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Research paper

A calculation of surface roughness depending on the axial feed rate and tool nose radius when turning the 40x steel

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Abstract

This paper presents the experimental investigation of the surface roughness in turning process of 40X steel with the different insert nose radius and different axial feed rate. By analyzing the experimental results, the appropriate formula was proposed to calculate surface roughness when turning 40X steel with different value of the insert nose radius and different axial feed rate. The most suitable regression of surface roughness was an exponential regression with the confidence level is more than 97.3 %. These formulas were successfully verified by experimental results with very promising results. In comparison of predicted results, the results from previous research, and the measured results, the results of proposed formulas gave the smallest errors (9.73 % in case insert nose radius is 0.2 mm and 1.46 % in case insert nose radius is 0.4 mm). The approach method of the present study can be applied in industrial machining to improve the surface quality in turning processes of the X40 Steel.

Keywords: *Calculating Surface Roughness; 40X Steel; CNC Turning Machine; Insert Nose Radius.*

1. Introduction

In fact, there are many factors that affect on the surface roughness in turning processes, in which two main factors that have a significant influence on surface roughness are the axial feed rate and insert nose radius. Therefore, studies about the theory calculation of surface roughness often use these two parameters (axial feed rate and insert nose radius) to build a mathematical formula [1 - 5].

Starting from practical requirements, according to the technical requirements of the mechanical part, the surface roughness requirement of difference mechanical parts is different. The problem is how to choose the cutter parameters and the axial feed rate. Thus, the studies about the prediction of the dependence of surface roughness on the axial feed rate and insert nose radius when turning processes have the high practical meaning. These studies can be applied to improve the surface quality and reduce the cost and time of testing.

The study of turning processes with different values of the axial feed rate and insert nose radius for machining the mechanical part with small surface roughness has been carried out by various experimental studies. In these studies, the relationship between surface roughness and machining parameters were built based on the experimental data.

However, the experimental research is often costly and time-consuming, it affects on the efficiency of the machining processes. In addition, the results of experimental research are usually only applicable to a few specific cases, that limits the meaning of these studies. In order to overcome the above limitations of experimental research methods, some scientists have conducted research to predict surface roughness when turning by different methods:

Application of artificial neutron network to predict surface roughness when turning is done by N.R. Abburi and U.S. Dixit [1], Baris Buldum et al [2] and Jean-Philippe Costes [3] conducted the surface spectroscopic analysis of the mechanical parts after turning, then performed Fourier transform to give a prediction surface roughness model when turning; The Adaptive Neuro-Fuzzy Inference System was applied to predict the surface roughness that was conducted by B. Sidda Reddy et al. [4]. However, the application of these method to predict the surface roughness in the production process often has many limitations, because in the units producing, the application of solutions for artificial intelligence, spectral analysis - Fourier analysis or fuzzy things are often difficult.

A number of scientists in the world have also studied to create the formulas that allow direct calculation of surface roughness of mechanical parts in each specific case: G. Boothroyd and W.A. Knight [5] proposed a formula for determining roughness as in expression (1).

$$R_a = 1000\frac{f^2}{18r\sqrt{3}} \approx 1000\frac{0.0321f^2}{r} \quad (1)$$

Where: f – is the axial feed rate, (mm /rev).
r – is the insert nose radius, (mm).

When machining with the feed rate is less than 2 times insert nose radius, J-E. Ståhl et al [6] proposed the formula (2).

$$R_a = 1000\frac{f^2}{18r\sqrt{3}} \approx 1000\frac{0.0321f^2}{r} \quad (2)$$

Groover [7] introduced the surface roughness formula as expressed in equation (3).

$$R_a \approx 1000\frac{f^2}{32.r} \quad (3)$$

Mitsubishi Material - Metalworking Solutions Company [8] Also Gave an Expression on the Relationship Between Surface Roughness and Axial Feed Rate and Insert Nose Radius when Turning as in Formula (4).

$$R_a = 1000\frac{f^2}{8.r} \quad (4)$$

Custompartnet company [9] introduced the formula (5) to calculate the surface roughness for each specific case when changing the axial feed rate or the tool nose radius.

