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Analysis and Effect of Process Parameters on Surface Roughness and Tool Flank Wear in Facing Operation

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Abstract

This experimental work presents a technique to determine the better surface quality by controlling the surface roughness and flank wear. In machining operations, achieving desired surface quality features of the machined product is really a challenging job. Because, these quality features are highly correlated and are expected to be influenced directly or indirectly by the direct effect of process parameters or their interactive effects. Thus The four input process parameters such as spindle speed, depth of cut, feed rate, and diameter have been selected to minimize the surface roughness and flank wear simultaneously by using the robust design concept of Taguchi $L_9(3^4)$ method . Taguchi's optimization analysis indicates that the factors level, its significance to influence the surface roughness and flank wear for the facing operation.

Keywords: Surface Roughness, Flank Wear, Facing, CMM

Introduction

A typical manufacturing process has several quantitative and qualitative output and performance characteristics that are indicative of its contribution to the success of a manufacturing company (1-8). Such characteristics will generally fit into the broader areas of quality and productivity, with subcategories that include product requirements, throughput, flexibility, labor hours, downtime, safety, and reliability. Furthermore, these and other characteristics can be interdependent a mismanaged increase in throughput can affect quality, for example. A robust system should therefore include a robust engineering process that seeks a balance among the output and performance aspects of a manufacturing process (2-4).

Along with in the several CNC industrial machining processes, facing is a fundamental machining operation. Facing is the removal of metal from the flat face of a rotating cylindrical work piece (3-7). Facing is used to produce a smooth finish on the surface of work piece. In the age of globalization manufacturers are constantly facing the challenges of quality, cost and lead time in order to survive in the cut-throat competitive market(6). The quality of machined components is evaluated in respect of how closely they adhere to set product specifications for length, width, diameter, surface finish, and reflective properties (9-10). Dimensional accuracy, tool wear and quality of surface finish are three factors that manufacturers must be able to control at the machining operations to ensure better performance and service life of engineering component. In the leading edge of manufacturing, manufacturers are facing the challenges of higher productivity, quality and overall economy in the field of manufacturing by machining (5-7). In this paper, Taguchi robust design of experiments was conducted by varying the machining parameters such as speed, feed and depth of cut and diameter for measuring the surface roughness and flank wear by using uncoated carbide inserts for facing operation.

2. Experimental Setup

Experiments have been performed on two-axis CNC facing machine (SPRINT16TC) at Indo Danish Tool Room, Jamshedpur (India). The photographic views of CNC facing and experimental set-up are shown in Figure 1.

2.1 Surface Roughness measurement

It was measured on Subtronic-10 surface tester giving R_a value in microns. R_a is measured along four different lines on the surface and the average value is considered for further analysis.

(a) (b)

Figure 1 Photographic view of (a) CNC facing and (b) experimental set-up

2.2 Flank Wear Measurement Setup

Precision measurement of the manufactured products in cartesian coordinate system can be performed by using a coordinate measuring machine (CMM). Model 850 – CARL ZEISS coordinate measuring machine, which is available at Indo Danish Tool Room, Jamshedpur (India), is utilized for the flank wear examination of the experimental tool insert. The available CMM at the Center which is presented in Figure 2 uses digital readouts, air bearings, computer controls to achieve volumetric accuracies in the order of 2.8+L/250 μm. The reference coordinate which is used throughout the machining operations is recreated by forming reference planes on the surfaces of the product. By intersecting surface, reference coordinate of the machined part is defined and fixed. After converting the CMM coordinate system to the part coordinate system, measuring probe becomes aware of the reference coordinate and angular position of the each axis. Comparison of the real flank wear value with the value predicted by CMM indicates flank wear in the tool face. In this experimental study flank wear measure in the tool face.

Figure 2 Coordinate measuring machine (CMM)

3. Work piece Material

The material used in this experimental is the commercial mild steel in the form of round bar with 30mm, 40mm and 50mm diameter. Nine experiment done accordingly Taguchi's L_9 orthogonal array. Cutting fluid flow kept constant throughout the experimentation. The chemical composition of flat bar material is given in Table 1.

Table 1 Chemical composition of mild steel

Material	C	Mn	Cu	Si
Mild Steel	0.16-0.29%	1.65%	0.6%	0.6%

4. Tool and tool material

A photographic view of tool inserts show in figure 3. The cutting materials are K10 type uncoated carbide inserts, and as per ISO specification, inserts are designated as CNMG 0808-QM H13A, which are having the following tool geometry: inclination angle, −6°; orthogonal rake angle, −6°; orthogonal clearance angle, 6°; auxiliary cutting edge angle, 15°; principal cutting edge angle, 75°; and nose radius, 0.8 mm. Cutting tool inserts were clamped onto a tool holder with a designation of DSKNL 2020K 12 IMP for facing operation make by CERADIZET.

