Prediction of Surface Roughness Based on Machining Condition and Tool Condition in Boring EN31 Steel

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Abstract— **Prediction of Surface roughness plays a vital role in manufacturing process. In manufacturing industries, productions of metallic materials require high surface finish in various components. In the present work, the effect of spindle speed, feed rate, depth of cut and flank wear of the tool on the surface roughness has been studied. Carbide tipped insert was used for boring operation. Experiments were conducted in CNC lathe. The experimental setup was prepared with sixteen levels of cutting parameters and was conducted with two tool tip conditions in dry machining. A piezoelectric accelerometer was used to measure the vibrational signals while machining. The data acquisition card which connected between accelerometer and lab-view software to record the signals. Simple linear and least median regression models were used for prediction of surface roughness. The models were developed by weka analysis software. The best suitable regression model is implemented based on maximum correlation coefficient and the minimum error values.**

Keywords: Tool Flank Wear, EN31, Surface roughness, Regression analysis, Vibration signals

I. INTRODUCTION

In machining process, sharp cutting tool edge is used to remove the material from the parent material. Boring is a process of enlarging a hole size after the drilling process. The tool wear mainly occurs during the boring operation is the flank wear. The surface roughness value varies due to work material condition, machining conditions, tool nomenclature and tool vibrations.

Earlier researchers have contributed some experimental works for the prediction of surface roughness from the effect of machining conditions and tool wear. C. J. Rao et al. [1] investigated the significance of machining parameters to produce better surface finish in machining of AISI 1050 using coated ceramic tool insert. K. Venkata Rao. et al. [2] developed the taguchi and multiple regression analysis models to study the effect of cutting parameter and work piece vibration on analysis of surface roughness. Pardeep Kumar et al. [3] optimized the cutting parameters for better the surface finish by increasing the speed and feed rate the reduction of surface roughness was 49.83%. Srithar et al. [4] investigated the surface roughness parameters in machining of AISI D2 steel using coated tip. The increase of cutting speed decreases the surface roughness, but gradual increasing of feed rate and depth of cut increases the surface roughness in turning operation. Varaprasad. Bh et al. [5] developed analysis of variance (ANOVA) models to study the effect of cutting parameters to predict the tool flank wear of AISI D3 hardened steel. M. Elangovan et al. [6] studied that the statistical parameters where extracted from vibration signals and constructed a multiple regression analysis model to predict the surface roughness in turning operation. Mahdi Danesh et al. [7] determined the tool wear by analysing surface sub image using undecimated wavelet transform and textural features. A.M. Badadhe et al. [8] optimize the cutting parameter to predict the surface roughness using analysis of variance (ANOVA) technique in boring of EN9 steel. Kuldip Singh Sangwan et al. [9] presented an ANN-GA approach to optimize the effect of machining parameter like feed rate, which minimizes the surface roughness, the increase of depth of cut and cutting speed that decrease the surface roughness in turning operation by using Ti-6Al-4v Titanium alloy. Shreemoy Kumar Nayak et al. [10] used grey relational analysis technique to optimize the machining parameters in turning operation. This technique performs was to predict the surface roughness. Sam Paul et al. [11] Studied the minimal fluid application to reduce the tool vibration and for better cutting performance during turning of hardened steel. Nexhat Qehaja et al. [12] investigated the effect of machining parameters on surface roughness and developed the regression analysis model to predict the surface roughness in dry turning process. Biswajit Das et al. [13] discussed the effect of cutting parameters that affect the surface roughness in turning of Cu-Tic material. The model is developed by using Artificial Neural Network analysis to predict the surface roughness.

