

The Research of PCD Tool Sharpening Process Parameters Based On Uniform Design

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Abstract-The grinding process parameters and grinding quality of PCD tool is an area still full of questions to be resolved. This paper bases on the uniform test method, process parameters of PCD tool sharpening are seen as the level factors, thus in different conditions of level factors have carried on actual grinding experiments for many times, getting a lot of grinding data; regression analysis this data and the establishment of regression mathematics model, obtaining the regression equation and the regression equation is for F-test, the reliability of the models is proved.

Keywords: uniform design; PCD cutting tool; regression analysis; grinding

I. INTRODUCTION

With the emergence of difficult-to-machine materials, the traditional tool material is increasingly difficult to meet the needs of the processing. In recent years, due to the good physical and chemical properties of super-hard material polycrystalline diamond (PCD), which has been widely used in the tools, cutting speed is one order of magnitude higher than the carbide, the tool life has also greatly improved[1-3]. Based on economic considerations, currently the most widely used PCD tool sharpening method is the PCD grinding wheel grinding PCD cutting tools. Because their hardness is close, making PCD cutting tool is more difficult compared to other materials, is not easy to get stable grinding quality[4-6]. The previous have done a lot of research about the PCD tool on the removal rate and wear ratio, and make great achievements, however, the grinding process parameters and grinding quality lacks of research.

This paper bases on the uniform design tools for PCD cutting process parameters, establishing the regression model, and F test to verify the reliability of the

model[7-8], then what is can provide imitate and guidance for improve sharpening quality about the PCD grinding wheel grinding PCD cutting tools on the actual production.

II. EXPERIMENT DESIGNS

A. Experimental design method

This article chooses uniform experimental design method to design, and divide into the following steps: First according to the need to examine the objective function, determining test indicators. Second combining actual production experience and relevant professional knowledge select test factors. Third according to the test conditions and experience to select the range of experiment factors divide the test level. Fourth designing uniform design table, arranging factor and level. Last determine the experimental program for test[9].

B. Experimental design

- 1) Test method: uniform test method.
- 2) Test equipment: PCD/CBN special grinder, diamond grinding wheel, PCD blade.
- 3) Objective function: flank surface roughness, grinding depth, edge serrated degree and edge radius.
- 4) Test factors: grinding wheel granularity (qualitative), grinding wheel concentration, grinding speed, grinding pressure, swing frequency.

In the arrangement of the above test factors and test indicators, testing with qualitative factors should be used mixed-level test. Since there is no ready-made uniform design table for choosing, this paper uses uniform design software version 5.0 operation to randomly generate uniform design table U15 (15x5x5x3x3), using to arrange experiments. In order to ensure the accuracy of the test data,

test is arranged under the same test parameters of two blades, each blade tests two times, the average value of the four times' measurements is seen as the grinding depth.

Arranged test table is shown in table I , the corresponding test level of each factor is shown in table II .

TABLE I : U15 (15 ×5 ×5 ×3 ×3) ARRANGEMENT OF UNIFORM EXPERIMENT

Speed (r/min)	Pressure (MP)	Frequency (times/min)	Concentration (%)	Wheel granularity
1200	0.48	20	125	W10
2200	0.12	40	100	W10
1600	0.48	50	75	W5
1800	0.36	30	100	W5
2400	0.24	30	75	W20
2800	0.24	50	125	W20
3000	0.12	20	75	W5
2600	0.60	60	100	W10
2000	0.60	30	125	W10
3600	0.36	60	75	W10
1400	0.12	60	100	W20
3200	0.36	50	125	W5
3400	0.60	40	75	W20
3800	0.24	40	125	W5
4000	0.48	20	100	W20

TABLE II : TEST VARIOUS FACTORS ATTAINMENT TABLE

Speed (r/min)	Pressure (MP)	Frequency (times/min)	Wheel granularity	Concentration (%)
1200	0.12	20	W5	75
1400	0.24	30	W10	100
1600	0.36	40	W20	125
1800	0.48	50		
2000	0.60	60		
2200				
2400				
2600				
2800				
3000				
3200				
3400				
3600				
3800				
4000				

III. TESTS RESULTS

In the acquisition process of test results, grinding depth measures by the micrometer, before and after the test, measuring the width of the blade, the difference between the two measurements is the grinding depth, the same set of

data tests two times for "A" blade, taking average value of the two times' measurement as m, similarly measuring average value of "B" blade's grinding depth takes it as n, entering the average value of m and n in the table. Measuring the edge serrated degree and the edge radius

need special equipment, it adopts MikroCAD system as testing equipment which is imported from the German GFM company, it can measure the edge of blade quickly, including the edge serrated degree, edge radius, etc. Since the measurement of surface roughness is more difficult after PCD tool grinding, the surface roughness measuring equipment of this experiment test which measures the flank blade is called SURFCOM 480 type, which is imported



Figure 1. Sets measuring parameter

from Japan. Putting the blade on workbench, mobilizing the position of the probe, and finally makes the probe contact with the blade flank, according to the need to set length which is measured, the test selects 4 mm, measurement of speed can also be set, as shown in figure 1, clicking on the screen of the start measuring button, it can determine the surface roughness as shown in figure 2, testing two periods of each blade, taking the average recorded.