Figure 3 photographic view of tool insert

5. Machining parameters and their levels

In this experimental study, spindle speed (x_1), depth of cut (x_2), feed (x_3), and diameter (x_4) were considered as machining parameters. Based on the pilot experimentation, parameters range has been decided [3]. The considered process parameters and their levels are listed in Table 2.

Table 2 Machining parameters and their levels

level	Spindle speed (rpm)	Depth of cut (mm)	Feed(mm/rev)	Diameter (mm)
1	600	0.4	0.1	30
2	700	0.5	0.2	40
3	800	0.6	0.3	50

6. Taguchi method

The quality engineering method proposed by Taguchi is commonly known as the Taguchi method or Taguchi approach. His approach provides a new experimental strategy in which a modified and standardized form of design of experiment (DOE) is used. In other words, the Taguchi approach is a form of DOE with special application principles. The concept of the Taguchi method is that the parameter design is performed to reduce the sources of variation on the quality characteristics of product, and reach a target of process robustness Taguchi designs experiments using specially constructed tables known as "orthogonal array" (OA). It utilizes the orthogonal arrays from experimental design theory to study a large number of variables with a small number of experiments. This technique helps to study effect of many factors (variables) on the desired quality characteristic most economically. By studying the effect of individual factors on the results, the best factor combination can be determined. The standardized Taguchi-based experimental design used in this study is an L_9 (3^4) orthogonal array (4).

6.1 Analysis of S/N ratio

In the Taguchi method, the term 'signal' represents the desirable value (mean) for the output characteristic and the term 'noise' represents the undesirable value (S.D) for the output characteristic. Therefore, the S/N ratio is the ratio of the mean to the S.D. S/N ratio is used to measure the quality characteristic deviating from the desired value. The S/N ratio η is defined as

$$S/N = -10log(M.S.D) \text{------------------------------(1)}$$

Where M.S.D is the mean square deviation for the output characteristic. To obtain optimal cutting performance, the–lower–the–better quality characteristic for Surface Roughness and flank wear must be taken [6]. The M.S.D. for the–lower– the–better quality characteristic can be expressed as:

$$M.S.D = \frac{1}{M}\sum_{i=1}^{M} y_i^2 \text{------------------------------------(2)}$$

Where y_i is the value of the observed data for the *i*-th test and M=1.

6.2 Design of Experiment

Four machining parameters were selected as control factors, each parameters have three levels, denoted by 1, 2, and 3. The experimental design was based on L_9 orthogonal array based on Taguchi method. Minitab 15 software was used for graphical analysis of the obtained data.

Table 3 experimental design matrix based on Taguchi L_9 orthogonal array

S.N.	Spindle speed (rpm)	Depth of cut(mm)	Feed (mm/rev)	Diameter (mm)
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

7. Result and discussion

7.1.1 Effect of input parameters on Surface roughness

In order to see the effect of input parameters on the surface roughness experiments were conducted using L9 OA (Table 3). The experimental data is given in Tables 4. Figures 4 show that the surface roughness first increases after then constant with the increase of spindle speed and decreases with increase in depth of cut and diameter and surface roughness first decrease after then increase with increase of feed in facing operation.

Table 4 Experimental result for surface roughness and flank wear in facing operation

Experi-ment	Spindle speed (rpm)	Depth of cut (mm)	Feed (mm/rev)	Diameter (mm)	Surface Roughness (μm)	S/ N ratio	Flank Wear(mm)	S/ N ratio
1	600	0.4	0.1	30	6.45	-16.1912	0.53	5.5145
2	600	0.5	0.2	40	7.21	-18.1587	0.41	7.7443
3	600	0.6	0.3	50	8.13	-18.2016	0.31	10.1728
4	700	0.4	0.2	50	6.54	-16.3116	0.39	8.1787
5	700	0.5	0.3	30	6.15	-15.7775	0.21	13.5556
6	700	0.6	0.1	40	7.23	-17.1828	0.19	14.4249
7	800	0.4	0.3	40	6.21	-15.8618	0.37	8.6360
8	800	0.5	0.1	50	6.56	-16.3381	0.18	14.8945
9	800	0.6	0.2	30	7.19	-17.1346	0.21	13.5556