II. EXPERIMENTAL SETUP AND PROCEDURE

The workpiece material used for experiments was EN31 steel. A bar of diameter 33mm x 100mm length was prepared. The chemical composition of the workpiece material is given in Table.1. The work piece end quench temperature is 820°

TABLE.1 CHEMICAL COMPOSITION OF EN 31

Carbon	**0.90-1.20%**
Manganese	**0.30-0.75%**
Chromium	**1.00-1.60%**
Silicon	**0.10-0.35%**
Sulphur	**0.050% max**
Phosphorous	**0.050% max**

The machine used for machining operation is HAAS CNC lathe machine and machining was done under dry cutting condition. The specification of CNC machine has the cutting capacity 406X1219mm, speed range 203X1219mm, max swing 483mm, spindle speed 2000 rpm, and chuck 3 Jaw-10''.

Fig. 1. CNC Lathe machine

Fig. 2. Carbide Insert with Tool Holder

Carbide tool inserts were used for the experiment with nose radius 0.4mm with tool grade CCMT 06020 for boring operation. The tool tips insert of flank wear after machining are measured using Tool maker's microscope instrument. The Tool tip is shown in Fig 2

Sixteen experiments were conducted by varying the cutting parameters along with two different flank wear (viz. New tool, flank wears 0.3mm) of the tool inserts. The two different spindle speeds were set at 400 rpm and 600rpm and for each speed the feed rate was set at 0.15 and 0.25 respectively. For each speed and feed rate combination, the depth of cut was kept at 0.5 and 0.75mm. The experimental setup was prepared based on the full factorial design.

TABLE.2 SHOWS THE PROCESS PARAMETERS AND THEIR LEVELS

MACHINING CONDITION	**SPEED (RPM)**	**FEED RATE (MM/SEC)**	**DOC (MM)**	**TOOL FLANK WEAR (MM)**
M1	400	*0.15*	0.5	0
M2	400	*0.15*	0.75	0
M3	400	*0.25*	0.5	0
M4	400	*0.25*	0.75	0
M5	600	*0.15*	0.5	0
M6	600	*0.15*	0.75	0
M7	600	0.25	0.5	0
M8	600	0.25	0.75	0
M9	400	0.15	0.5	0.3
M10	400	0.15	0.75	0.3
M11	400	0.25	0.5	0.3
M12	400	0.25	0.75	0.3
M13	600	0.15	0.5	0.3
M14	600	0.15	0.75	0.3
M15	600	0.25	0.5	0.3
M16	600	0.25	0.75	0.3

2.1 Accelerometer mounting

The accelerometer is used to measure the vibration of machines, vehicles, and measuring gravity, etc. In this study, piezoelectric accelerometer is used to measure vibration in boring operation while machining. This accelerometer is mounted on the tool holder near the tool post. When machining, the vibration signal goes through the charge amplifier into the data acquisition card system the digital signals were recorded in the system through USB port by using Lab-view software. The recorded signals were then processed to extract different statistical features. The data acquisition card system and analog to digital converter, convert the vibration signal in the digital form.

Fig. 3. Accelerometer setup

2.2. Statistical Features

The statistical analysis of vibration signals yields different parameters. The statistical parameters taken for this study are mean, standard error, median, standard deviation, sample variance, kurtosis, skewness, range, minimum, maximum and sum. Thus the statistical features of each machining condition were extracted for 200 signals.

III. REGRESSION ANALYSIS

The regression analysis is a statistical procedure which shows the relationship between the dependent variables and independent variables. It provides and estimates the values of the dependent variable from the values of the independent variable. These estimation procedures the regression lines. The regression line X on Y is $X = a + bY$ and the regression line Y on X is $Y = a + bx$. The regression equation of X on Y is $X - X = b_{xy}\left(y - y\right)$ and the regression equation of Y on X is $Y - Y = b_{yx}\left(X - X\right)$.

Where $b_{xy} = r\frac{\sigma_X}{\sigma y}$, $b_{yx} = r\frac{\sigma_X}{\sigma_y}$ the variable that are trying to be predicted (Y) is called the dependent (or response) variable. The variable x is called the independent (or predictor, or explanatory) variable. In linear regression the correlation coefficient values and the two variables are treated as equals.

