Predicting the surface roughness of workpiece in external plunge centerless grinding process

Dự đoán độ nhám của bề mặt chi tiết khi gia công mặt trụ ngoài bằng phương pháp mài vô tâm chạy dao hướng kính

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Abstract

This paper introduces a study on predicting the surface roughness in external plunge centerless grinding. In this study, based on the theory of external plunge grinding, we investigated the relationship between the surface roughness and the grinding process parameters, including the grinding wheel parameters, the workpiece parameters etc. The results show that the value of surface roughness in external plunge centerless grinding are in agreement with the experimental data. Therefore, they can be used for the prediction of the surface roughness in practice.

Keywords:

External plunge grinding; Surface roughness; Prediction; Grinding parameter

Tóm tắt

Bài báo này giới thiệu một nghiên cứu về dự đoán giá trị độ nhám khi mài vô tâm bề mặt trụ ngoài. Trong nghiên cứu này, dựa trên cơ sở lý thuyết của mài vô tâm ngoài, mối quan hệ giữa các thông số của quá trình mài vô tâm với độ nhám bề mặt gia công đã được khảo sát. Các thông số này gồm có thông số của đá mài, các thông số của chi tiết gia công... Kết quả nghiên cứu cho thấy các giá trị độ nhám bề mặt gia công khi mài vô tâm khá phù hợp với các giá trị độ nhám bề mặt xác định bằng thực nghiệm. Vì thế cho nên các kết quả của nghiên cứu này có thể dùng để dự đoán độ nhám bề mặt khi mài trong thực tế.

Từ khóa:

Mài vô tâm bề mặt ngoài; Nhám bề mặt; Dự đoán; Thông số mài

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1. INTRODUCTION

Among mechanical machining methods, external plunge centerless grinding is a popular method which brings more productivity in comparison with centered grinding since it spends less time for work-holding and dismantle. Moreover, the stability of the centerless grinder is higher than that of the centered grinder [1].

Like other machining methods, the quality of the surface finished by external plunge centerless grinding is evaluated using many parameters. Of which, the surface roughness is the most important. In practice, the surface roughness of a machining process as well as of an external plunge centerless grinding depends on many factors such as the cutting or grinding parameters, the dressing parameters, the cooling and lubrication and so on. Therefore, simulating the external plunge centerless grinding process to predict the surface roughness in particular cases will help to reduce the time for determining the optimum or reasonable grinding parameters. It can also lead to the cost reduction and the enhancement of the product quality [1, 2].

In the empirical method, surface roughness models (as in [2-8]) are normally developed as a function of machining conditions. Although the determination of empirical models is not complicated but the use of them are usually connected with fixed process conditions. As a results, the scope of empirical models is limited.

In this paper, based on the theory of the grinding process, the relationship between surface roughness in external plunge centerless grinding and the grinding process parameters grinding including the wheel velocity, the workpiece velocity, the depth of cut, the wheel diameter etc. are investigated. Moreover, a model for prediction of the surface roughness when external plunge centerless grinding is proposed. Also, the surface roughness results calculated by the model are in agreement with the experimental data.

2. ESTABLISMENT OF SURFACE ROUGHNESS EQUATION

From analyzing of chip forming in grinding, Hecker et at. proposed the surface roughness equation [9]:

$$R_a = R_{factor}.0.37.h_m \tag{1}$$

Where, h_m is maximum of underformed chip thickness; R_{factor} is necessary to adjust the empirical values to the analytical expression obtained in Eq. (1); R_{factor} = 0.87 [9].

The existing chip thickness can be predicted as follows [10]:

$$h_m = 2\sqrt{\frac{1}{Nr}\frac{v_w}{v_G}\sqrt{\frac{t}{d_e}}} \tag{2}$$

In which,

v_w is workpiece velocity. If ignoring the slip between control wheel and workpiece, the wheel velocity can be control as the workpiece velocity: $v_W = v_C$; with v_C is control wheel velocity;

v_G is grinding wheel velocity.

t is depth of cut.

d_e is equivalent wheel diameter; d_e is determined by:

$$\frac{1}{d_e} = \frac{1}{d_G} + \frac{1}{d_W} \tag{3}$$

Where, d_G, d_C and d_w are the grinding wheel diameter, the control wheel diameter and the workpiece diameter respectively.

r is the ratio of the chip width to the thickness; In practice, it is difficult to determine the value of r and it is assumed in the range of 10-20 [11]. In this work r was assumed to be equal to 20 as in [12].

N is the number of active grits per unit area; it can be predicted by the following equation [13]:

$$N = 4f\frac{1}{d_g^2}\frac{1}{\sqrt[3]{\left(\frac{4\pi}{3\epsilon}\right)^2}} \quad (4)$$

Where,

f is the fraction of diamond particles involved in active grinding process; It is assumed that only one half of diamond particles are engaged in cutting and $f = 0.5$ [14];

d_g is the equivalent spherical diameter of diamond grit; d_g is calculated by [1]:

$$d_g = 15.2/M \quad (5)$$

In which, M is the mesh number used in the grading sieve; ϵ is volume fraction of diamond in grinding wheel. In this study, the grinding wheels have a concentration of 80, or volume fraction $\epsilon = 0.2$ [15].

