A Study on Surface Roughness of Workpiece When Surface Grinding Using CBN Grinding Wheel

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***Abstract*— In this paper, experimental research process when grinding with CBN grinding wheel has been conducted. Conducting experiments grinding 3 types of steel including 3X13, SKD11 and SUJ2 with CBN grinding wheel on a surface grinder. In each experiment, the value of the velocity of workpiece, the feed-rate and the depth of cut will be changed. The analysis of experimental results to determine the degree of influence of each cutting parameters on the surface roughness when grinding each type of steel. The interaction effect between cutting parameters and surface roughness when grinding different steel types is also analyzed in this paper. This study also conducted a surface comparison when grinding three types of steel mentioned above. Finally, this study compares the degree of impact of each cutting parameter to the roughness when grinding different types of steel.**

Keywords—CBN grinding wheel; cutting parameter; 3X13 steel; SKD11 steel; SUJ2 steel.

I. INTRODUCTION

The invention of super hard abrasive material-Cubic Boron Nitride (CBN), has contributed to significantly improving the economic-technical efficiency of grinding method. This abrasive is significantly applied by advanced industrial countries in mechanical processing since the 70s of the 20th century. The CBN material is almost twice as hard as that of aluminum oxide and its heat resistance is up to 15000C. Due to the extremely high hardness, the grinding wheel made of CBN is capable of maintaining very small tolerance and the cutting process is stable, which creates a high and stable machining surface quality. In addition, CBN grinding wheel is capable of removing regular residues on the surface of the workpiece without compensating for the wear of grinding wheel [1].

Highlight Surface roughness is a parameter that has a great influence on the workability and durability, longevity of the part. When machining the machine part surface by grinding, roughness is often chosen as one of the criteria to evaluate the efficiency of the machining process because grinding is often chosen as the final finishing method for surfaces that require high gloss. Empirical research to investigate the effect of cutting parameters on surface roughness when grinding has been carried out by many studies [1-5]. The results of each study are the basis for controlling the grinding process to process the rough surface of the parts to meet the requirements.

3X13 steel is a type of stainless steel commonly used to make machine parts working in corrosive, heavy-load environments. SKD11 and SUJ2 are two types of high-alloy steel, which are often used to manufacture machine parts that require high surface gloss (dies, bearings). All three types of steel are commonly used in grinding technology. The authors of this paper have conducted an empirical study to investigate the effect of cutting parameters on surface roughness when grinding these three steels using CBN grindstone [6-8]. In this study, the authors studied the grinding process of all three types of steel on CBN grinding wheel, conducted analysis of results to gain a more general view of the grinding process of these three steel types

II. EXPERIMENTAL STUDY

A. *Experimental steel*

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The three types of steel used in this study included 3X13, SKD11 and SUJ2, all of which were tempered to 62HRC (Figure 1). The chemical composition of the three steel types is shown in Table I.

TABLE I. COMPOSITION OF THE MAIN ELEMENTS OF STEELS

Composite [%]	**Steel**		
	3X13	***SKD11***	***SUJ2***
C	0.42	1.5	1.00
Mn	1.00	0.3	0.35
Si	1.00	0.25	0.25
Cr	13.00	11.5	1.45
Al	-	-	0.02
Cu	-	-	0.10
V	-	0.25	-
Mo	-	0.3	-
Ni	-	0.35	-
S	0.005	-	-

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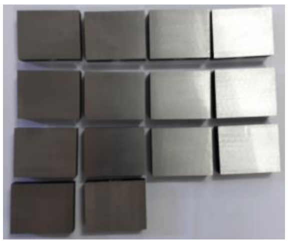
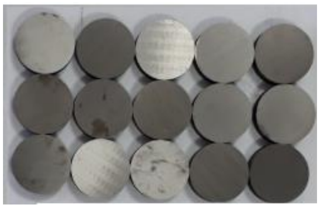


3X13 steel

SKD11 steel



SUJ2 steel

Fig. 1. *Components*

B. *Grinding machines and grinding wheel*

Toyoda surface grinder has been used to test the grinding process. The grinding wheel to be used was CBN with the HY-180x13x31.75-100# (Korea).

