Influence of Process Parameters and Responses on Performance of CNC Machine Turning Operation by using Multiple Regression Method

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Abstract—Influence of process parameters and responses on performance of CNC machine turning operation on EN-31 steel material in turning operations. This study aims at determining the factors and their interaction that may affect the responses. The response such as surface finish is greatly influenced by factors such as speed, feed rate and depth of cut. Multiple regression method is used to analyze the performance of process parameter on response such as surface finish rate is done on CNC lathe on EN31 sample. Hence, multiple regression model for surface finish has been developed, as a function of spindle speed, feed rate and depth of cut.. It was concluded that surface finish is highly dependent on spindle speed.

Keywords- *speed , feed, depth of cut, responses, Parameters ,Multiple Regression method, surface finish ,*

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I. INTRODUCTION

In manufacturing industries, main objective of manufacturer is quality and productivity of the product. Surface roughness is the controlling parameters to determine the quality of product. Several factors influence the Surface roughness in a CNC Lathe for turning operations such spindle speed, feed rate and depth of cut, tool nose radius, tool geometry and material properties. Some machine operator used 'Trial and error' method to set-up turning operation lathe machine cutting conditions. Hence an optimum setting is required to find out to ensure minimization of surface roughness .Thus multiple regression method is used to find the influence of various parameters on surface finish in turning operation.

II. LITERATURE REVIEW

Chang et al.[1] Diagnosed a method to predict surface roughness in-process. In their research, the relative motion caused by the machining process measure in process using a cylindrical capacitive is placement sensor (CCDS). The CCDS was installed at the quill of a spindle and the sensing was not disturbed by the cutting. A simple linear regression method is developed to predict surface roughness using the measured signals of relative motion. The linear regression model was proposed and its effectiveness was verified from cutting tests.
Choudhury et al.[2] the development of surface roughness prediction models for turning EN 24T steel (290 BHN) using a response surface methodology. A factorial design technique was used to study the effects of the main cutting parameters such as cutting speed, feed, and depth of cut on surface roughness.

Full Factorial Experiment:
In order to overcome shortcomings of the Taguchi methods the full factorial design can be applied (Montgomery, 1997)[10]. The full factorial experiment includes all possible interactions between design variables when several factors are under observation then no of levels of these factors is to be limited. Otherwise experiment would be very large.
The experimental design is classified in the following manner
2N full factorial design - each design variable is defined at only the lower and upper level (two levels).Each factor with minimum two levels can be studied in order to obtain the output response. If the factors are two levels then following orthogonal array can be selected:
L4, L8, L12, L16, L32. [12]
3^N full factorial design –
Each design variable is defined at the lower and upper level and also in the midpoints (three levels).

If the factors are three levels then following orthogonal array can be selected: L9, L18, and L27.[12]
In the case of N=3 the 3N full factorial design contain 27 design points

Linear Regression Method:
Since linear regression is used to determine the correlation between a criterion variable and a combination of predictor variables, the statistical multiple regression method is applied. It can be used to analyze data from any of the major quantitative research designs

Simple Linear Regression

When the study involves one dependent variable and independent variable and if the relation between them is linear then it is called as Simple Linear Regression.

Multiple Regression Analysis

In experiment if the response (Y) is linearly related to more than one independent variable, then the relation is called multiple linear Regressions.
Let X1, X2, X3,…….Xn are independent variable then

$$Pi = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \ldots\ldots\ldots + \beta n X_{ni}$$

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Where β_0, β_1, β_2 β_n = regression co-efficient

For surface roughness:
$Pi = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i}$

Yi= Surface Roughness (µm)
X_{1i}= Spindle Speed (rpm)
X_{2i} = Feed Rate (mm/min)
X_{3i} = Depth of Cut (mm)
β_0, β_1, β_2, β_3 = regression co-efficient

III. PROBLEM OBJECTIVE

Main Objective in Industry is:

- Production Rate should be maximum
- Operation Cost should be minimum
- Quality of Machining
- Factors which have influence on surface roughness in turning operations are such as controllable factors like spindle speed , feed rate, depth of cut and uncontrollable factors like tool geometry and material properties of tool and workpiece

IV. EXPERIMENTAL SET UP

CNC Lathe Machine,
Cutting Tool Used: Carbide tool.
Surface roughness Measuring instrument:
Material: EN-31

TABLE I. CHEMICAL COMPOSITION OF EN-31

Chemical composition of EN-31	
ELEMENT	Chemical composition (wt. %)
C	1.08%
Si	0.25%
Mn	0.53%
S	0.015%
P	0.022%
Ni	0.33%
Cr	1.46%
Mo	0.06%

MECHANICAL PROPERTIES OF EN-31

Table 2: Mechanical Properties of EN-31	
MECHANICAL PROPERTIES OF EN-31	
ELEMENT	VALUE
Tensile Strength	750 N/mm^2
Yield Stress	450 N/mm^2
Density	7.8 kg/m^3
Hardness	63 HRC

Handy surf E-MC-S24B is used for Surface Roughness Measuring instrument

In this paper, experiments are conducted using statistical three –level full factorial experiment design.. Thus, the number of experiment need to be executed are $N^K = 3^K = 3^3 = 27$.

