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# Prediction of Surface Roughness and Optimization of Cutting Parameters in CNC Turning of Rotational Features

**Yousif K. Shounia [a*], Tahseen F. Abbas [b], Raed R. Shwaish [c]**

[a] Production Engineering and Metallurgy Dept. Baghdad, Iraq, 71407@student.uotechnology.edu.iq

[b] Production Engineering and Metallurgy Dept. Baghdad, Iraq, 70047@uotechnology.edu.iq

[c] Production Engineering and Metallurgy Dept. Baghdad, Iraq, readshuishe@gmail.com

*Corresponding author.

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K E Y W O R D S

CNC turning, Surface roughness, Taguchi orthogonal array

A B S T R A C T

*This research presents a model for prediction surface roughness in terms of process parameters in turning aluminum alloy 1200. The geometry to be machined has four rotational features: straight, taper, convex and concave, while a design of experiments was created through the Taguchi L25 orthogonal array experiments in minitab17 three factors with five Levels depth of cut (0.04, 0.06, 0.08, 0.10 and 0.12) mm, spindle speed (1200, 1400, 1600, 1800 and 2000) r.p.m and feed rate (60, 70, 80, 90 and 100) mm/min. A multiple non-linear regression model has been used which is a set of statistical extrapolation processes to estimate the relationships input variables and output which the surface roughness which prediction outside the range of the data. According to the non-linear regression model, the optimum surface roughness can be obtained at 1800 rpm of spindle speed, feed-rate of 80 mm/min and depth of cut 0.04 mm then the best surface roughness comes out to be 0.04 μm at tapper feature at depth of cut 0.01 mm and same spindle speed and feed rate pervious which gives the error of 3.23% at evolution equation.*

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## 1. Introduction

The wide applications in the engineering and industrial fields of aluminum alloys, 1200 aluminum alloys with good mechanical properties such as hardness, tensile force, etc. were selected [1]. It is of great importance in the manufacture of automobiles and its importance in other engineering applications because of its super properties, the machining of these alloys is very important in form of the surface roughness and affect the operating parameters when using traditional cutting machines. Coarseness is an important parameter to investigate the products of better quality and they were with the higher cutting speed with less feed finish and cut depth produced better finish surface. This paper is to study CNC Turing process parameters that affect the surface roughness of part with compound rotational feature-based and access to optimization [2]. Through this paper the part with four rotational features to be represented and the tool path to be generated. Then, the data transmitted through the Internet to perform the CNC machining process and monitoring by the camera [٣] .The Taguchi methods have been used widely in engineering analysis to optimize performance characteristics by means of settings of design parameters, the obtained data. Taguchi's orthogonal array is highly functional design, used to estimate main effects using few experimental tests only [4].It has the ability to optimize designs for quality, performance, and cost, which presents a systematic approach that is simple and effective. System design involves the application of scientific and engineering knowledge required. The delta and rank values are used to identify the factors that have the greatest effect on each characteristic of each response. Instead, assess the rates of these variables that meet your objectives. Sometimes the best level of a factor for a single response characteristic varies from the best level for a different response characteristic. To resolve this issue, it may help to predict the results of a number of combinations of factors at the level to see which one produces the best outcome.

- Delta Measures the size of the effect by taking the difference between the highest and lowest characteristic average for a factor.[٥]
- Rank The ranks in a response table help you quickly identify which factors have the largest effect. The factor with the largest delta value is given rank 1, the factor with the second largest delta is given rank 2, and so on.

While less surface roughness is always better in the production environment, therefore the surface roughness was classified as "smaller is better" and the signal to noise ratio was calculated in this case as follows:

$$S/N\ ratio\ of\ Ra = -10\ log\frac{1}{n}\ (\sum_{i=1}^{n} y^2) \qquad (1)$$

While the effect of each cutting condition was calculated in this case as follows:

$$\%\ effect\ of\ condition = \frac{delta\ of\ facor}{\sum delta} * 100\ \% \qquad (2)$$

Literature review for Surface Roughness that focuses on input of Spindle speed, feed rate and depth of cut and output Surface Roughness .

