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Study on Cutting Parameters to Reduce the Surface Roughness in Hard Turning of SKD 61 Steel using Taguchi Method

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ABSTRACT

In this article, the Taguchi method was used to optimize cutting parameters to achieve minimum roughness during hard turning of SKD 61 steel. Cutting parameters selected include cutting speed, feedrate, and depth of cut. Experiments were organized by the use of L9 orthogonal array. The influence of each factor on the output response is analyzed by Minitab software. Signal to noise and analysis of variance are applied to statistical analysis. The result indicates that the feedrate has an outstanding influence compared to the other two variables. Optimal processing conditions to achieve the minimum roughness has been given. In addition, a regression equation describing the relationship between roughness and cutting parameters was built with the determination coefficient R-sq of 93.99%.

KEYWORDS: *surface roughness, hard turning, SKD 61 tool steel, dry cutting, Taguchi method*

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INTRODUCTION

SKD 61 is a tool steel with high hardness and wear resistance, especially after heat treatment. That is why SKD61 steel is widely used in industry. It is very suitable for making high-pressure die castings, extrusion dies, wear-resistant cutting blades, hot stamping die sets, and so on. In this study, the turning process of SKD 61 steel was conducted to investigate the influence of the turning process parameters on the surface roughness. Surface roughness is an important parameter to evaluate the machining quality in metal cutting. There are many factors that affect the machining roughness such as the characteristics of the cutting tool, the properties of the workpiece, the phenomena occurring during the cutting process, and the cutting parameters[1, 2]. Among them, cutting parameters including cutting speed, feedrate and depth of cut are the factors that have a great influence on the roughness[3-6]. Therefore, optimization of cutting parameters has been carried out in many types of machining such as turning[7-9], milling[10-12], grinding[13, 14], etc.

In experimental studies, the optimization method developed by Taguchi is the widely used method. Taguchi method brings high efficiency in experimental optimization because of its robustness, simplicity and economy[15, 16].

In this work, Taguchi method was used to determine the effect of cutting parameters on surface roughness during hard turning of SKD 61 steel. In addition, the relationship between the machining parameters and the roughness expressed by the mathematical equation has been built.

EXPERIMENTAL SETUP

As shown in Figure 1, hard turning of SKD61 without using coolant fluid (dry turning) was performed on an EMCO Maxxturn 45 turning CNC machine. The SKD61 steel workpieces, which had a length of 120 mm and a diameter of 20 mm, were heat-treated to the hardness of 50HRC. In each experiment, a new tool with a CBN insert was used. The surface roughness was measured by a Mitutoyo SV-3100.

Each experiment run with a set of velocity v (m/min), depth of cut d (mm), and feedrate f (mm/rev) based on Taguchi L9 orthogonal array method

FIGURE 1: EXPERIMENTAL SETUP

TABLE 1: SURFACE ROUGHNESS VALUES OBTAINED FROM EXPERIMENTS

No.	v (m/min)	d (mm)	f (mm/rev)	Ra (µm)	S/N
1	40	0,1	0,05	0,919	0,73369
2	40	0,2	0,1	1,611	-4,14191
3	40	0,3	0,15	1,789	-5,05221
4	60	0,1	0,1	1,052	-0,44031
5	60	0,2	0,15	1,53	-3,69383
6	60	0,3	0,05	1,11	-0,90646
7	80	0,1	0,15	1,17	-1,36372
8	80	0,2	0,05	0,821	1,713137
9	80	0,3	0,1	1,132	-1,07693

RESULTS AND DISCUSSIONS

Table 1 shows the results of the nine experiments following the Taguchi method setup.

The signal to noise (S/N) ratios were used to determine the rank of each parameter regarding the surface roughness value. The smaller the better type was selected as in the equation (1)

$$\frac{S}{N} = -10 log \frac{1}{n} (\sum_{i=1}^{n} y_i^2) \quad (2)$$

Where y_i is the observed data from surface roughness measurement

n is the number of experiments that are repeated.

By using the Minitab software version 19.0, the values of S/N above can be used to determine the rank of each parameter as presented in Table 2.

The results clearly indicate the important role of the feed rate parameter in getting better surface quality, followed by the cutting velocity and the depth of cut respectively.

TABLE 2: THE RESPONSE FOR S/N RATIOS.