TABLE II. CUTTING PARAMETER AND THEIR LEVELS

Independent	**The Level of Each Parameter**		
Variables	***Level1***	***Level2***	***Level3***
cutting speed (RPM)	1000	1200	1450
Feed Rate (mm/rev)	0.06	0.12	0.20
Depth of cut (mm)	0.10	0.21	0.28

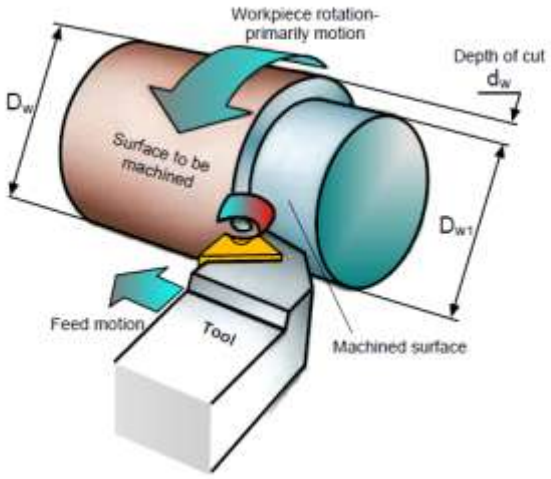

Figure 1. Turning Process

V. ANALYSIS

Multiple regression Method:

$Yi = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i}$
Yi= Surface Roughness (µm)
X_{1i}= Spindle Speed (rpm)
X_{2i} = Feed Rate (mm/min)
X_{3i} = Depth of Cut (mm)
β_0, β_1, β_2, β_3 = regression co-efficient

$$\begin{bmatrix} n & \sum X_{1i} & \sum X_{2i} & \sum X_{3i} \\ \sum X_{1i} & \sum X_{1i}^2 & \sum X_{1i}X_{2i} & \sum X_{1i}X_{3i} \\ \sum X_{2i} & \sum X_{1i}X_{2i} & \sum X_{2i}^2 & \sum X_{2i}X_{3i} \\ \sum X_{3i} & \sum X_{1i}X_{3i} & \sum X_{2i}X_{3i} & \sum X_{3i}^2 \end{bmatrix} \begin{bmatrix} \beta_0 \\ \beta_1 \\ \beta_2 \\ \beta_3 \end{bmatrix} = \begin{bmatrix} \sum Y_i \\ \sum X_{1i}Y_i \\ \sum X_{2i}Y_i \\ \sum X_{3i}Y_i \end{bmatrix}$$

For Surface Roughness

N =27
$\sum X_{1i}$ = 33750
$\sum X_{2i}$ = 2.7
$\sum X_{3i}$ = 8.55
$\sum Y_i$ = 26.89
$\sum X_{1i}^2$ = 43312500
$\sum X_{2i}^2$ = 0.315
$\sum X_{3i}^2$ = 3.2625
$\sum X_{1i} X_{2i}$ = 3375
$\sum X_{1i} X_{3i}$ = 10687.5
$\sum X_{2i} X_{3i}$ = 0.855

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$\sum X_{1i}Y_i = 32765$
$\sum X_{2i}Y_i = 2.629333$
$\sum X_{3i}Y_i = 8.0905$
After solving Matrix A ;
$\beta 0 = 2.312$
$\beta 1 = -0.000753$
$\beta 2 = -1.3260$
$\beta 3 = -0.7651$

TABLE III. EXPERIMENTAL RESULT AND PREDICTED SURFACE ROUGHNESS USING MULTIPLE REGRESSION METHOD

Sr.No	SURFACE ROUGHNESS Ra (µm)	Predicted surface roughness (Multiple regression method)
1	1.90	1.377935
2	1.90	1.26317
3	0.84	1.11015
4	1.15	1.311635
5	1.35	1.19687
6	0.68	1.04385
7	1.00	1.245335
8	0.90	1.13057
9	0.90	0.97755
10	1.30	1.189685
11	0.58	1.07492
12	0.72	0.9219
13	0.81	1.123385
14	1.00	1.00862
15	0.89	0.8556
16	1.05	1.057085
17	0.85	0.94232
18	0.93	0.7893
19	0.74	1.001435
20	0.64	0.88667
21	0.75	0.73365
22	0.78	0.935135
23	0.84	0.82037
24	0.75	0.66735
25	0.93	0.868835
26	0.80	0.75407
27	0.85	0.60105

VI. RESULT AND DISCUSSION

In order to validate to result the confirmation of experiment where conducted for each output characteristics (surface roughness).Surface roughness are obtained and compared with predicted value as shown in below table

TABLE IV. PREDICTED OPTIMAL VALUES AND RESULT OF CONFORMATION EXPERIMENT

Response	Optimal Parameters	Multiple regression method (predicted Value)	Experimental Value (actual value)
Surface Roughness	3 level of spindle speed , 2nd level of feed rate and 3rd level of depth of cut	0.8	0.7

VII. CONCLUSION

The controlling parameters of the process in this paper are spindle speed, feed rate and depth of cut and different levels. The responses are validated by using multiple regression analysis. Based on result following conclusion can be drawn

- 3 level (1450 rpm) of spindle speed, 2nd level (0.12mm/rev) of feed rate and 3rd level (0.28mm) of depth of cut are optimum parameters of surface roughness.

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