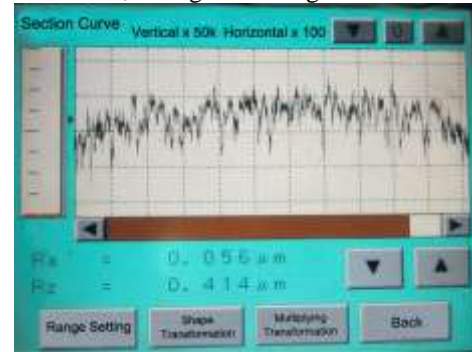


Figure 2. Surface roughness Ra、Rz

According to the test and finally get this trial data such as shown in table III

TABLE III: EXPERIMENTAL RESULTS

Speed (r/min)	Pressure (MP)	Frequency (time/min)	Concentration (%)	Serrated degrees (μm)
1200	0.48	20	125	0.9
2200	0.12	40	100	0.85
1600	0.48	50	75	0.85
1800	0.36	30	100	0.8
2400	0.24	30	75	1.0
2800	0.24	50	125	0.8
3000	0.12	20	75	0.8
2600	0.60	60	100	0.85
2000	0.60	30	125	0.9
3600	0.36	60	75	0.85
1400	0.12	60	100	0.8
3200	0.36	50	125	0.85
3400	0.60	40	75	1.0
3800	0.24	40	125	0.9
4000	0.48	20	100	0.85

IV. THE TEST DATA REGRESSION ANALYSIS AND INSPET

In order to establish the regression equation, the independent and dependent variables must be parameterized, qualitative factors “A” has three states (and level), namely $A1 = W5 = (1, 0)$, $A2 = W10 = (0, 1)$, $A3 = W20 = (0, 0)$. So put the qualitative factors A into three virtual variables. Obviously, only two of the three pseudo variables are

linearly independent, A1 and A2.

In order to facilitate the expression, during the analysis of the process we parameter all factors and the objective function, set: $X1$ =grinding speed (r/min), $X2$ =grinding pressure (MP), $X3$ =swing frequency (time/min), $X4$ = concentration (%), $Y1$ = edge serrated degrees (μm), $Y2$ = grinding depth (mm), $Y3$ =edge radius (μm), $Y4$ =flank Ra (μm), $Y5$ =flank Rz (μm).

The regression analysis uses the uniform design software. Inputting the data of the test results; getting the results of regression analysis[10]:

TABLEIII: EXPERIMENTAL RESULTS

Grinding Depth (mm)	Edge Radius (μm)	R_a (μm)	R_z (μm)	Wheel Granularity
0.068	8.0	0.058	0.52	W10
0.062	6.7	0.061	0.45	W10
0.030	5.2	0.056	0.40	W5
0.020	5.3	0.066	0.50	W5
0.082	10.0	0.070	0.51	W20
0.085	10.2	0.068	0.45	W20
0.042	5.2	0.053	0.41	W5
0.062	7.0	0.060	0.50	W10
0.060	7.5	0.067	0.48	W10
0.048	6.4	0.065	0.54	W10
0.028	9.5	0.066	0.49	W20
0.020	5.1	0.056	0.38	W5
0.075	13.0	0.066	0.55	W20
0.030	5.5	0.053	0.42	W5
0.085	9.4	0.058	0.43	W20

$$Y_1 = 0.9183807 - 0.0044520 \cdot (X_4 - 100) - 0.0555099 \cdot A_1 + 0.0000621 \cdot (X_1 - 2600) \cdot A_1 - 1.1719349 \cdot (X_2 - 0.36) \cdot (X_2 - 0.36) - 0.0038379 \cdot (X_2 - 0.36) \cdot (X_4 - 100) - 0.0001298 \cdot (X_3 - 40) \cdot (X_3 - 40) - 0.0000160 \cdot (X_3 - 40) \cdot (X_4 - 100) + 0.0025689 \cdot (X_3 - 40) \cdot A_2 + 0.0000244 \cdot (X_4 - 100) \cdot (X_4 - 100) + 0.0025375 \cdot (X_4 - 100) \cdot A_1 + 0.0080886 \cdot (X_4 - 100) \cdot A_2$$

