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A Study on Prediction of Surface Roughness in a Milling Process

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***Abstract*—This paper presents a study of the prediction of surface roughness in a milling process. On the basis of inheriting theoretical studies of the milling process, this study has built a model for predicting the surface roughness of a workpiece when surface milling using a face milling tool. The accuracy of the model has been assessed through the comparison of roughness when calculating and testing milling 40Cr steel. The results showed that the roughness value when calculating is very close to that when testing, with an average deviation of only about 0.077µm.**

Keywords—40Cr steel; roughness model; surface milling using a face milling tool.

I. Introduction

Surface milling with a face milling tool is a machining method for high productivity and precision, which is increasingly popular in mechanical processing. When evaluating the efficiency of surface machining using a face milling tool, surface roughness is often chosen as one of the first criteria. It's because the surface roughness of workpieces has a great effect on the workability and durability of the products. To have a basis for selecting the parameters of the process and control of the technological system in order to workpiece surfaces with small roughness, many studies have been done by scientists with different methods. Among them, the study direction most conducted by scientists is empirical study to determine the effect of machining process parameters on surface roughness, such as studies of Khleif et al. [1]; Ali Riza Motorcu et al. [2]; Duong Xuan-Truong et al. [3], Pathak et al. [4]; Sredanović et al. [5]; etc. However, the experimental study process is often costly and time-consuming, which affects the efficiency of the machining process. On the other hand, the results of empirical studies are only applicable to a few specific cases. In order to overcome the above limitations of the experimental study method, a number of scientific studies were also conducted by the theoretical method to build the surface roughness model, namely: Rui Wang et al. [6] developed a surface roughness model for the case where a triangular section is used; Patricia Mu˜noz-Escalona et al. [7] developed a surface roughness model for the case of using a square piece; Jie Gu et al. [8] developed a surface roughness model with worn inserts, etc. This paper will inherit theoretical studies on the process of surface milling using a face milling tool to build surface roughness model.

II. Development Of A Surface Roughness Model

In order to control the surface roughness of the workpiece when milling through the cutting force signal, Cus et al. [9], Yaser Hadi [10] performed the simulation of milling process according to the genetic programming (GP) method and built the surface roughness model as follows:

$$R_a = 0.0254.\left(\frac{593}{293 - P_c}\right)^2 \quad (1)$$

In equation (1), Pc is the cutting force. The determination of the cutting force Pc can be done by experimental or calculation methods. In this study, the value of cutting force is performed by the calculation method, which is detailed in the study of Qin Li et al. [11]. However, to make this study clearer, the determination of Pc can be summarized through formulas from (2) to (11).

$$P_c = \sqrt{P_z^2 + P_x^2} \quad (2)$$

In which:

$$P_z = N_{fr}\,.cos\gamma + F_f^{fr}\,.sin\gamma + F_f^{ed} \quad (3)$$

$$P_x = -N_{ed} - F_f^{ed}\,.cos\gamma + N_{fr}\,.sin\gamma \quad (4)$$

With:

$$F_f^{ed} = N_{ed}\,.f \quad (5)$$

$$F_f^{fr} = N_{fr}\,.f \quad (6)$$

In equations (5) and (6): *f* is the friction coefficient between the cutting tool and the surface of machined workpiece, γ is the rake angle of the cutting tool. The components N_{ed} and N_{fr} are determined using the following equations:

$$N_{ed} = \sigma_{el}\,.S_{cut} \quad (7)$$

$$N_{fr} = \sigma_{com}\,.S_{pr} \quad (8)$$

In equations (7) and (8): σ_{el} and σ_{com} are the compressive strength and bending stress of the material, respectively. The components S_{cut} and S_{pr} are determined by the following formulas:

$$S_{cut} = B\,.\,h_r \qquad (9)$$

$$S_{pr} = B\,.\,t' \qquad (10)$$

In equations (9) and (10): *B* is the width of the cutting edge, h_r is the length of wear on the back of the cutting tool. The value of t' is determined as follows:

$$t' = \frac{S_z\,.\,t}{R\,.\,sin\left[arccos\left(1-\frac{t}{R}\right)\right]} \qquad (11)$$

In equation (11): S_z is the feed rate, mm/tooth; R is the radius of cutting tool, mm; t is the depth of cut, mm.