Kanakaraja [6], This study investigated the effects of cutting parameters and the prediction model on surface roughness in the fabrication of the aluminum alloy using the Taguchi and ANOVA method to investigate the best particle parameters that contribute to S/N ratio of surface roughness and the mathematical model for roughness prediction.

Sahay and Ghosh [7], uses a surface response methodology that represents mathematical and statistical techniques to achieve the objective of increasing the surface roughness of the aluminum alloy while decreasing cutting depth, decreasing surface roughness (Ra) with increasing cutting speed and feeding rate. Abbas [8] in this study, the objective is to obtain optimal values of CNC turning parameters (cutting speed, depth of cut and feed rate) which result in an optimal value of surface roughness by machining aluminum shaft. In this work, Taguchi method was carried out on machining of aluminum material in dry cutting using CNC turning machine type Star-Chip 450 equip with carbide cutting tool type DNMG 332. Surface roughness was measured using the POCKET SURF EMD-1500 tester. The results obtained of the surface roughness (Ra) are about (1.14-1.91) μm, and the best was at cutting speed 250m/min, feedrate 0.05mm/rev and depth of cut 0.5mm which is referred to the optimum machining parameters.

## 2. Experiment Arrangement

*I. Machine Specification*

The experiments were carried out under dry machining conditions on a Lab-Volt 5500-B5 CNC Lathe as shown in Figure 1, which has a maximum spindle speed of 3400 rpm, spindle power of 746 W, maximum feed-rate up to 762 mm/min.

**Figure 1: CNC Turing machine**

*II. Workpiece Material*

The workpiece material was Aluminum alloy 1200 taken in the form of round bars each of 45 mm diameter and 75 mm length. The chemical composition and mechanical properties of the metal are given in Tables 1 and 2.

**Table 1: Chemical composition of aluminum 1200 alloy**

| | Al% | Fe + Si % | Mn% | Ti% | Cu% | Zn% |
|---|---|---|---|---|---|---|
| Measurement | 98.810 | 0.891 | 0.048 | 0.046 | 0.015 | 0.093 |
| Standard | 99.0 max | 1.0 max | 0.05max | 0.05max | 0.05 max | 0.10 max |

**Table 2: Mechanical of aluminum 1200 alloy**

| | metric |
|---|---|
| Density | 2.7 g/cm$^3$ |
| Tensile Strength | 70-105 MP |

*III.Cutting Insert and holder*

In tests, carbide chemical vapor deposition (CVD) insert of ISO designation (TPMR110308-F1 TP2501) has been used for the experiment. The cutting insert was clamped onto a tool holder having ISO designation (SECOTOOL-S CTGPR1212-11), as shown in Figure 2.

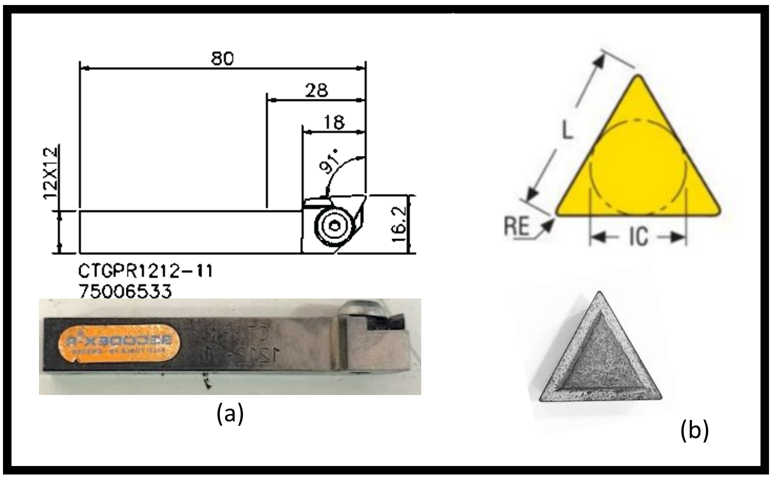


**Figure 2: (a)Holder (b) carbide insert**

*IV. Surface Roughness Measurement*

In the present work, the effect of variation of the various cutting parameter (feed rate, depth of cut and spindle speed) on the surface finish of the workpiece have been studied [9]. The average roughness (Ra) is the area between the roughness profile and its mean line or the integral of the absolute value of the roughness profile height over the evaluation length [10]. The portable gauge of surface roughness

Federal's is available at production and metallurgy engineering Department/UOT, shown in Figure 3.