Level	v	d	f
1	-2.8201	-0.3568	0.5135
2	-1.6802	-2.0409	-1.8864
3	-0.2425	-2.3452	-3.3699
Delta	2.5776	1.9884	3.8834
Rank	2	3	1

The plot in Figure 2 visualizes the main effects of each parameter. It is easy to observe that at the cutting speed of 80 m/min, the depth of cut of 0.1 mm, and the feed rate of 0.05 mm/rev, the optimal condition for the smallest roughness surface was reached.

A model to calculate the surface roughness Ra based on the investigating parameters was built as in equation (2):

$$Ra = 0.992 - 0.00997\, v + 1.483\, d + 5.463\, f \qquad (2)$$

This model helps to find the optimize set of parameters within preset boundaries in order to find the best surface roughness Ra value. It is necessary to note that this simple linear regression model base on the response values (i.e., surface roughness values) might not be the best model but rather than a modest tool available in Minitab software to quickly obtain an overall evaluation and analysis of the harvested data. Therefore, a further examination of the modal using the ANOVA table was performed as shown in Table 3.

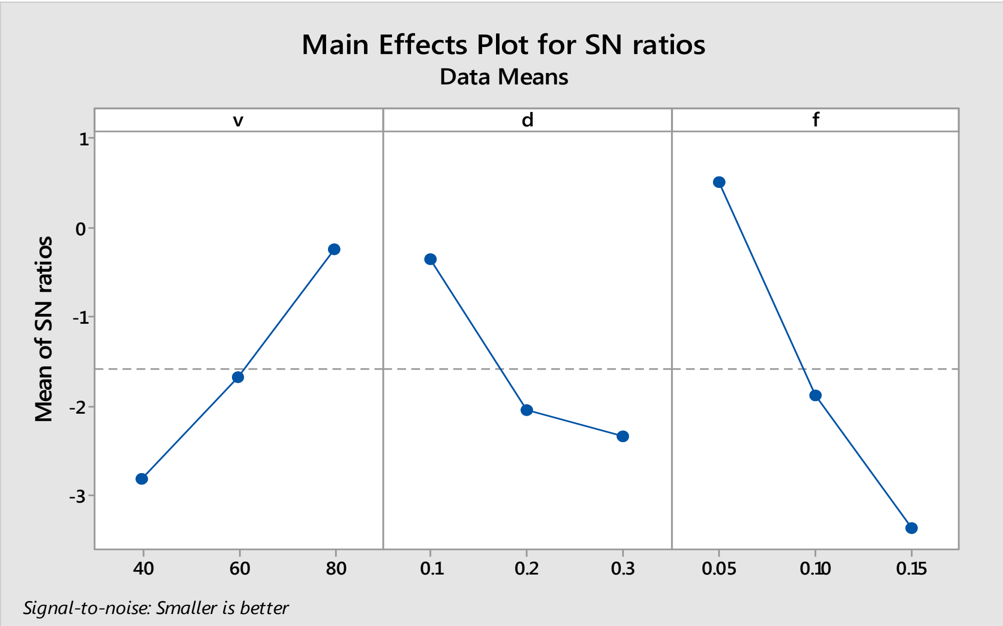

FIGURE 2: MAIN EFFECTS PLOT FOR SN RATIOS

TABLE 3: ANALYSIS OF VARIANCE TABLE

Source	DF	Adj-SS	Adj-MS	F-Value	P-Value
Regression	3	0.81814	0.27271	26.05	0.002
v	1	0.23840	0.23840	22.78	0.005
d	1	0.13202	0.13202	12.61	0.016
f	1	0.44772	0.44772	42.77	0.001
Error	5	0.05234	0.01047	-	-
Total	8	0.87048	-	-	-
R-sq = 93.99%					

The R-sq value of 93.99% suggested that the linear model is highly accurate. The P-values of the cutting speed v and f which are no bigger than 0.005 indicates that they bear significant meaning in the model. In other words, they have a great impact on the result of the surface roughness in experiments.

CONCLUSION

This research focused on researching the influence of machining parameters on the hard turning of hardened SKD 61 steel. There is some conclusion that can be drawn from the result of the experiments:

- Feedrate was the most important parameter while selecting the machining option, followed by the cutting speed and the depth of cut.
- The linear model of the surface roughness built in this research reaches a very high accuracy of 93.99% which can be considered reliable for finding the optimal value of the surface roughness based on the three cutting parameters mentioned above.
- Best surface roughness achieved in this machining condition margin is with the cutting speed of 80 m/min, the depth of cut of 0.1 mm, and the feed rate of 0.05 mm/rev.

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