$$R_a = 1000\frac{f_i^2}{24.r_i} \quad (5)$$

Where: f_I– is the axial feed rate, (inch /rev).
r_I– is the tool nose radius, (inch).
Thus, the relationship between surface roughness with the axial feed rate and the tool nose radius when turning has been proposed by many studies. However, the above formulas that gives the different surface roughness when applied to a specific case. To demonstrate this observation, it is assumed that the turning process with axial feed rate is 0.097 (mm/rev), insert nose radius is 0.4 (mm). By using these equation (1), (2), (3), (4), (5), the corresponding surface roughness values are 0.76; 1.89; 0.74; 2.94 and 0.98 µm.
Thus, although the formulas from (1) to (5) were used to predict surface roughness, it is possible to reduce machine adjustment time, trial machining time. It contributed to improve the efficiency of the machining process. But choosing which formula to ensure that the predicted results close to the actual value, that requires specific experimental studies to assess the suitability of each formula in each specific condition.
Above formulas that are theoretical formulas to predict the surface roughness. These formulas are depending on the geometric parameters of insert such as insert nose radius, nose angle, etc. In this paper, the experimental turning process was conduct by 40X steel on a CNC machine, then compare surface roughness by experimental and by calculated with 5 formulas above to select the most suitable model for surface roughness prediction when turning the 40X steel.

2. Experimental method

2.1. Testing machine

The experiments were carried out on Doosan Lynx 220L CNC lathe at Center for Mechanical Engineering, Hanoi University of Industry, Ha Noi city, Vietnam, (Figure 1).

Fig. 1: Testing Machine.

2.2. Experimental sample

The sample is 40X steel, hardness reaches HB = 280. The machined sample is prepared as shown in Figure 2. The turning processes was carried out on a 44 mm diameter cylinder.

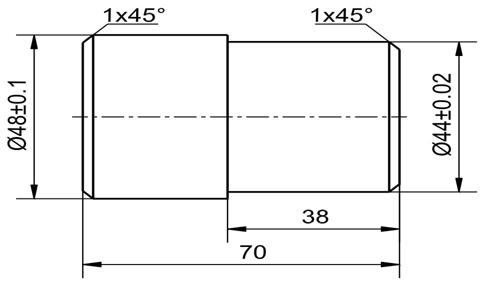

Fig. 2: Experimental Sample.

2.3. Experimental turning tool

Two types of cutting tools used in this study are the two most commonly used cutting tools, including the cutting insert with a radius of 0.2 (mm), with the symbol TNMG160402GP of KYOCERa - Japan and The cutting insert has a radius of 0.4 (mm), with the symbol TNMG160404MA - Korea.

2.4. Surface roughness tester

Surface roughness tester is TESA RUGOSURF 10 Roughness Gauge. At each value of the tool load, experiment with 03 samples, each sample was measured roughness 03 times, the value of surface roughness at each experimental point was the average value of 9 consecutive measurements.

3. Experimental results

3.1. Regression equation

Conduct experiments with the above two types of cutting pieces with the axial feed rate of each type of cutting insert selected according to the manufacturer's recommendation. Specifically, the axial feed rate values are 0.04 ÷ 0.18 (mm/rev) and 0.1 ÷ 0.4 (mm/rev) corresponding to TNMG160402GP and TNMG160404MA cutting insert.
Use the TNMG160402GP insert to machine the 40X steel with 15 different values of vertical tooling, cutting depth and cutting speed of 0.1 (mm) and 250 (m/min), respectively. The surface roughness results of each experimental are listed in Table 1.

Table 1: Experimental Results of Surface Roughness by Using an Insert Nose Radius of 0.2 mm

Run.N	f (mm/rev)	R_a(µm)	
		Predicted	Measured
1	0.04	0.54	0.59
2	0.05	0.73	0.77
3	0.06	0.95	0.95
4	0.07	1.17	1.24
5	0.08	1.41	1.51
6	0.09	1.66	1.46
7	0.1	1.92	1.66
8	0.11	2.19	1.87
9	0.12	2.48	2.26
10	0.13	2.77	2.58
11	0.14	3.07	2.74
12	0.15	3.38	3.30
13	0.16	3.69	4.20
14	0.17	4.02	4.69
15	0.18	4.35	5.15

From the data in tables 1, for a cut insert with a nose radius of 0.2 (mm), the relationship of surface roughness and axial feed rate is modeled as by equation (6) with a determination coefficient R^2 = 0.9703.

$$R_a = 47.04 f_d^{1.3886} \quad (6)$$

Use TNMG160404MA insert to machine the 40X steel with 7 different values of axial feed rate, the cutting depth and cutting speed are 0.1 (mm) and 250 (m/min), respectively. The surface roughness results of each experimental are presented in Table 2.