**Figure 3: Measurement surface roughness**

## 3. Software Design

*I. Design Factors*

An L25 mixed-level Taguchi Orthogonal Array experimental design was selected in order to study the effect of machining conditions, i.e., Spindle Speed n, feed rate F,and depth of cut d when turning AL alloy 1200 [11]. Experimental runs were conducted following a randomized order to avoid the imminent bias on experimental results. Table 3 tabulates the turning parameters accompanied by their levels.

**Table 3: Levels of the variable used in experiments**

| Factors | | Level | | | | | |
|---|---|---|---|---|---|---|---|
| | | I | II | III | IV | V | Units |
| n | Spindle Speed | 1200 | 1400 | 1600 | 1800 | 2000 | rpm |
| F | Feed rate | 60 | 70 | 80 | 90 | 100 | mm/min |
| d | Depth of cut | 0.04 | 0.06 | 0.08 | 0.10 | 0.12 | mm |

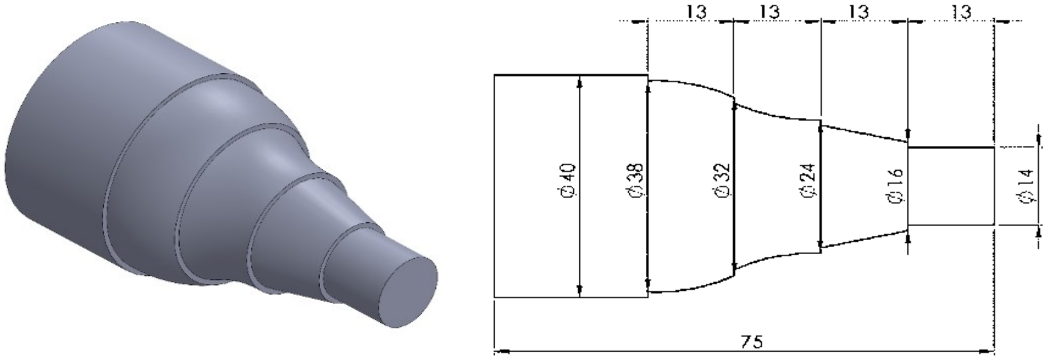


**Figure 4: Configuration of the specimen**

*II. Experimental Result for each Feature*

The operations were carried out within the automation laboratory in the Department of Production and Metal Engineering at the University of Technology, while the control was carried out outside the laboratory to ensure the effectiveness of the machining and monitoring shown in Figures 5 and 6.

**Figure 5: Machining**

**Figure 6: Specimens after turning**

*I. Straight Feature*

At straight feature with 14mm diameter, therefore, cutting speed between 53 m/min to 88 m/min with five-level. The best surface roughness is 0.67 µm at depth of cut 0.04 mm, cutting speed 79 m/min and feed-rate 90 mm/min. The best cutting parameters as shown in Table 4, depth of cut 0.04 mm, feed-rate 90 mm/min and cutting speed 79 m/min.