C. *Experimental design*

For each type of steel, the testing process was conducted according to a matrix of 15 experiments. Each cutting parameter will receive three levels of values (Table II), the experimental matrix is shown in Table III.

TABLE II. VALUE OF INPUT PARAMETERS AT THE CODING LEVELS

Parameter	**Value at the coding level**		
	-1	***0***	***1***
x_1, v (m/min)	5	10	15
x_2, f (mm/stroke)	3	4	5
x_3, t (mm)	0.01	0.015	0.02

TABLE III. EXPERIMENTAL MATRIX AND RESPONSE

No.	**x_1**	**x_2**	**x_3**	**x_1(v) m/min**	**x_2(f) mm/str.**	**x_3(t) mm**	**Ra (µm)**		
							3X13	***SKD11***	***SUJ2***
1	-1	-1	0	5	3	0.015	0.55	0.46	1.12
2	1	-1	0	15	3	0.015	0.86	0.75	1.42
3	-1	1	0	5	5	0.015	0.83	0.82	1.16
4	1	1	0	15	5	0.015	0.93	0.68	1.55
5	-1	0	-1	5	4	0.010	0.93	0.59	1.34
6	1	0	-1	15	4	0.010	0.9	0.66	1.16
7	-1	0	1	5	4	0.020	0.82	0.82	1.11
8	1	0	1	15	4	0.020	0.99	0.8	1.16
9	0	-1	-1	10	3	0.010	1.22	0.55	1.14
10	0	1	-1	10	5	0.010	1.36	0.65	1.2
11	0	-1	1	10	3	0.020	1.48	0.62	1.13
12	0	1	1	10	5	0.020	1.44	0.66	1.37
13	0	0	0	10	4	0.015	1.46	0.54	0.92
14	0	0	0	10	4	0.015	1.54	0.52	0.98
15	0	0	0	10	4	0.015	1.5	0.55	1.02

D. *Analysis of results*

After grinding, each sample was measured roughness at least three times using the SJ201 roughness meter. The roughness value at each experiment is the average value of successive measurements, shown in Table III. ANOVA analysis results are presented in Table IV.

TABLE IV. ANOVA ANALYSIS

Par.	**Coefficients**			**P-value**		
	3X13	***SKD11***	***SUJ2***	***3X13***	***SKD11***	***SUJ2***
Int.	1.5000	0.5367	0.97333	0.0000	0.00001	0.0001
x_1	0.0688	0.0250	0.07	0.0714	0.25374	0.2399
x_2	0.0563	0.0538	0.05875	0.1209	0.03928	0.314
x_3	0.0400	0.0563	-0.0088	0.2418	0.03376	0.8742
x_1*x_1	-0.5863	0.1192	0.16083	0.00004	0.00870	0.0919
x_2*x_2	-0.1213	0.0217	0.17833	0.0411	0.48205	0.0691
x_3*x_3	-0.0038	0.0617	0.05833	0.9359	0.08314	0.4843
x_1*x_2	-0.0525	-0.1075	0.0225	0.2728	0.01118	0.7741
x_1*x_3	0.0500	-0.0225	0.0575	0.2936	0.44929	0.4737
x_2*x_3	-0.0450	-0.0150	0.045	0.3393	0.60792	0.5709
Out.	3X13		SKD11		SUJ2	
Sig. F	0.0018		0.0301		0.3484	
R^2	0.9748		0.9167		0.7266	

The analysis results in Table IV shows that:

- For 3X13 and SUJ2 steel, the velocity of workpiece has the greatest impact on the surface roughness, followed by the influence of the feed-rate and the depth of cut. For SKD11 steel, the depth of cut is the parameter that has the most influence on the roughness of the surface, followed by the influence of the feed-rate, the velocity of workpiece has the least impact on surface roughness.

- For 3X13 and SKD11 steel, the interaction effect of velocity of workpiece and the feed-rate has the greatest impact on surface roughness, followed by the degree of influence of the interaction between the velocity of workpiece and the depth of cut, the interaction between the feed-rate and the depth of cut is the least affected.