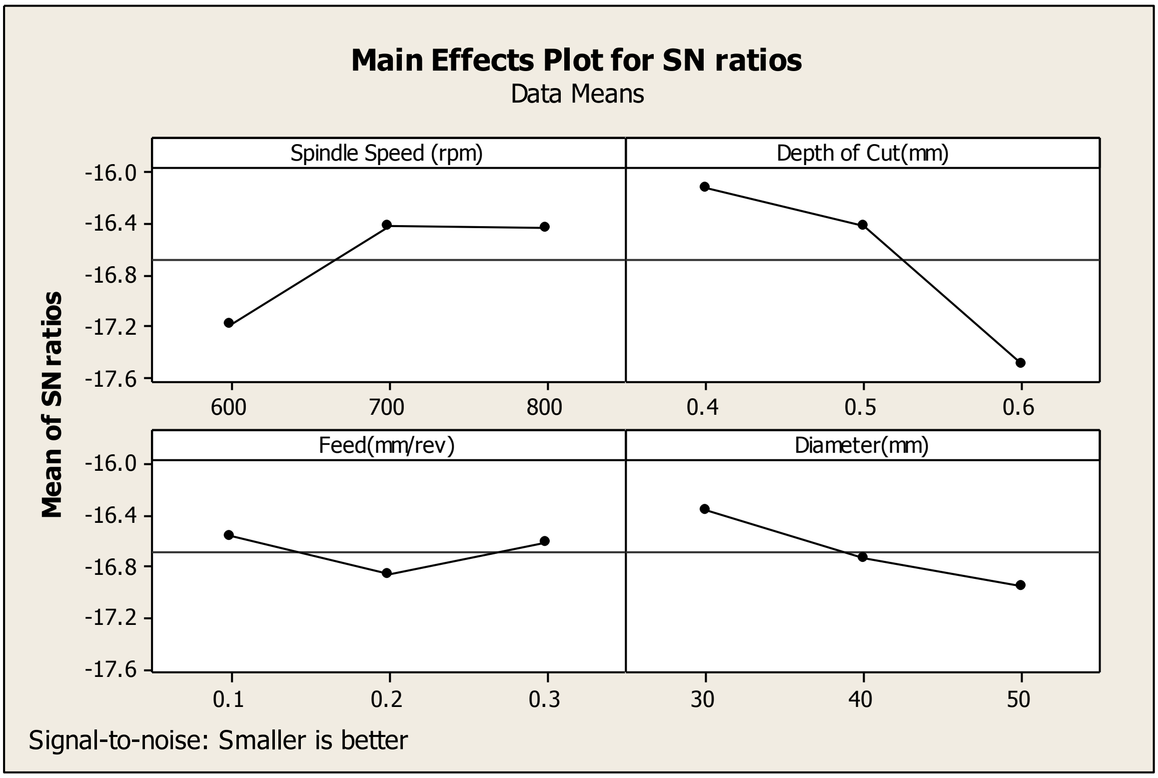

Figure 4 Effect of input parameters on Surface roughness

7.1.2 Selection of Optimal Levels

The response table 5 shows the average of each response characteristic for each level of each factor. The Tables include ranks based on delta statistics, which compare the relative magnitude of effects. The delta statistic is the highest minus the lowest average for each factor. Minitab assigns ranks based on delta values; rank 1 to the highest delta value, rank 2 to the second highest, and so on. The ranks indicate the relative importance of each factor to the response. The ranks and the delta values for various parameters show that the depth of cut has greatest effect on surface roughness and is followed by spindle speed, diameter and feed in that order. As surface roughness is the "lower the better" type quality characteristic, from Figure 3 it can be seen that the second level of spindle speed, first level of depth of cut, first level of feed and first level of diameter result in minimum value of surface roughness.

Table 5 Response Table for Signal to Noise Ratios for surface roughness Smaller is better

Level	Spindle speed (rpm)	Depth of cut (mm)	Feed (mm/rev)	Diameter(mm)
1	-17.18	-16.12	-16.57	-16.37
2	-16.42	-16.42	-16.87	-16.73
3	-16.44	-17.51	-16.61	-16.95
Delta	0.76	1.38	0.30	0.58
Rank	2	1	4	3

7.2.1 Effect of input parameters on Flank Wear

In order to see the effect of input parameters on the wear experiments were conducted using L9 OA (Table 3). The experimental data is given in Tables 4.

Figure 5 shows that the flank wear increases with the increase of spindle speed and depth of cut and flank wear first decrease after than increase with the increase of feed and diameter.