**Tables 4: Data and result of straight feature (A) Experimental result for Straight Feature**

| | d(mm) | $V_c$ | F | Ra |
|---|---|---|---|---|
| 1 | 0.04 | 53 | 60 | 1.48 |
| 2 | 0.04 | 62 | 70 | 0.77 |
| 3 | 0.04 | 70 | 80 | 0.81 |
| 4 | 0.04 | 79 | 90 | 0.67 |
| 5 | 0.04 | 88 | 100 | 1.10 |
| 6 | 0.06 | 53 | 70 | 1.69 |
| 7 | 0.06 | 62 | 80 | 2.18 |
| 8 | 0.06 | 70 | 90 | 1.26 |
| 9 | 0.06 | 79 | 100 | 1.27 |
| 10 | 0.06 | 88 | 60 | 1.32 |
| 11 | 0.08 | 53 | 80 | 2.02 |
| 12 | 0.08 | 62 | 90 | 1.31 |
| 13 | 0.08 | 70 | 100 | 1.45 |
| 14 | 0.08 | 79 | 60 | 1.30 |
| 15 | 0.08 | 88 | 70 | 2.46 |
| 16 | 0.10 | 53 | 90 | 1.18 |
| 17 | 0.10 | 62 | 100 | 1.68 |
| 18 | 0.10 | 70 | 60 | 2.52 |
| 19 | 0.10 | 79 | 70 | 1.09 |
| 20 | 0.10 | 88 | 80 | 1.85 |
| 21 | 0.12 | 53 | 100 | 2.84 |
| 22 | 0.12 | 62 | 60 | 2.20 |
| 23 | 0.12 | 70 | 70 | 2.16 |
| 24 | 0.12 | 79 | 80 | 2.11 |

25 0.12 88 90 1.85

**(B) Response table for signal to noise ratios smaller is better**

| Level | d | $V_c$ | F | Sum |
|---|---|---|---|---|
| 1 | 0.6692 | -4.1702 | -5.0380 | |
| 2 | -3.5644 | -4.0834 | -3.5406 | |
| 3 | -4.3555 | -3.6562 | -2.7986 | |
| 4 | -2.1957 | -1.6628 | -1.7595 | |
| 5 | -6.8866 | -2.7604 | -3.1962 | |
| Delta | 7.5558 | 2.5074 | 3.2785 | 13.3417 |
| Rank | 1 | 2 | 3 | |
| Effect | 57% | 19% | 24% | |

*II. Taper Feature*

At tapper feature with mean diameter is 19 mm, therefore, cutting speed between 72 m/min to 119 m/min with five-level. The best surface roughness is 0.37 µm at depth of cut 0.06 mm, feed-rate 80 mm/min and cutting speed 84. The best cutting parameters as shown in Table 5, depth of cut 0.04 mm, feed-rate 80 mm/min and cutting speed 96 m/min.

**Tables 5: Data and result of tapper feature (A) Experimental result for taper feature**

| | d | Vc | F | Ra |
|---|---|---|---|---|
| 1 | 0.04 | 72 | 60 | 1.13 |
| 2 | 0.04 | 84 | 70 | 0.75 |
| 3 | 0.04 | 96 | 80 | 0.42 |
| 4 | 0.04 | 107 | 90 | 0.83 |
| 5 | 0.04 | 119 | 100 | 0.75 |
| 6 | 0.06 | 72 | 70 | 2.48 |
| 7 | 0.06 | 84 | 80 | 0.37 |
| 8 | 0.06 | 96 | 90 | 0.89 |
| 9 | 0.06 | 107 | 100 | 0.73 |
| 10 | 0.06 | 119 | 60 | 0.79 |
| 11 | 0.08 | 72 | 80 | 0.71 |
| 12 | 0.08 | 84 | 90 | 1.22 |
| 13 | 0.08 | 96 | 100 | 1.01 |
| 14 | 0.08 | 107 | 60 | 1.26 |
| 15 | 0.08 | 119 | 70 | 0.92 |
| 16 | 0.10 | 72 | 90 | 1.12 |
| 17 | 0.10 | 84 | 100 | 1.41 |
| 18 | 0.10 | 96 | 60 | 1.29 |
| 19 | 0.10 | 107 | 70 | 1.17 |
| 20 | 0.10 | 119 | 80 | 1.24 |
| 21 | 0.12 | 72 | 100 | 0.99 |
| 22 | 0.12 | 84 | 60 | 1.74 |
| 23 | 0.12 | 96 | 70 | 1.17 |
| 24 | 0.12 | 107 | 80 | 1.94 |
| 25 | 0.12 | 119 | 90 | 1.65 |

