

Effects Of Cutting Parameters On Surface Roughness In Grinding Using Hai Duong 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 Hai Duong 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, Cn80.G.V1.TB1. 400x40x230x35 m/s 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.

Key words: external cylindrical grinding, Hai Duong 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 Hai Duong grinding wheel.

2. Experiment system

Machine: using external cylindrical machine UG-200 (figure 1).

Hai Duong grinding wheel: Cn80.G.V1.TB1. 400x40x230x35 m/s.



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 $\varnothing 30$. The chemical composition of D2 steel after heat treatment is shown in Table 1. Roughness measurement device is SJ401 Mitutoyo, Japan as shown in Fig. 2.



Fig. 2. Roughness measurement device SJ401

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
%	1.52	0.21	0.42	10.34	0.85	0.32	0.04	0.15

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

Grinding parameters	Symbol	Unit	Levels		
			-1	0	1
Workpiece velocity	A	m/min	20	35	50
Depth of cut	B	mm	0.005	0.010	0.015
Longitudinal feed rate	C	mm/rev	6	10	14

Table 3. Experiment matrix

No.	Levels		
	A	B	C
1	-1	-1	0
2	1	-1	0
3	0	0	0
4	0	0	0
5	-1	0	1
6	0	1	1
7	0	-1	1
8	0	0	0
9	0	1	-1
10	-1	1	0
11	1	1	0
12	-1	0	-1
13	1	0	-1
14	1	0	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

Test no.	Grinding parameters						R _a (μm)
	Levels			Values			
	A	B	C	A (m/min)	B (mm)	C (mm/rev)	
1	-1	-1	0	20	0.005	10	0.800
2	1	-1	0	50	0.005	10	0.867
3	0	0	0	35	0.010	10	0.925
4	0	0	0	35	0.010	10	0.944
5	-1	0	1	20	0.010	14	1.619
6	0	1	1	35	0.015	14	2.976
7	0	-1	1	35	0.005	14	1.532
8	0	0	0	35	0.010	10	0.867
9	0	1	-1	35	0.015	6	0.973
10	-1	1	0	20	0.015	10	1.493
11	1	1	0	50	0.015	10	2.466
12	-1	0	-1	20	0.010	6	1.599
13	1	0	-1	50	0.010	6	1.426
14	1	0	1	50	0.010	14	2.851
15	0	-1	-1	35	0.005	6	1.089

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

Table 5. Results of ANOVA analysis

	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Sig. F</i>			
Regression	9	7.1002	0.7889	16.1216	0.0035			
Residual	5	0.2447	0.0489					
Total	14	7.3449						
	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>	<i>Lower 95.0%</i>	<i>Upper 95.0%</i>
Intercept	0.9120	0.1277	7.1408	0.0008	0.5837	1.2403	0.5837	1.2403
A	0.2624	0.0782	3.3547	0.0202	0.0613	0.4634	0.0613	0.4634
B	0.4525	0.0782	5.7857	0.0022	0.2515	0.6535	0.2515	0.6535
C	0.4864	0.0782	6.2188	0.0016	0.2853	0.6874	0.2853	0.6874
AB	0.2265	0.1106	2.0478	0.0959	-0.0578	0.5108	-0.0578	0.5108
AC	0.3513	0.1106	3.1757	0.0247	0.0669	0.6356	0.0669	0.6356
BC	0.3900	0.1106	3.5260	0.0168	0.1057	0.6743	0.1057	0.6743
A ²	0.3629	0.1151	3.1521	0.0253	0.0669	0.6588	0.0669	0.6588
B ²	0.1316	0.1151	1.1433	0.3047	-0.1643	0.4276	-0.1643	0.4276
C ²	0.5989	0.1151	5.2021	0.0035	0.3029	0.8948	0.3029	0.8948

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 20 m/ min to 35 m/ min, the roughness of the surface is less changed. However, when the workpiece velocity increases from 35 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 6 mm/ rev to 10 mm/ rev, the roughness of the surface is little changed, however, if the value of longitudinal feed rate is 10mm/ rev 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.

