Influences Of Parameters On Surface Roughness When Cylindrical Grinding D2 Steel By CBN Grinding Wheel

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***Abstract*—This paper presents the effect of grinding parameters on surface roughness when external cylindrical grinding D2 steel using CBN grinding wheel. Three grinding parameters mentioned in this study include workpiece velocity, depth of cut, and longitudinal feed rate. The factor selected as the criterion for evaluating the grinding process is the surface roughness of the workpiece. The CBN grinding wheel, 1A1-400D-40T-2X-75HSL100N100BI, was used in this study. The experiment was conducted with 15 experiments according to the Box-Behken matrix. After analyzing experimental results, the three grinding parameters significantly affected surface roughness. The influence of the interaction between the grinding parameters on surface roughness was also analyzed in this study. This study has also built a regression model on the relationship between surface roughness and the grinding parameters with the correlation coefficient 96.67%. This is the basis for selecting and controlling the value of the grinding parameters in order to obtain the surface roughness according to specific requirements. Finally, the further research is also mentioned in this paper.**

Keywords—external cylindrical grinding, CBN grinding wheel, D2 steel, surface roughness.

1. Introduction

In machining process, external cylindrical grinding is commonly used to refine important surfaces (Stephen Malkin et al. 2008, Marinescu Loan D et al. 2006). Surface quality of external cylindrical grinding is evaluated by many parameters. In particular, surface roughness is a factor that greatly influences the working ability of elements and is often used as a criterion for evaluating the quality of grinding materials.

D2 steel is widely used to manufacture moulds and cutting tools with the outstanding advantages such as high hardness, high abrasion resistance, low quenching stress (Ashton Acton Q. 2012). The research on grinding D2 steel has been conducted by a number of researches such as study on cutting force, surface roughness and chip thickness when using minimum quantity lubrication (MQL) technology (Ming WW et al. 2007). The effect of cutting parameters on cutting force when grinding with discontinuous grinding wheel (Bobby O. P. Soepangkat et al. 2017). Evaluating the cutting ability of CBN grinding by electroplating method in Vietnam (Tran Thi Van Nga. 2017). The influence of cutting parameters on surface roughness when grinding with CBN grinding wheel (Chih Hsiang Chang et al. 2010). The influence of cutting parameters on surface roughness when grinding with CBN wheel (Nguyen Thi Phuong et al. 2017), ect.

In this paper, the experimental method is used to determine the effect of grinding parameters on surface roughness when external cylindrical grinding D2 steel using CBN grinding wheel.

2. Experiment system

Machine: using external cylindrical machine MH: M-1-00217 - TSUGAMI FANUC (figure 1).

CBN grinding wheel: 1A1-400D-40T-2X-75HSL100N100BI.

Fig. 1. Grinding machine

Experimental material is D2 steel. Before the experiment, the workpiece was machined through turning steps, heat treatment reached hardness 54-56HRC, semi-sharp grinding, and the diameter of workpiece ∅40. The chemical composition of D2 steel after heat treatment is shown in Table 1. Roughness measurement device is SJ201 Mitutoyo, Japan as shown in Fig. 2.

Fig. 2. Roughness measurement device SJ201

3. Experimental design

The experiment was conducted according to the Box-Behnken matrix, which is commonly used in experimental optimization (Nguyen Van Du et al. 2011). The value of the input parameters is suitably selected for fine grinding conditions of high hardness materials and suitable for technological capabilities of machines. Values at the three levels of the grinding parameters for experiments are shown in Table 2.

Experimental matrix of Box-Behnken for 3 experimental variables at the three levels of grinding parameters was designed by Minitab 16 software as shown in Table 3.