Table 2: Experimental Results of Surface Roughness by Using an Insert Nose Radius of 0.4 mm

Run. N	*f* (mm/rev)	R_a(µm) Predicted	Measured
1	0.1	1.00	1.00
2	0.15	2.23	2.23
3	0.2	4.03	4.03
4	0.25	6.06	6.06
5	0.3	8.76	8.76
6	0.35	11.61	11.61
7	0.4	16.05	16.05

From the data in tables 2, for a cut insert with a nose radius of 0.4 (mm), the relationship of surface roughness and axial feed rate is modeled as by equation (6) with a determination coefficient R^2 = 0.9996.

$$R_a = 95.569 f_d^{1.9798} \quad (7)$$

3.2. Verification of the surface roughness equation

Surface roughness when calculated according to the formula (1) to (5) and by proposed model are presented in Table 3 for case using an insert nose radius of 0.2 mm and presented in Table 4 for case using an insert nose radius of 0.4 mm. The calculated results of each previous research equations, proposed equations and measured results were expressed in Fig. 3 for case using an insert nose radius of 0.2 mm, and expressed in Fig. 4 for case using an insert nose radius of 0.4 mm

Table 3: Experimental and Predicted Results of Surface Roughness by Using an Insert Nose Radius of 0.2 mm

Run. N	*f* (mm/rev)	R_a(µm) Calculated Eq.(1)	Eq.(2)	Eq.(3)	Eq.(4)	Eq.(5)	Predicted	Measured
1	0.04	0.26	1.29	0.25	1.00	0.33	0.54	0.59
2	0.05	0.40	2.01	0.39	1.56	0.52	0.73	0.77
3	0.06	0.58	2.91	0.56	2.25	0.75	0.95	0.95
4	0.07	0.79	3.96	0.77	3.06	1.02	1.17	1.24
5	0.08	1.03	5.19	1.00	4.00	1.33	1.41	1.51
6	0.09	1.30	6.59	1.27	5.06	1.69	1.66	1.46
7	0.1	1.61	8.17	1.56	6.25	2.08	1.92	1.66
8	0.11	1.94	9.92	1.89	7.56	2.52	2.19	1.87
9	0.12	2.31	11.86	2.25	9.00	3.00	2.48	2.26
10	0.13	2.71	13.98	2.64	10.56	3.52	2.77	2.58
11	0.14	3.15	16.30	3.06	12.25	4.08	3.07	2.74
12	0.15	3.61	18.82	3.52	14.06	4.69	3.38	3.30
13	0.16	4.11	21.55	4.00	16.00	5.33	3.69	4.20
14	0.17	4.64	24.49	4.52	18.06	6.02	4.02	4.69
15	0.18	5.20	27.66	5.06	20.25	6.75	4.35	5.15
Average different (%)		17.63	348.48	18.07	239.19	29.97	9.73	0.00

Figure 3 shows the comparison of the value of striation when experimenting with TNMG160402GP knife.

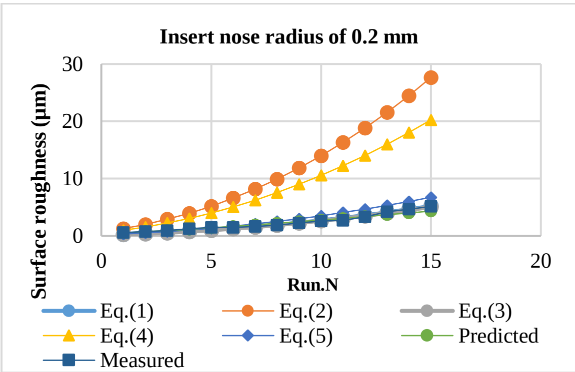

Fig. 3: Experimental and Calculated Surface Roughness by Using an Insert Nose Radius of 0.2 mm.

For case using an insert nose radius of 0.2 mm.
The comparison and verification results of surface roughness model were described in Fig. 3. It is very clear from this figure that the surface roughness increase with increasing of axial feed rate and the predicted results of proposed models were very close to the experimental results. Besides, the different value between proposed equation and experimental is the smallest (9.73 %). So, one of the most suitable regressions of surface roughness was an exponential regression as given in Eq. 6. These results showed that the exponential regression model was shown to be successfully investigated of surface roughness in turning processes of 40X steel.