Substituting the equations (2), (3), (4), (5), (5) into (6) and after mathematical simplification, the value of the surface roughness can be determined by:

$$R_a = 4{,}7038.\frac{1}{\mathrm{M}}.t^{1/4}.\left(\frac{1}{f.r}\right)^{1/2}.\left(\frac{v_W}{v_G}\right)^{1/2}\left(\frac{4\pi}{3\epsilon}\right)^{1/3}.\left(\frac{d_G.d_W}{d_G+d_W}\right)^{1/4} \quad (6)$$

3. RESULTS AND DISCUSSION

For evaluation of equation (6), the values of surface roughness of experimental and the values of the surface roughness which were predicted by the equation were compared. The experimental values were found in [16] and they using the same in-put parameters in seven values of workpiece velocity (seven values of control wheel speed) with calculated values.

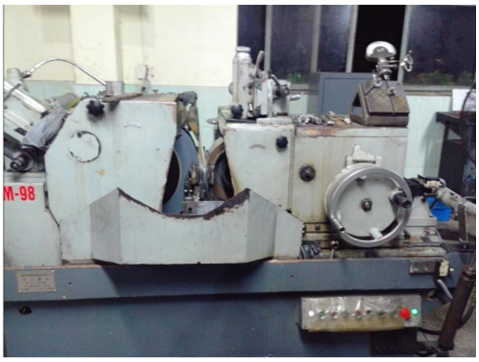

Fig 1. M1080B external centerless grinder

The values of grinding process parameters as below:

- Centerless grinder: M1080B (figure 1);
- Grinding wheel: Cn80.TB$_1$.G.V$_1$.500.150.305x35m/s
- Control wheel: R.273.150.127; 22/27/32/37/42/47 and 52 (rev/min) in speed;
- Workpiece: 30 (mm) in diameter; 130 (mm) in length;
- Grinding allowance: 0,05 (mm);
- Plunge feed-rate: 10 (μm/s).

The experimental (R_a) and calculated (R_a^*) values of the surface roughness were shown in Table 1 and Figure 2. From these values it is clear that there is an agreement between R_a and R_a^*. The maximum different between them is 11.5% and the average different between them is 8.3%.

Also, the value of the surface roughness will be increased if the value of the workpiece velocity are increased.

Table 1. Experimental and calculated values of the surface roughness

Runs	$v_w(m/min)$	R_a (μm) [16]	R_a^* (μm)	% Error
1	18.9	0.40	0.44	3.71%
2	23.2	0.42	0.48	5.89%
3	27.4	0.43	0.52	8.19%
4	31.7	0.45	0.56	9.20%
5	36.0	0.48	0.60	9.17%
6	40.3	0.49	0.64	10.45%
7	44.6	0.50	0.67	11.50%

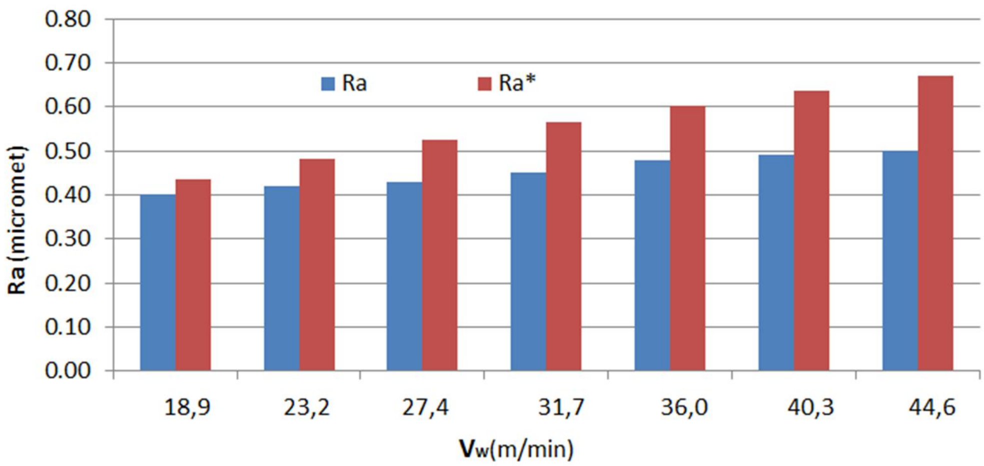

Fig 2. The workpiece velocity versus the surface roughness

4. CONCLUSIONS

Based on the theory of grinding process, a model for prediction of the surface roughness when external plunge centerless grinding was proposed. In the model the relations between the surface roughness and many grinding process parameters such as the grinding wheel parameters, the workpiece parameters and so on was taken into account.

The calculated result values of the surface roughness when using the model are in agreement with the experimental values. As a result, the model can be used for determining the surface roughness in practice.

By using this explicit model, the surface roughness when external plunge centerless grinding can be found accuracy and simply.

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