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, 850 m/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 rate 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 0.280 μm 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 requirements in machining process, as it is considered as one of the index of product quality. It measures the finer irregularities of the surface texture. Achieving the desired surface quality is critical for the functional behaviour of a part. Surface roughness influences the performance of mechanical parts and their production costs because it affects factors, such as friction, ease of holding lubricant, electrical and thermal conductivity, geometric tolerances and more. The ability of a manufacturing operation to produce a desired surface roughness depends on various parameters. The factors that influence surface roughness are machining parameters, tool and work piece material properties and cutting conditions. For example, in turning operation the surface roughness depends on cutting speed, feed rate, depth of cut, tool nose radius, lubrication of the cutting tool, machine vibrations, tool wear and on the mechanical and other properties of the material being machined. Even small changes in any of the mentioned factors may have a significant effect on the produced surface [1]. Therefore, it is important for the researchers to model and quantify the relationship between roughness and the parameters affecting its value. The determination of this relationship remains an open field of research, mainly because of the advances in machining and materials technology and the available modeling techniques. In machinability studies investigations, statistical design of experiments is used quite extensively. Statistical design of experiments refers to the process of planning the experiments so that the appropriate data can be analyzed by statistical methods, resulting in valid and objective conclusions [2]. Design methods such as factorial designs, response surface methodology (RSM) and Taguchi methods are now widely used in place of one factor at a time experimental approach which is time consuming and exorbitant in cost.

II. METHODOLOGY

To carry out 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 number.
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 tests are conducted by considering four cutting parameters: cutting speed (v), feed rate (f), depth of cut (d), and tool no. of cuts (n). Total 2^4= 16 cutting experiments are carried out. Low-middle-high level of cutting parameters in cutting space of two level full factorial experimental design are shown in Table 2. Ranges of cutting parameters are selected based on shop floor. All the experiments were carried out 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. Surface finish of the work piece material was measured by Surf tester. The surface roughness was measured at three equally spaced locations around the circumference of the work pieces to obtain the statistically significant data for the test. In the present work, the work piece material was the mild steel. This material has good wear and corrosion resistance. A mechanical property of the material

<table>
<thead>
<tr>
<th>Sr.No.</th>
<th>Parameters</th>
<th>Level 1</th>
<th>Level 2</th>
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<tr>
<td>1</td>
<td>Cutting speed (v), m/min</td>
<td>1150</td>
<td>850</td>
</tr>
<tr>
<td>2</td>
<td>Feed (f), mm/rev</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>3</td>
<td>Depth of cut (d), mm</td>
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<td>1</td>
</tr>
<tr>
<td>4</td>
<td>No. of cuts</td>
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Table 1 Input parameters and their levels.

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<tr>
<th>N</th>
<th>F</th>
<th>DOC</th>
<th>No. of cuts</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>Diameter</th>
<th>Surface finish</th>
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<td>13.64</td>
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A=N-975/175, B=F-0.75/0.25, C=DOC-1.5/0.5, D=T-1.5/0.5
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Image No.1 - Surface Roughness measurement Instrument

Image No.2 - Surface Roughness images of all components
The fitted regression model for diameter is

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

The fitted regression model for diameter is

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

\[ Z = \begin{bmatrix} 12.83 \\ 0.93 \\ 0.95 \\ -0.4525 \\ -0.695 \end{bmatrix} \]

\[ X'X = \begin{bmatrix} 16 & 0 & 0 & 0 \\ 0 & 16 & 0 & 0 \\ 0 & 0 & 16 & 0 \\ 0 & 0 & 0 & 16 \end{bmatrix} \]

\[ (X'X)^{-1} = \begin{bmatrix} 0.0625 & 0 & 0 & 0 \\ 0 & 0.0625 & 0 & 0 \\ 0 & 0 & 0.0625 & 0 \\ 0 & 0 & 0 & 0.0625 \end{bmatrix} \]

\[ X'Y = \begin{bmatrix} 14.1 \\ 13.2 \\ 13.1 \\ 13.1 \\ 11.7 \\ 13.2 \\ 10.96 \\ 13.96 \\ 13.13 \\ 13.14 \\ 11.1 \\ 13.98 \\ 13.1 \\ 13.72 \\ 13.64 \end{bmatrix} \]

\[ S = \begin{bmatrix} 0.57 \\ 8.68 \\ 16.2 \\ 2.8 \\ 16.68 \\ 13.28 \\ 12.68 \\ 11.5 \\ 20.13 \\ 14.87 \\ 16.2 \\ 15.2 \\ 6.13 \\ 5.76 \\ 12.22 \end{bmatrix} \]

\[ SF = (X'X)^{-1}X'S \]
The fitted regression model for Surface Roughness is

\[ Y_{\text{fit}} = 12.1 + 0.80125A - 0.73125B + 0.3375C - 1.50125D \]
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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 N

Fig. No. 11. Surface plot of diameter Vs N

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 tool nose 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 as 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/rev, 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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