Table 1. Chemical composition of D2 steel

Chemical element	**C**	**Si**	**Mn**	**Cr**	**Mo**	**V**	**Al**	**Cu**
%	1.50	0.20	0.40	11.30	0.90	0.25	0.02	0.10

Table 2. Grinding parameters and their values at the three levels

Grinding parameters	**Symbol**	**Unit**	**Levels**		
			-1	0	1
Workpiece velocity, v	x_1	m/min	28	40	52
Depth of cut, t	x_2	mm	0.005	0.010	0.015
Longitudinal feed rate, f	x_3	mm/rev	5	10	15

Table 3. Experiment matrix

No.	**Levels**		
	x_1	x_2	x_3
1	-1	1	0
2	1	1	0
3	0	0	0
4	0	0	0
5	-1	0	1
6	1	0	1
7	0	1	-1
8	0	-1	1
9	0	0	0
10	-1	0	-1
11	1	0	-1
12	-1	-1	0
13	1	-1	0
14	0	-1	-1
15	0	1	1

4. Result and discussion

The experiment was carried out for D2 steel grinding test with 15 test runs as shown in Table 3. At each test run, grinding samples are performed on three samples, with each sample measuring the roughness at least 3 times. The roughness value at each experimental point is presented in Table 4.

Table 4. Results of the experiment

No.	Grinding parameters						R_a (μm)
	Levels			Values			
	x_1	x_2	x_3	v (m/min)	t (mm)	f (mm/rev)	
1	-1	1	0	28	0.015	10	1.736
2	1	1	0	52	0.015	10	2.867
3	0	0	0	40	0.010	10	1.075
4	0	0	0	40	0.010	10	1.098
5	-1	0	1	28	0.010	15	1.882
6	1	0	1	52	0.010	15	3.315
7	0	1	-1	40	0.015	5	1.131
8	0	-1	1	40	0.005	15	1.781
9	0	0	0	40	0.010	10	1.008
10	-1	0	-1	28	0.010	5	1.859
11	1	0	-1	52	0.010	5	1.658
12	-1	-1	0	28	0.005	10	0.930
13	1	-1	0	52	0.005	10	1.008
14	0	-1	-1	40	0.005	5	1.266
15	0	1	1	40	0.015	15	3.461

The ANOVA analysis results for surface roughness are presented as in Table 5.

Table 5. Results of ANOVA analysis

	df	*SS*	*MS*	*F*	*Significance F*			
Regression	9.0000	9.6021	1.0669	16.1216	0.0035			
Residual	5.0000	0.3309	0.0662					
Total	14.0000	9.9330						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.0603	0.1485	7.1391	0.0008	0.6785	1.4421	0.6785	1.4421
x1	0.3051	0.0910	3.3548	0.0202	0.0713	0.5389	0.0713	0.5389
x2	0.5263	0.0910	5.7860	0.0022	0.2924	0.7601	0.2924	0.7601
x3	0.5656	0.0910	6.2189	0.0016	0.3318	0.7994	0.3318	0.7994
x1*x2	0.2633	0.1286	2.0466	0.0961	-0.0674	0.5939	-0.0674	0.5939
x1*x3	0.4085	0.1286	3.1759	0.0247	0.0779	0.7391	0.0779	0.7391
x2*x3	0.4538	0.1286	3.5277	0.0168	0.1231	0.7844	0.1231	0.7844
x1*x1	0.4218	0.1339	3.1509	0.0254	0.0777	0.7660	0.0777	0.7660
x2*x2	0.1531	0.1339	1.1435	0.3046	-0.1911	0.4972	-0.1911	0.4972
x3*x3	0.6963	0.1339	5.2013	0.0035	0.3522	1.0405	0.3522	1.0405

The results in Table 5 show that:

All three parameters such as the workpiece velocity, depth of cut and longitudinal feed rate have a significant influence on the surface roughness as shown in Fig. 3. The value of workpiece velocity increases from 28 m/ min to 40 m/ min, the roughness of the surface is less changed. However, when the workpiece velocity increases from 40 m / min or more, the surface roughness increases rapidly. For the depth of cut, increasing the value of depth of cut will cause to rapidly increase the surface roughness. When the longitudinal feed rate increases from 5 mm/ stroke to 10 mm/ stroke, the roughness of the surface is little changed, however, if the value of longitudinal feed rate is 6mm/ stroke or higher, the surface roughness increases very quickly.