Table 4: Experimental and Predicted Results of Surface Roughness Using an Insert Nose Radius of 0.4 mm

Run. N	*f* (mm/rev)	R_a(µm) Calculated Eq.(1)	Eq.(2)	Eq.(3)	Eq.(4)	Eq.(5)	Predicted	Measured
1	0.1	0.80	2.01	0.78	3.13	1.04	1.00	1.00
2	0.15	1.81	4.56	1.76	7.03	2.34	2.23	2.23
3	0.2	3.21	8.17	3.13	12.50	4.17	4.03	4.03
4	0.25	5.02	12.90	4.88	19.53	6.51	6.06	6.06
5	0.3	7.22	18.82	7.03	28.13	9.38	8.76	8.76
6	0.35	9.83	26.05	9.57	38.28	12.76	11.61	11.61
7	0.4	12.84	34.70	12.50	50.00	16.67	16.05	16.05
Average different (%)		18.46	110.93	20.62	217.58	5.81	1.46	0.00

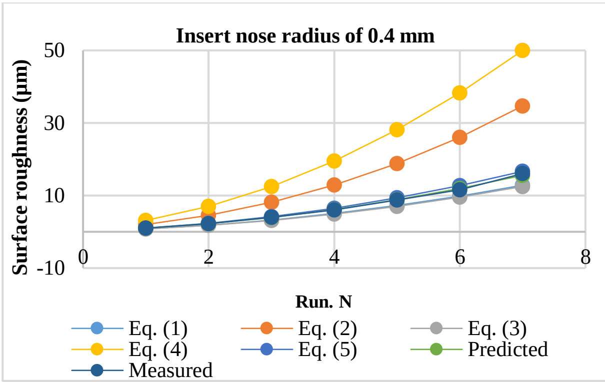

Fig. 4: Experimental and Calculated Surface Roughness by Using an Insert Nose Radius of 0.4 mm.

For case using an insert nose radius of 0.4 mm.
The comparison and verification results of surface roughness model were described in Fig. 4. It is very clear from this figure that the surface roughness increase with increasing of axial feed rate and the predicted results of proposed models were very close to the experimental results. Besides, the different value between proposed equation and experimental is the smallest (1.46 %). So, one of the most suitable regressions of surface roughness was an exponential regression as given in Eq. 7. These results showed that the exponential regression model was shown to be successfully investigated of surface roughness in turning processes of 40X steel.

4. Conclusions

This study was selected the suitable formulas to predict the surfaces roughness when turning 40X steel on CNC lathes. One of the most suitable regressions of surface roughness was an exponential regression as given in Eq. 6 and Eq. 7. The surface roughness decreases with decreasing of axial feed rate.
When machining the 40X steel by turning method, with a tool with an insert nose radius of 0.2 (mm) use the formula (1) or (3) to calculate the surface roughness; Use formula (2) to calculate the surface roughness when using an insert nose radius of 0.4 (mm). Besides, formulas (6) and (7) can be used to calculated the surface roughness for the two corresponding cases of the insert nose radius of 0.2 (mm) and 0.4 (mm).

These equations can be used to predict the surface roughness when turning the 40X steel to reduce machine adjustment time, test machining time, and contributing to improving the economic and technical efficiency of the machining processes.

References

[1] N.R. Abburi and U.S. Dixit (2006), A knowledge-based system for the prediction of surface roughness in turning process. *Robotics and Computer-Integrated Manufacturing 22*, 363–372. https://doi.org/10.1016/j.rcim.2005.08.002.

[2] Baris Buldum, Aydın ŞIK, Ali Akdagli and Mustafa Berkan Biçer (2017), ANN surface roughness prediction of AZ91D magnesium alloys in the turning process. *Materials Testing 59*, 916-920. https://doi.org/10.3139/120.111088.

[3] Jean-Philippe Costes (2013), A predictive surface profle model for turning based on spectral analysis. *Journal of Materials Processing Technology, Elsevier, 213, Issue 1,* 94-100. https://doi.org/10.1016/j.jmatprotec.2012.08.009.

[4] B. Sidda Reddy, J. Suresh Kumar, K. Vijaya Kumar Reddy (2009), Prediction of Surface Roughness in Turning Using Adaptive Neuro-Fuzzy Inference System. *Jordan Journal of Mechanical and Industrial Engineering, Volume 3, Number 4,* 252 – 259.

[5] G. Boothroyd and W.A. Knight (1989), Fundamental of Machining and Machine Tool. *Marcel Dekker*, New York.

[6] J-E. Ståhl, F. Schultheiss, and S. Hägglund (2011), Analytical and Experimental Determination of the R_a Surface Roughness during Turning. *Procedia Engineering 19*, 349 – 356. https://doi.org/10.1016/j.proeng.2011.11.124.

[7] Groover, M. P (1996), Fundamentals of Modern Manufacturing. *Prentice Hall*, Upper Saddle River, NJ.

[8] http://www.mitsubishicarbide.com/en.

[9] https://www.custompartnet.com/.