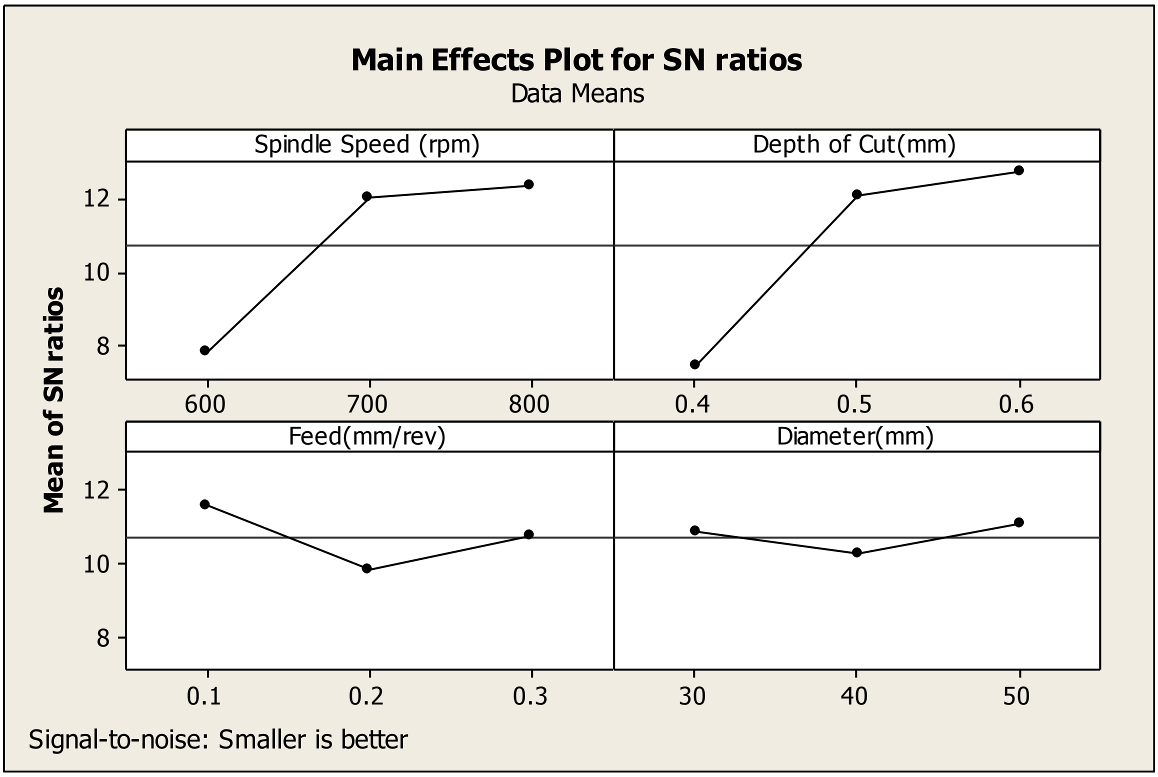

Figure 5 Effect of input parameters on flank wear

7.2.2 Selection of Optimal Levels

The response table 6 shows the average of each response characteristic for each level of each factor. The Tables include ranks based on delta statistics, which compare the relative magnitude of effects. The delta statistic is the highest minus the lowest average for each factor. Minitab assigns ranks based on delta values; rank 1 to the highest delta value, rank 2 to the second highest, and so on. The ranks indicate the relative importance of each factor to the response. The ranks and the delta values for various parameters show that depth of cut has the greatest effect on flank wear and is followed by spindle speed, feed and diameter in that order. As flank wear is the "lower the better" type quality characteristic, from Figure 3 it can be seen that the third level of spindle speed, third level of depth cut, first level of feed and third level of diameter result in minimum value of flank wear.

Table 6 Response Table for Signal to Noise Ratios for flank wear Smaller is better

Level	Spindle speed (rpm)	Depth of cut (mm)	Feed (mm/rev)	Diameter(mm)
1	7.811	7.443	11.611	10.875
2	12.053	12.065	9.826	10.268
3	12.362	12.718	10.788	11.082
Delta	4.552	5.275	1.785	0.814
Rank	2	1	3	4

8. Conclusions

In the present investigation, analysis of cutting parameters influence on surface roughness and flank wear of tool in CNC facing of mild steel have been successfully studied by Taguchi. By the experimental and the analytical results, the following conclusions were drawn.

1) The optimum conditions for smaller surface roughness are spindle speed at 700 rpm, depth of cut at 0.4mm, feed at 0.1 and diameter at 30mm.
2) The optimal machining condition for flank wear in tool was 800 rpm spindle speed, 0.6mm depth of cut, 0.1 mm/rev feed and 50mm diameter.
3) Based on Taguchi design of experiments and analysis, the cutting speed is the main factor that has the highest influence on surface roughness as well as flank wear of facing processes.

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