**(B) Response table for signal to noise ratios smaller is better**

| Level | d | $V_c$ | F | Sum |
|---|---|---|---|---|
| 1 | 2.61789 | -1.37457 | -1.60886 | |
| 2 | 1.30803 | 0.32244 | -1.47869 | |
| 3 | -0.0243 | -3.6562 | -2.7986 | |
| 4 | -1.88254 | -0.95504 | -0.88612 | |
| 5 | -3.23862 | -0.18953 | 0.44976 | |
| Delta | 5.85651 | 2.35162 | 3.91313 | 12.12126 |
| Rank | 1 | 3 | 2 | |
| Effect | 48% | 20% | 32% | |

*III.Convex Feature*

At convex feature with the average diameter is 27mm. Therefore, cutting speed between 102 m/min to 170 m/min with five-level. The best surface roughness is 0.31 µm at depth of cut 0.04 mm, feed-rate 80 mm/min and cutting speed 136 m/min. The best cutting parameters as shown in Table 6, depth of cut 0.04 mm, feed-rate 70 mm/min and cutting speed 136 m/min.

**Tables 6: Data and result of convex feature** ***(A) Experimental result for convex feature***

| | d | Vc | F | Ra |
|---|---|---|---|---|
| 1 | 0.04 | 102 | 60 | 2.08 |
| 2 | 0.04 | 119 | 70 | 0.74 |
| 3 | 0.04 | 136 | 80 | 0.31 |
| 4 | 0.04 | 153 | 90 | 0.48 |
| 5 | 0.04 | 170 | 100 | 1.44 |
| 6 | 0.06 | 102 | 70 | 0.46 |
| 7 | 0.06 | 119 | 80 | 0.42 |
| 8 | 0.06 | 136 | 90 | 0.84 |
| 9 | 0.06 | 153 | 100 | 1.93 |
| 10 | 0.06 | 170 | 60 | 1.85 |
| 11 | 0.08 | 102 | 80 | 1.85 |
| 12 | 0.08 | 119 | 90 | 1.34 |
| 13 | 0.08 | 136 | 100 | 1.15 |
| 14 | 0.08 | 153 | 60 | 2.49 |
| 15 | 0.08 | 170 | 70 | 0.33 |
| 16 | 0.10 | 102 | 90 | 2.56 |
| 17 | 0.10 | 119 | 100 | 1.40 |
| 18 | 0.10 | 136 | 60 | 0.76 |
| 19 | 0.10 | 153 | 70 | 1.05 |
| 20 | 0.10 | 170 | 80 | 0.85 |
| 21 | 0.12 | 102 | 100 | 1.14 |
| 22 | 0.12 | 119 | 60 | 0.83 |
| 23 | 0.12 | 136 | 70 | 1.23 |
| 24 | 0.12 | 153 | 80 | 0.54 |
| 25 | 0.12 | 170 | 90 | 1.65 |

**(B) Response table for signal to noise ratios smaller is better**

| Level | d | $V_c$ | F | |
|---|---|---|---|---|
| 1 | 1.92591 | -2.84022 | -3.11380 | |
| 2 | 0.95745 | 1.26848 | 3.35843 | |
| 3 | -1.47755 | 2.23819 | 3.84810 | |
| 4 | -1.52682 | -0.47835 | -1.44335 | |
| 5 | -0.05099 | -0.36011 | -2.82137 | |
| Delta | 3.45273 | 5.07840 | 6.96190 | 15.49303 |
| Rank | 3 | 2 | 1 | |
| Effect | 21% | 38% | 41% | |

*IV. Concave Feature*

At concave feature with the average diameter is 35mm. Therefore, cutting speed between 132 m/min to 220 m/min with five-level. Best surface roughness is 0.23 µm at depth of cut 0.08 mm, feed-rate 70 mm/min and cutting speed 220. The best cutting parameters as shown in Table 7 depth of cut 0.04 mm, feed-rate 70 mm/min and cutting speed 220m/min.