From the equations (1) to (11), a model for determining the surface roughness of the machined workpiece will be built according to the equation (12), in which R_{factor} is included in this equation to adjust for each specific case of processing conditions. From this equation, it is possible to calculate the value of the surface roughness according to the cutting parameters, the geometric parameters of the cutting tool and parameters of some properties of the machined material.

$$\begin{cases} R_a = R_{factor}\dfrac{8932}{\left[293 - B\sqrt{M^2+N^2}\right]^2} \\ M = -\sigma_{el}.h_r(1+f.cos\gamma) + \sigma_{com}.t'.sin\gamma \\ N = \sigma_{com}.t'(cos\gamma + f.sin\gamma) + f.\sigma_{el}.h_r \\ t' = \dfrac{S_z\,.\,t}{R\,.\,sin\left[arccos\left(1-\frac{t}{R}\right)\right]} \end{cases} \qquad (12)$$

III. Comparison Of Surface Roughness Between Calculating And Experiment

Some results of experimental study on milling 40Cr using PVD-coated milling cutter by Nguyen Hong Son [12] will be used to compare the surface roughness value between the calculation result according to equation (12) and test results. The parameters used during the test will also be used during the calculation in this study as shown in Table I. Under these machining conditions, the authors had determined the correction coefficient R_{factor} =1.9953. The roughness value when calculating by formula (12) and the roughness value when testing is presented in Table II and Figure 1.

TABLE I. Parameters for determining surface roughness

Parameter	Unit	Value
v	m/min	185; 223.65; 250
t	mm	0.281; 0.4; 0. 519
R	mm	62.5
S_z	mm/tooth	0.08; 0.1; 0.13; 0.16; 0.18
B	mm	10
γ	Degree	25
h_r	mm	0 (considered in the condition of using a new cutter, not worn in the back)
σ_{el}	MPa	200
σ_{com}	MPa	400

TABLE II. Comparison of surface roughness when calculating and testing

No.	v (m/min)	S_z (mm/tooth)	t (mm)	Ra(measured) [12] (µm)	Ra(calculated) (µm)	Deviation (µm)
1	146.35	0.1	0.281	0.26	0.244	0.016
2	223.65	0.1	0.519	0.40	0.259	0.141
3	146.35	0.16	0.519	0.27	0.300	0.030
4	223.65	0.16	0.519	0.15	0.300	0.150
5	120	0.13	0.4	0.16	0.268	0.108
6	250	0.13	0.4	0.26	0.268	0.008
7	185	0.08	0.4	0.18	0.242	0.062

8	185	0.13	0.6	0.13	0.285	0.155
9	185	0.13	0.4	0.29	0.268	0.022
10	185	0.13	0.4	0.26	0.268	0.008
11	185	0.13	0.4	0.37	0.268	0.102
12	185	0.13	0.4	0.34	0.268	0.072
13	185	0.13	0.4	0.41	0.268	0.142
Mean				0.2677	0.2699	0.0770

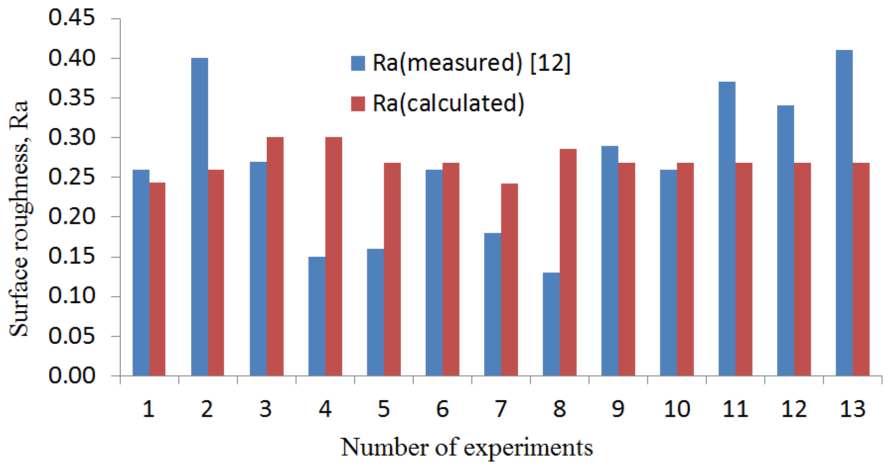

Fig. 1. *Surface roughness when testing and calculating*

Table II and Figure 1 show that the roughness value when calculating is quite consistent compared to the test. The average deviation between the calculated results and the tested results is only 0.077 µm. The largest deviation between the calculated results and the tested results is only 0.155 µm. As a result, equation (12) is perfectly suitable for prediction of the surface roughness of the workpiece.