$$Y_2 = 0.0711081 - 0.0007586 \cdot (X_3 - 40) - 0.0538010 \cdot A_1 + 0.0117319 \cdot A_2 - 0.0000702 \cdot (X_1 - 2600) \cdot (X_2 - 0.36) - 0.0000007 \cdot (X_1 - 2600) \cdot (X_3 - 40) - 0.0000002 \cdot (X_1 - 2600) \cdot (X_4 - 100) - 0.2505032 \cdot (X_2 - 0.36) \cdot (X_2 - 0.36) + 0.0019250 \cdot (X_2 - 0.36) \cdot (X_3 - 40) - 0.0031935 \cdot (X_2 - 0.36) \cdot (X_4 - 100) + 0.0381155 \cdot (X_2 - 0.36) \cdot A_1 + 0.0000409 \cdot (X_3 - 40) \cdot (X_4 - 100) + 0.0000129 \cdot (X_4 - 100) \cdot (X_4 - 100)$$

$$Y_3 = 10.2096945 + 3.6146872 \cdot (X_2 - 0.36) - 5.2773689 \cdot A_1 - 4.9367953 \cdot A_2 + 0.0000580 \cdot (X_1 - 2600) \cdot (X_3 - 40) + 27.1160919 \cdot (X_2 - 0.36) \cdot (X_2 - 0.36) - 0.0596402 \cdot (X_2 - 0.36) \cdot (X_4 - 100) - 3.2528083 \cdot (X_2 - 0.36) \cdot A_1 - 3.0608562 \cdot (X_2 - 0.36) \cdot A_2 - 0.0007716 \cdot (X_3 - 40) \cdot (X_4 - 100) + 0.0161044 \cdot (X_4 - 100) \cdot A_2$$

$$Y_4 = 0.0721521 - 0.0000079 \cdot (X_1 - 2600) - 0.0002987 \cdot (X_3 - 40) + 0.0001522 \cdot (X_4 - 100) - 0.0100093 \cdot A_1 - 0.0067795 \cdot A_2 - 0.0000002 \cdot (X_1 - 2600) \cdot (X_4 - 100) + 0.00000020 \cdot (X_1 - 2600) \cdot A_1 + 0.0000145 \cdot (X_1 - 2600) \cdot A_2 + 0.0002039 \cdot (X_2 - 0.36) \cdot (X_3 - 40) + 0.0072432 \cdot (X_2 - 0.36) \cdot A_2 - 0.0000216 \cdot (X_3 - 40) \cdot (X_3 - 40) + 0.0001646 \cdot (X_3 - 40) \cdot A_1 + 0.0003261 \cdot (X_3 - 40) \cdot A_2$$

$$Y_5 = 0.4731518 - 0.0010623 \cdot (X_4 - 100) - 0.0589159 \cdot A_1 + 0.0003856 \cdot (X_1 - 2600) \cdot (X_2 - 0.36) + 0.0000039 \cdot (X_1 - 2600) \cdot (X_3 - 40) + 0.0000024 \cdot (X_1 - 2600) \cdot (X_4 - 100) - 0.0020044 \cdot (X_2 - 0.36) \cdot (X_4 - 100) + 0.2543271 \cdot (X_2 - 0.36) \cdot A_2 - 0.0000914 \cdot (X_3 - 40) \cdot (X_4 - 100) - 0.0054242 \cdot (X_3 - 40) \cdot A_1 - 0.0016899 \cdot (X_3 - 40) \cdot A_2 + 0.0000169 \cdot (X_4 - 100) \cdot (X_4 - 100)$$

Using analysis of variance technology tests the regression mode:

$$F = \frac{S_R / p}{S_e / (n - p - 1)} \sim F(p, n - p - 1)$$

S_R : Regression sum of squares; S_e : residual sum of squares; P : degree of freedom of S_R ; $n - p - 1$: degree of freedom of S_e .

In a given significant level α , if $F > F_{1-\alpha}(p, n - p - 1)$ the regression model is credible.

For Y_1 (serrated degrees), according to the uniform design software, getting the analysis of variance in table IV:

TABLEIV: Y1 ANALYSIS OF VARIANCE TABLE

Variance Source	Quadratic Sum	Degree of Freedom	Mean Square	F	P
SR	0.0538	11	0.0053	3400.5830	0.000007
SE	0.0000	3	0.0000		
ST	0.0538	14			

Given the significant level of 0.05, you can check $F_{0.05}(11, 3) = 8.763$, in table 4, $F = 3400.583 > F_{0.05}(11, 3)$, so the regression equation of the Y1 regression effect is remarkable. According to the uniform design software analysis, $R^2 = 0.9999$, and the regression effect of regression equation of Y2, Y3, Y4 Y5 all are remarkable, the relationship between each independent variable is very close.

V. CONCLUSIONS

In this paper, firstly, according to the uniform designs the experiment, after many times grinding gets a large number of grinding actual data; Then using uniform design software analyzes this data and gets five independent nonlinear regression equations, which reflect the function relation between parameters and all the objectives of functions; Finally, making an analysis of variance of this regression equation (F inspection), the results show that the regression effect of the five nonlinear regression equation is remarkable, the relationship between each independent variable is very close. Therefore, the research results can provide imitate and guidance for improve sharpening quality about the PCD grinding wheel grinding PCD cutting tools on the actual production.

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