Regarding to the interaction effect between parameters, the interaction between the depth of cut and the longitudinal feed rate has the greatest impact on surface roughness. The following effect is the interaction between the workpiece velocity and the longitudinal feed rate. The interaction between the workpiece velocity and the depth of cut has little effect on surface roughness. To verify the results, it can be seen in Fig. 4, 5 and 6.

As shown in Table 5, the relationship between surface roughness and grinding parameters is expressed in the regression equations (1). From this equation, it can be easy to determine the surface roughness depending values of input parameters. This equation has a correlation coefficient R^2 = 0.9667. This coefficient is very close to 1, which proves that equation (1) has a great match compared to experimental data. This can be used to predict surface roughness. The results were compared with experimental values as shown in Fig 7.

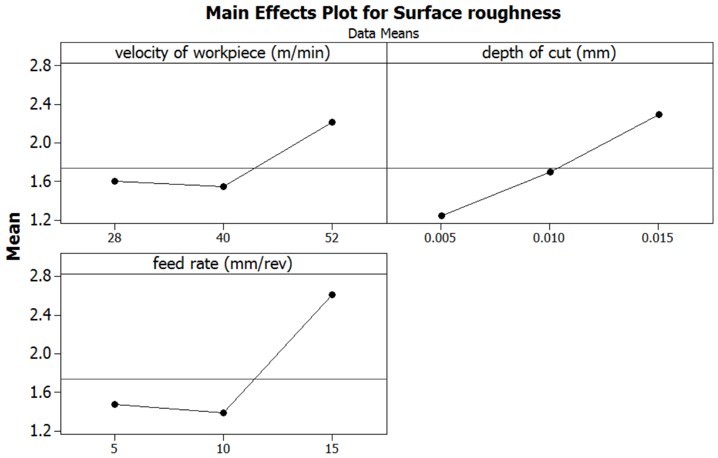

Fig 3. The effect of the grinding parameters on surface roughness

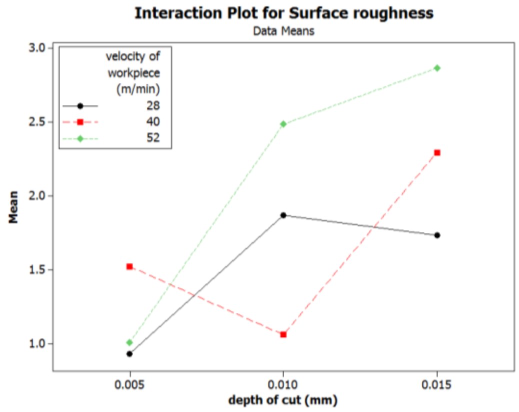

Fig 4. The effect of interaction between velocity of workpiece and depth of cut on surface roughness

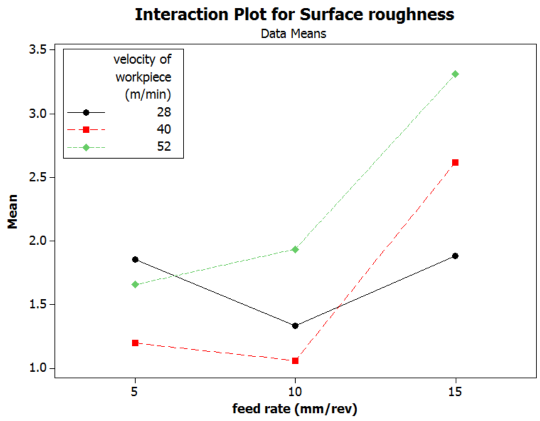

Fig 5. The effect of interaction between velocity of workpiece and feed rate on surface roughness