**Tables 7: Data and result of concave feature (A) Experimental result for concave feature**

| | d (mm) | Vc (m/min) | F (mm/min) | Ra (µm) |
|---|---|---|---|---|
| 1 | 0.04 | 132 | 60 | 0.75 |
| 2 | 0.04 | 154 | 70 | 0.36 |
| 3 | 0.04 | 176 | 80 | 0.39 |
| 4 | 0.04 | 198 | 90 | 0.35 |
| 5 | 0.04 | 220 | 100 | 0.60 |
| 6 | 0.06 | 132 | 70 | 0.45 |
| 7 | 0.06 | 154 | 80 | 0.35 |
| 8 | 0.06 | 176 | 90 | 0.40 |
| 9 | 0.06 | 198 | 100 | 1.18 |
| 10 | 0.06 | 220 | 60 | 0.75 |
| 11 | 0.08 | 132 | 80 | 1.40 |
| 12 | 0.08 | 154 | 90 | 1.50 |
| 13 | 0.08 | 176 | 100 | 0.81 |
| 14 | 0.08 | 198 | 60 | 0.82 |
| 15 | 0.08 | 220 | 70 | 0.23 |
| 16 | 0.10 | 132 | 90 | 0.61 |
| 17 | 0.10 | 154 | 100 | 1.23 |
| 18 | 0.10 | 176 | 60 | 0.93 |
| 19 | 0.10 | 198 | 70 | 0.86 |
| 20 | 0.10 | 220 | 80 | 0.83 |
| 21 | 0.12 | 132 | 100 | 0.59 |
| 22 | 0.12 | 154 | 60 | 1.35 |
| 23 | 0.12 | 176 | 70 | 1.43 |
| 24 | 0.12 | 198 | 80 | 0.51 |
| 25 | 0.12 | 220 | 90 | 1.20 |

**(B) Response table for signal to noise ratios smaller is better**

| Level | d (mm) | $V_c$ (m/min) | F (mm/min) | Sum |
|---|---|---|---|---|
| 1 | 6.6214 | 3.0777 | 0.9490 | |
| 2 | 5.0149 | 2.0132 | 5.3557 | |
| 3 | 1.9750 | 3.0983 | 4.3684 | |
| 4 | 1.2108 | 3.3127 | 3.2531 | |
| 5 | 0.6269 | 3.9472 | 1.5229 | |
| Delta | 5.9945 | 1.9340 | 4.4067 | 12.3352 |
| Rank | 1 | 3 | 2 | |
| | 48% | 16% | 36% | |

## 4. Regression Model

This paper uses a mathematical multiple non-linear regression model to predict surface roughness in the machining of aluminum alloys, which is used to assess the association between the indicator parameter and the mixture of the expected variables. It can be used to analyze data from any significant quantitative research method, such as basic empirical, correctional and laboratory projects. This model is also able to handle interval ordinal or categorical data and provides estimates both of the magnitude and statistical significance of the relationships between variables [12]. Therefore, multiple regression analysis will be helpful to predict the criterion variable finish surface roughness via predictor variables, such as spindle speed, feed, and depth of cut.

$$Ra = X_1 + X_2 d + X_3 V_c + X_4 F - X_5 d^2 + X_6 V_c^2 + X_7 F^2 + X_8 d * V_c - X_9 d * f + X_{10} f * V_c \quad (3)$$

Where Ra is the estimated response and d, Vc, and F is the depth of cut, cutting speed, and feed rate, because these are the controllable machining parameters. They can be used to predict the surface roughness which will influence the product quality, where the coefficients X1, X2, X3--------X10 are to be estimated. To test the developed model, the evaluation is used to investigate and model the relationship between a response variable and one or more independent variables.[١٣]

The actual surface roughness profile as shown in figure 7 while predict profile as shown in Figure 8.