IV. RESULT AND DISCUSSION

The below graph shows the surface roughness based on flank wear and the surface roughness variation based on machining as well as tool condition.

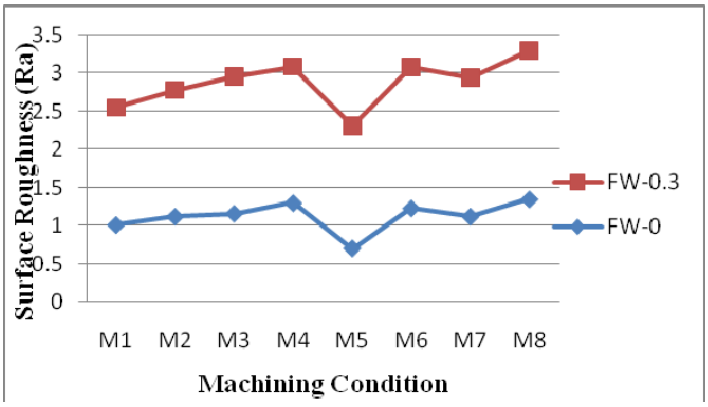

Fig.4. Surface Roughness Based on Flank Wear

4.1 Prediction of surface roughness using Linear Regression

The result of linear regression model was developed for predicting the surface roughness, including machining conditions and the result was given in Table 4.1.

Ra = 0.0002 SPINDLE SPEED + 1.7418 FEED + 0.9357 DOC + 2.1563 FW -2.1819 Mean + 0.9461 Median + 0.1627 Sample Variance + 0.0072 Kurtosis -0.0991Skewness -0.031 Range + 0.1517 Minimum + 0.0616 Maximum +0.1764

Where,

DOC – Depth of cut

FW - Flank wear

Table: 4.1 Result of linear regression model

PARAMETERS	**LINEAR REGRESSION**
Correlation coefficient	**0.9744**
Mean absolute error	**0.0556**
Root mean squared error	**0.0794**
Relative absolute error	**17.6179%**
Root relative squared error	**22.3792%**

4.2 Prediction of surface roughness using Least Median Square (LMS)

The regression models were built to predict the surface roughness based on machining conditions, tool post vibration and flank wear using LMS technique. The results of the model were given in the Table 4.2.

Ra = 1.7583 FEED + 0.5822 DOC + 1.3623 FW + 36.6024 Mean + 2.0117 Median + 0.8429 Standard Deviation + 0.2653 Sample Variance + 0.0006 Kurtosis -0.0161 Skewness + 0.0035 Range +0.1065 Minimum + 0.0238 Maximum -0.0204 Sum + 0.4067

Where,

DOC – Depth of cut

FW - Flank wear

Table: 4.2 RESULT OF LEAST MEDIAN SQUARE MODEL

PARAMETER	LEAST MEDIAN SQUARE
Correlation coefficient	0.8152
Mean absolute error	0.0807
Root mean squared error	0.2326
Relative absolute error	25.5722 %
Root relative squared error	65.5106 %

V. CONCLUSION

The present study on regression analysis functions as an approach for predicting the surface roughness by the influence of cutting conditions during the boring of EN 31 by using carbide insert. It has been observed that the cutting condition is the main influencing parameter of surface roughness. The flank wear and tool post vibration also affects the surface roughness while machining.

The analysis was carried out by developing surface roughness prediction models using Regression analysis functions(Linear regression and Least Median Square) with cutting speed, feed rate, and depth of cut, flank wear and tool post vibration as process parameters. This surface roughness of work in boring process can be successfully modelled.

From the above Table 4.1 and 4.2 shows the numerical values of the linear regression model and Least Median Square model analysis. From these two models the linear regression model was compared with the Least Median Square model. From the above result, the correlation coefficient 0.9744 is the highest value and its value is nearer to 1. The Linear Regression model analysis is performed well to predict the Surface Roughness. Thus the linear regression model method can be utilized for the prediction of surface roughness.

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