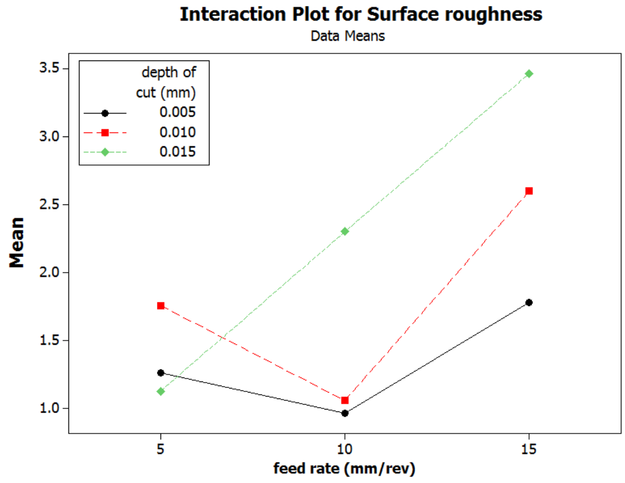

Fig 6. The effect of interaction between depth of cut and feed rate on surface roughness

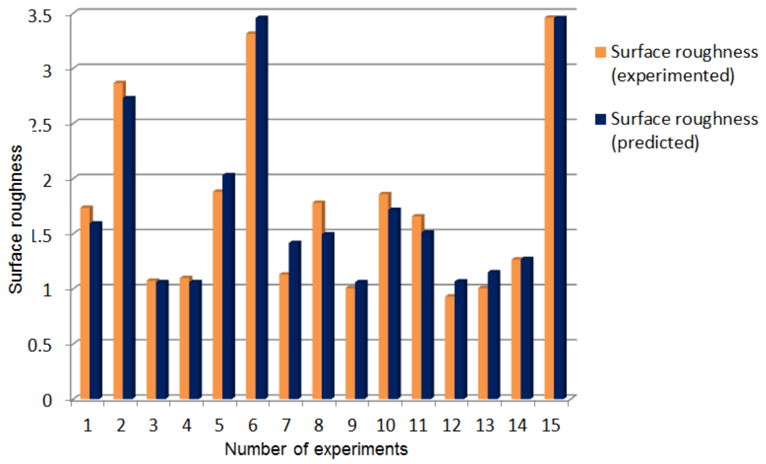

Fig. 7. Comparison between the theory as shown in Eq. (1) and the experiment

$$R_a = 1.0603 + 0.3051 \times x_1 + 0.5263 \times x_2 + 0.5656 \times x_3 + 0.2633 \times x_1 \times x_2 + 0.4085 \times x_1 \times x_3 + 0.4538 \times x_2 \times x_3 + 0.4216 \times x_1^2 + 0.1531 \times x_2^2 + 0.6963 \times x_3^2 \quad (1)$$

The observation in Fig 7 shows that the surface roughness according to equation (1) is very close to the experimental values. The average deviation between the predicted results and the experimental results is only about 8.17%. From that, the regression model presented in (1) is completely suitable for predicting surface roughness when external cylindrical grinding D2 steel by using grinding wheel 1A1-400D-40T-2X-75HSL100N100BI.

5. Conclusion

This paper proposed the effect of grinding parameters on surface roughness when external cylindrical grinding D2 steel using CBN grinding wheel. Some conclusions are drawn as follows:

1. The process of experiment for grinding D2 steel by using CBN grinding wheel was done in order to determine the influence of grinding parameters including workpiece velocity, depth of cut and longitudinal feed rate on surface roughness of workpiece. The effect of the interaction between these parameters on surface roughness was also performed. This study has also built the model to predict the surface roughness depending on grinding parameters. This is the basis for selecting the suitable value of the grinding parameters to ensure the value of surface roughness in each specific case.

2. The influence of the dressing parameters, cooling and lubrication technology on surface roughness has not been mentioned; thus determining the optimal value of these parameters for grinding process will be discussed in further studies.

Acknowledgement

The work was supported by Ha Noi university of Industry (https://www.haui.edu.vn/).

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