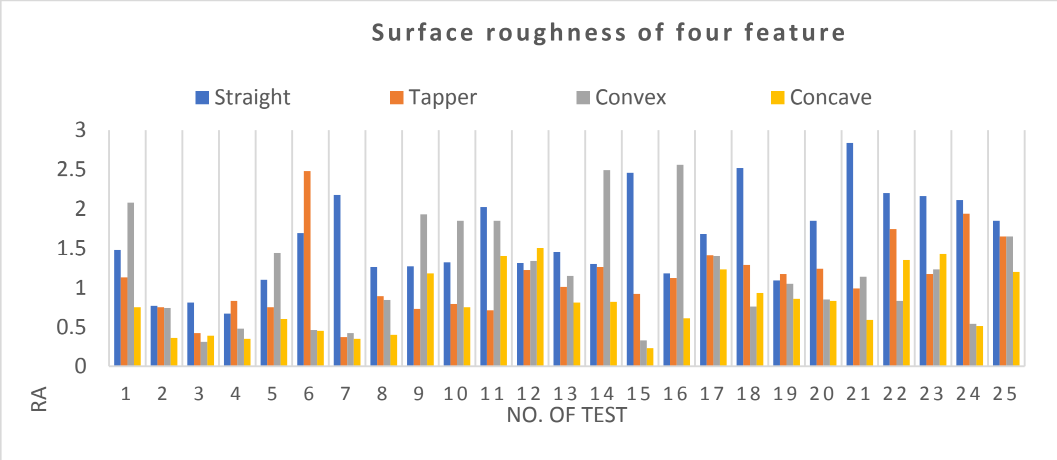


**Figure 7: Actual surface roughness of four feature**

$Ra = 8.25 + 31.2d - 0.126Vc - 0.084F + 2d^2 + 0.000638\, Vc^2 + 0.000717F^2 + 0.289dV_c - 0.498d * F$ (4) for the fit equation for Straight Feature

$Ra = 11.89 - 17.0\, d - 0.1472Vc - 0.0842F + 36d^2 + 0.000522\, Vc^2 + 0.000710F^2 - 0.376d * F + 0.518d * Vc$ (5) for the fit equation for Tapper Feature

$\mathrm{Ra} = 20.37 + 15.2\mathrm{d} - 0.1212\,\mathrm{Vc} - 0.291 * \mathrm{F} - 199\mathrm{d}^2 + 0.000409\mathrm{Vc}^2 + 0.001815\mathrm{F}^2 + 0.058\mathrm{d} * \mathrm{F} + 0.101\mathrm{d} * \mathrm{Vc}$ (6) for the fit equation for Convex Feature

$Ra = 6.72 + 23.0d - 0.0287Vc - 0.1029F - 73d^2 + 0.000037Vc^2 + 0.000873F^2 + 0.159d * Vc - 0.407d * f$ (7) for the fit equation for Concave Feature