- For SUJ2 steel, the interaction between the velocity of workpiece and the depth of cut has the greatest impact on surface roughness, followed by the degree of impact of the interaction between the feed-rate and the depth of cut, the interaction between the velocity of workpiece and the feed-rate has the least impact on surface roughness.

- Surface roughness when grinding SKD11 steel is always smaller than when grinding steel 3X13 and SUJ2 steel, this comment will be more clear when observing Figure 2.

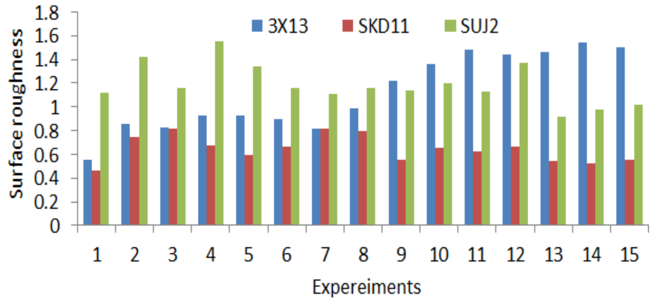
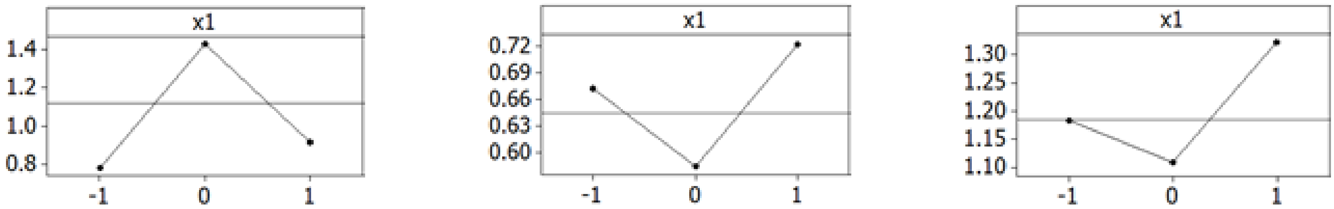


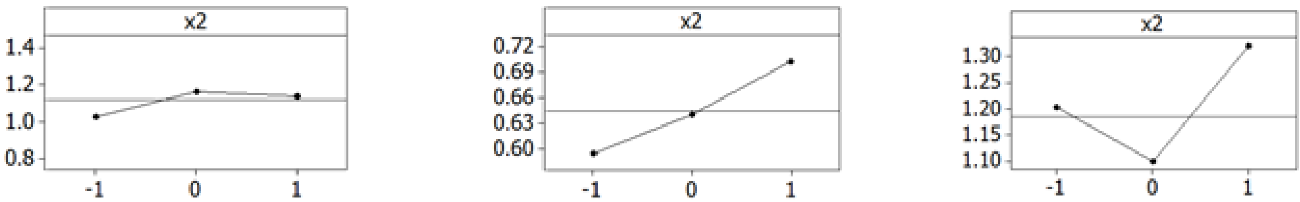
Fig. 2. Surface roughness for different steels

From the results in Table III, a comparison of the influence of each cutting parameter on the surface roughness when grinding for each type of steel will be conducted. The results are shown in Figures 3, 4 and 5.



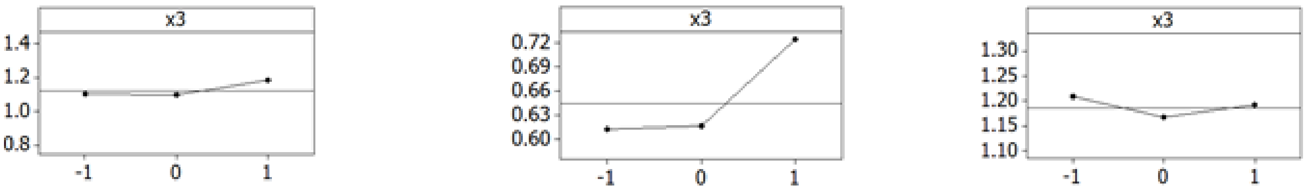
a) 3X13 steel *b) SKD11 steel* *c) SUJ2 steel*