IV. Conclusion

Based on theoretical studies of the milling process, a model of surface roughness was proposed in this study. The accuracy of the model has been verified when comparing the calculated roughness values and experimental roughness values. The results show that the roughness value when calculating is very suitable compared to the test. As a result, the surface roughness model proposed in this study is perfectly suitable to predict the surface roughness of part when milling. The use of this roughness model allows to reduce machine adjustment time, test machining time, and contribute to improving the efficiency of the milling process.

References

[1] Ali Abbar Khleif and Mostafa Adel Abdullah, “Effect of Cutting Parameters on Wear and Surface Roughness of Stainless Steel (316L) Using Milling Process,” Al-Nahrain University, College of Engineering Journal (NUCEJ) Vol.91 No.2, 6192, 2016, pp.286 – 292.

[2] Ali Riza Motorcu, Abdil Kus, Rıdvan Arslan, Yücel Tekin, Rıdvan Ezentaş, “Evaluation of tool life – tool wear in milling of 11523nconel 718 superalloy and the investigation of effects of cutting parameters on surface roughness with Taguchi method,” Tehnički vjesnik 20, 5, 2013, pp.765-774.

[3] Duong Xuan-Truong, Tran Minh-Duc, “Effect of cutting condition on tool wear and surface roughness during machining of Inconel 718,” International Journal of Advanced Engineering Technology, 2013, pp.102-112

[4] B. N. Pathak, K. L. Sahoo, and Madhawanand Mishra, “Effect of Machining Parameters on Cutting Forces and Surface Roughness in Al-(1-2) Fe-1V-1Si Alloys,” Materials and Manufacturing Processes, No. 28, 2013, pp. 463–469.

[5] B. Sredanović, G. Globočki-Lakić, D. Kramar, F. Pušavec, “Influence of Workpiece Hardness on Tool Wear in Profile Micro-milling of Hardened Tool Steel,” Tribology in Industry, Vol. 40, No. 1, 2018, pp. 100-107, DOI: 10.24874/ti.2018.40.01.09

[6] Rui Wang, Bingxu Wang, Gary C. Barber, Jie Gu and J.David Schall, “Models for Prediction of Surface Roughness in a FaceMilling Process Using Triangular Inserts,” lubricants, Vol. 9. No. 7, 2019, doi:10.3390/lubricants7010009

[7] Patricia Mu˜noz-Escalona, Paul G. Maropoulos, “A geometrical model for surface roughness prediction when facemilling Al 7075-T7351 with square insert tools,” Journal of Manufacturing

Systems, 2014, http://dx.doi.org/10.1016/j.jmsy.2014.06.011

[8] Jie Gu , Gary C. Barber , Qinyu Jiang & Simon Tung, "Surface Roughness Model for Worn Inserts of Face Milling: Part I — Factors that Affect Arithmetic Surface Roughness," Tribology Transactions, Vol. 44, No. 1,2008, pp. 47-52

[9] F. Cus, U. Zuperl, "Model reference-based machining force and surface roughness control," Journal of Achievements in Materials and Manufacturing Engineering, Vol. 9. No. 2, 2008, pp.115-122

[10] Yaser Hadi, "Prediction of Surface Roughness for Periodic End Mill Tool Holder," Applied Mechanics and Materials, Vol. 330, 2013, pp. 262-268

[11] Qin Li, Jiao Li, Chen Hao, Qian Yu-Bo, "Study on Prediction the Cutting Force of the Face Milling," International Conerence on inormation, Networking and Automation (iCiNA), Vol. 2, 2010, pp. 403-407.

[12] Nguyen Hong Son, "Effect of Cutting Parameters on Cutting Force and Surface Roughness of Workpiece When Milling 40Cr Steel Using PVD-Coated Cutter," International Journal of Science and Engineering Investigations, Vol. 9, No. 96, 2020, pp.13-18.