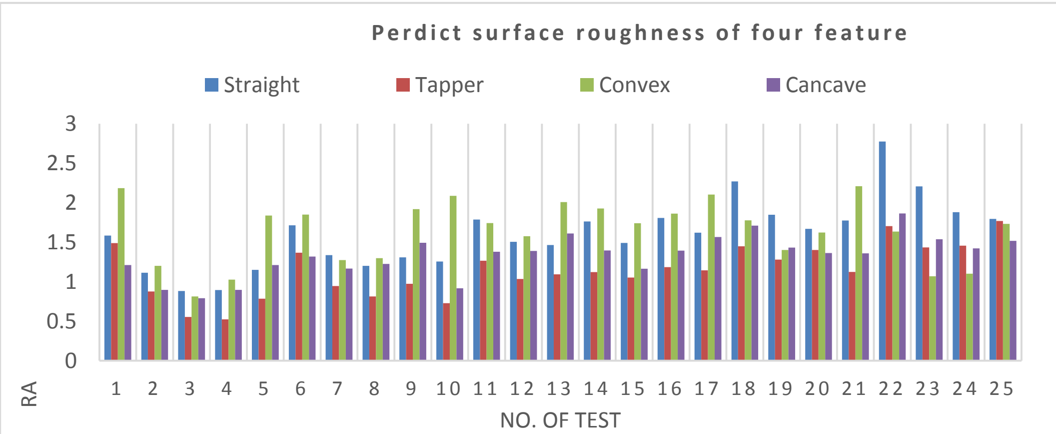


**Figure 8: Predict Surface roughness of four feature**

## 5. Evaluation

It evaluates of four equation Eqs. (4,5,6 and 7) that uses three specimen depth of cut (0.01, 0.07 and 0.15) mm and Spindle Speed 1800 rpm and feed rate 80 mm/min. The result of the measurement surface roughness of these is shown in Table 8.

**Table 8: Actual roughness surface of evaluation specimens**

| depth of | Spindle | Feed rate | Straight | Tapper | Convex | Concave |
|---|---|---|---|---|---|---|

| | cut (mm) | Speed(rpm) | (mm/min) | (Ra µm) | (Ra µm) | (Ra µm) | (Ra µm) |
|---|---|---|---|---|---|---|---|
| 1E | 0.01 | 1800 | 80 | 0.25 | 0.04 | 0.08 | 0.15 |
| 2E | 0.07 | 1800 | 80 | 1.23 | 0.76 | 1.53 | 1.22 |
| 3E | 0.15 | 1800 | 80 | 1.85 | 1.83 | 1.65 | 1.34 |

While the percentage error of each feature was calculated in this case as follows:

$$\Delta\, error = |Ra(Actual) - Ra\,(predict)| \quad (8)$$

$$\%\, error = \frac{\sum \Delta\, error}{\sum actual\, Ra} * 100\,\% \quad (9)$$

As a result of three specimens are applied to predict the equation for each feature and measure the difference between actual and predict is shown in Table 9.

**Table 9: Predict and Δ error of evaluation specimens**

| No. of Test | Predict Straight (Ra µm) | Δ Error | Predict Tapper (Ra µm) | Δ Error | Predict Convex (Ra µm) | Δ Error | Predict Concave (Ra µm) | Δ Error |
|---|---|---|---|---|---|---|---|---|
| 1E | 0.28866 | 0.0366 | 0.01103 | 0.02897 | 0.06971 | 0.05029 | 0.05506 | 0.09494 |
| 2E | 1.14972 | 0.0802 | 0.68459 | 0.07541 | 1.23209 | 0.29791 | 1.01998 | 0.20002 |
| 3E | 2.32020 | 0.4702 | 1.98587 | 0.15587 | 1.85313 | 0.20313 | 1.48894 | 0.14894 |
| % | | 3.3% | | 2.6% | | 4.3% | | 2.71% |

It is observed similar behavior of straight, taper and concave feature depth of cut approximate 50% and to surface roughness while affected in a convex decrease to 21%, while feed rate to 41% at convex feature. The effect of cutting speed of straight, taper and concave features approximate to 21% while the effect of cutting speed at convex feature is 38%.

## 6. Conclusions

In this research, CNC Lathe is used to machine aluminum alloy 1200, where that study the machining conditions on machining performances and Conclusions could be summarized as follows:

1. Surface roughness decreased when spindle speed increased. Also, the surface roughness value increased with increasing feed rate and, depth of cut. The minimum value of surface roughness is (0.23 µm) at (2000 r.p.m), (70 mm/min) and (0.8 mm) in concave feature. While maximum value is (2.84 µm) at (1200 r.p.m), (100 mm/min) and (0.12 mm) in straight feature. The surface roughness can be improved by increasing the spindle speed.
2. From the results obtained by experiment, the greatest of surface roughness (Ra) depends on the depth of cut and followed by feed rate and speed
3. The surface roughness increases as the depth of cut increases where the relation is linear while optimum feed rate and speed on between level 3,4.
4. The best surface finish has been obtained in machining concave dues to increase the cutting speed because of increase diameter.

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