient. The normal probability plot shows the model fitting as shown in figure 2.

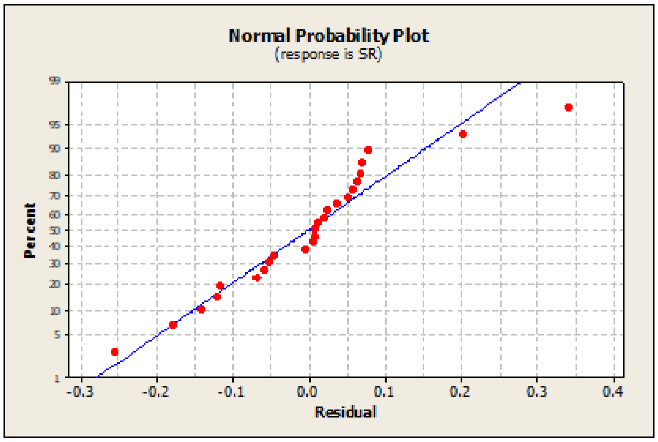

Figure 2: Normal Probability Plot

When Feed is held constant at its middle value, Fig. 3 displays the estimated response surface for Surface Roughness in respect to the process parameters of Temp and CS. The figure shows that, for all values of Cutting Speed, the SR tends to fall significantly with an increase in Surface temperature. It means that higher surface temperature enhances the surface finish.

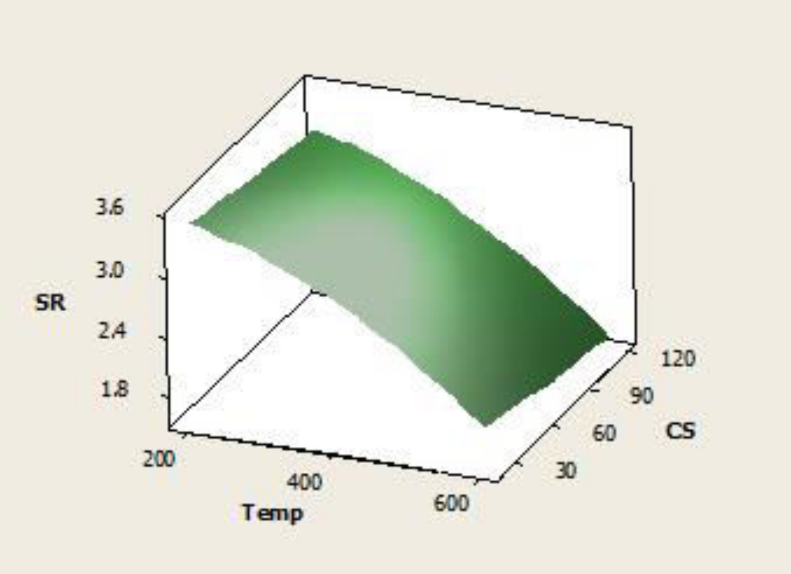

Figure 3: Surface plot of SR, VS Temp, CS

The estimated response surface for Surface Roughness with respect to the process parameters of Temp and Feed is shown in Fig. 4 when CS is maintained at its middle value. The graphic illustrates how the SR tends to decrease dramatically when Surface temperature rises for all values of Feed.

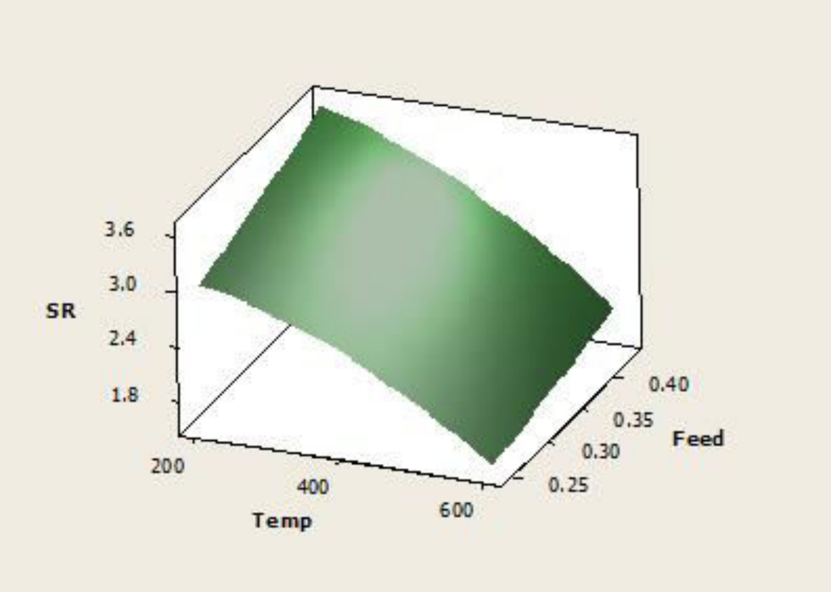

Figure 4: Surface plot of SR, VS Temp, Feed

When Temp is held constant at its middle value, Fig. 5 displays the estimated response surface for Surface Roughness in respect to the process parameters of CS and Feed. The surface roughness increases with increase in both cutting speed and feed. The highest surface roughness is obtained at the high feed and cutting speed. The Feed is more significant than cutting speed as shown in to the figure.

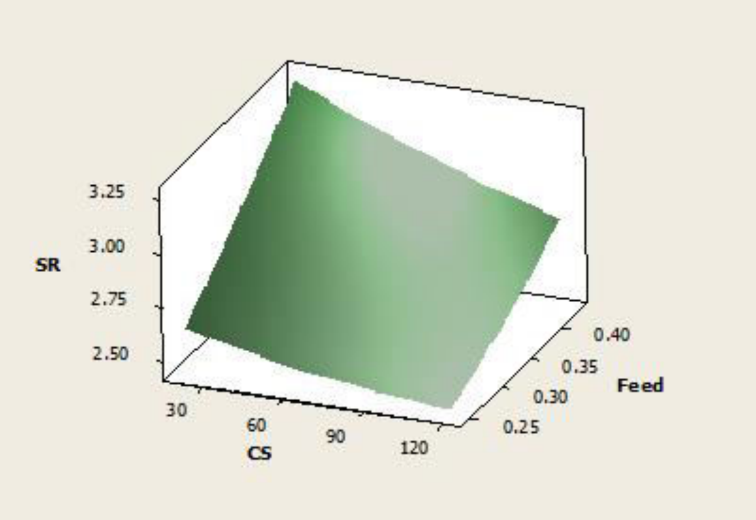

Figure 5: Surface plot of SR, VS CS, Feed

CONCLUSION

The current work used Taguchi to optimize experimentation, and RSM was used to identify the process parameters that had a substantial impact on surface roughness. This work presents the creation of a comprehensive mathematical model using response surface methodology (RSM) to correlate the interactive and higher order influences of different turning operation parameters. Relevant experimental data from surface roughness experiments are used in this model.

- The most important control factor for cutting force and feed force is temperature. Low cutting and feed forces are advantages of hot machining.
- Surface Roughness reduces as temperature rises, as cutting speed increases, and as feed rate falls.
- The most important factor influencing Surface Roughness is temperature. Good surface finish can be achieved by hot machining at high temperatures, high cutting speeds, and low feed rates.

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