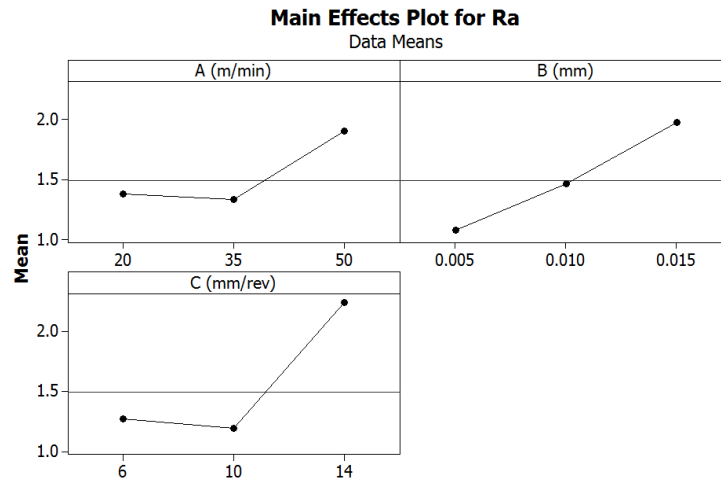


Fig 3. The effect of the grinding parameters on surface roughness

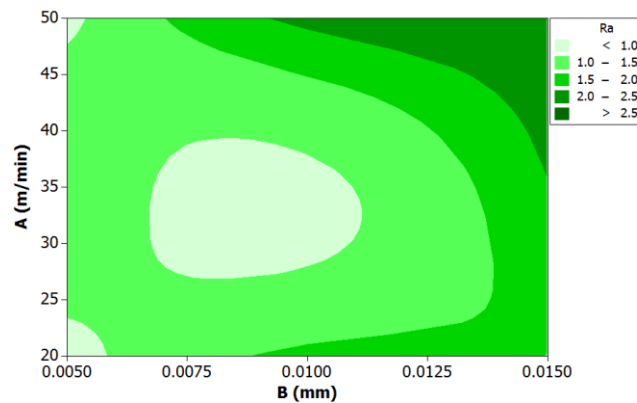


Fig 4. The effect of interaction between velocity of workpiece and depth of cut on surface roughness

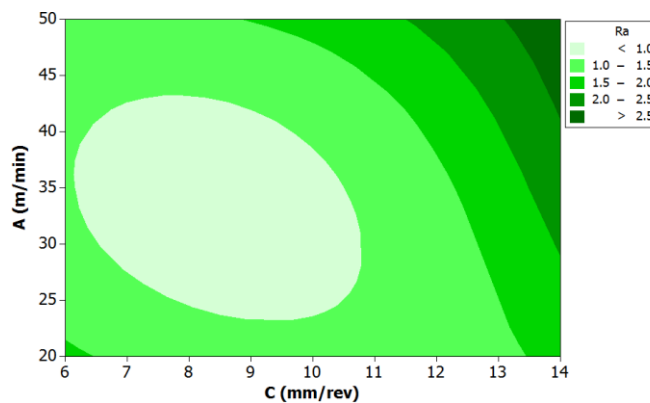


Fig 5. The effect of interaction between velocity of workpiece and feed rate on surface roughness

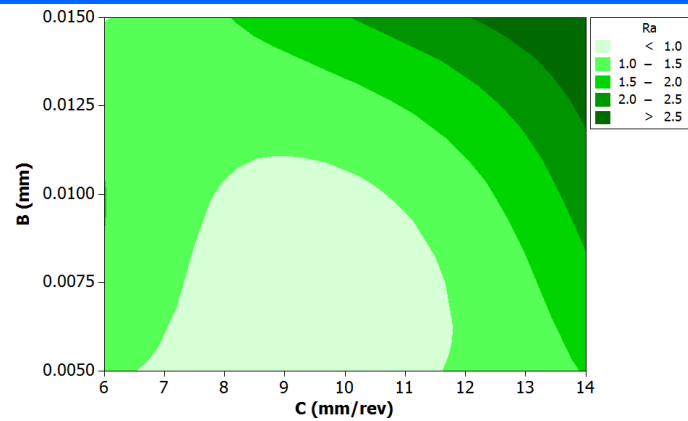


Fig 6. The effect of interaction between depth of cut and feed rate on surface roughness

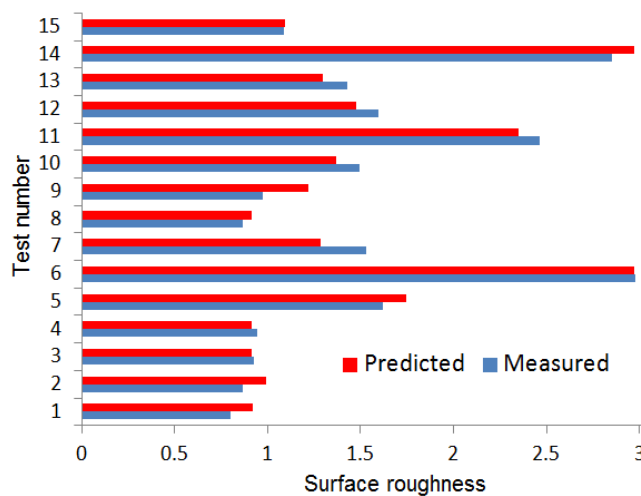


Fig. 7. Comparison between the theory as shown in Eq. (1) and the experiment

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 8.2%. 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 Cn80.G.V1.TB1. 400x40x230x35 m/s.

$$Ra = 0.9120 + 0.2624A + 0.4525B + 0.4864C + 0.2265AB + 0.3513AC + 0.3900BC + 0.3629A^2 + 0.1316B^2 + 0.5989C^2 \quad (1)$$

Conclusions

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

- The process of experiment for grinding D2 steel by using Hai Duong 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.

- 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.

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