Fig. 3.*Main Effects Plot of workpiece velocity for steels*



a) 3X13 steel *b) SKD11 steel* *c) SUJ2 steel*

Fig. 4.*Main Effects Plot of feed-rate for steels*



a) 3X13 steel *b) SKD11 steel* *c) SUJ2 steel*

Fig. 5. Main Effects Plot of depth of cut for steels

Figure 3 shows that the rule of influence of the velocity of workpiece on the surface roughness when grinding is relatively the same when grinding SKD11 and SUJ2 steel. Specifically, when grinding SKD11 and SUJ2, when increasing the velocity of workpiece (from 5 to 10 m / min), the surface roughness has decreased value, further increasing the velocity of workpiece the surface roughness increases. As for 3X13 steel grinding case, when increasing the velocity of workpiece, surface roughness will increase. However, if the velocity of workpiece is increased, surface roughness tends to decrease.

Figure 4 shows that the rule of influence of the feed-rate on the surface roughness when processing three types of steel is completely different. For 3X13 steel, the velocity of workpiece has very little effect on surface roughness. For SKD11 steel, increasing the velocity of workpiece will increase the surface roughness. For SUJ2 steel, the surface roughness will decrease with increasing feed-rate. However, if the feed-rate continues to increase, the surface roughness decreases.

The observation of Figure 5 shows that the depth of cut has very little effect on surface roughness when grinding 3X13 and SUJ2 steel. As for SKD11 steel, increasing the depth of cut will increase the surface roughness.

III. CONCLUSION

Some conclusions drawn from this study when grinding using CBN wheel are as follows:

When grinding 3X13 and SUJ2 steel, the velocity of workpiece has the greatest impact on surface roughness, followed by the influence of the feed-rate and the depth of cut. When grinding SKD11 steel, the depth of cutt is the parameter that has the most impact on surface roughness, followed by the influence of the feed-rate, the velocity of workpiece has the least impact on surface roughness [6-8].

When grinding 3X13 and SKD11, the interaction between the velocity of workpiece and the feed-rate has the greatest impact on surface roughness, followed by the degree of impact of the interaction between the velocity of workpiece and the depth of cut, the interaction between the feed-rate and the depth of cut is the least affected. When grinding SUJ2 steel, the interaction between the velocity of workpiece and the depth of cut has the greatest impact on surface roughness, followed by the degree of influence of the interaction between the feed-rate and the depth of cut, the interaction between the velocity of workpiece and the feed-rate has the least effect on surface roughness [6-8].

Surface roughness when grinding SKD11 steel is always smaller than when grinding steel 3X13 and SUJ2 steel.

When grinding SKD11 and SUJ2, and when increasing the velocity of workpiece, the surface roughness has reduced value, further increasing the velocity of workpiece, the surface roughness increased. As for 3X13 steel grinding case, when increasing the velocity of workpiece, surface roughness will increase. However, if further increasing velocity of workpiece, surface roughness tends to decrease. For 3X13 steel, the feed-rate has very little effect on surface roughness. For SKD11 steel, increasing the feed-rate will increase the surface roughness. For SUJ2 steel, the surface roughness decreases with increasing feed-rate. However, if the feed-rate continues to increase, the surface roughness decreases. The depth of cut has very little effect on surface roughness when grinding 3X13 and SUJ2 steel. As for SKD11 steel, increasing the depth of cut will increase the surface roughness.

REFERENCES

[1] S. M. Deshmukh, R. D. Shelke, C. V. Bhusare, “Optimization of Cylindrical Grinding Process Parameters of Hardened Material using Response Surface Methodology,” International Journal of Innovative Science, Engineering & Technology, 3 (11), 2016, pp. 216-219.

[2] Dayananda Pai, Shrikantha Rao, Raviraj Shetty, Rajesh Nayak, “Application of response surface method on surface roughness in grinding of aerospace materials (6061Al-15Vol%SiC25P),” ARPN Journal of Engineering and Applied Sciences, 5 (6), 2010, pp. 23-28.

[3] Pawan Kumar, Anish Kumar, Balinder Singh, “Optimization of Process Parameters in Surface Grinding Using Response Surface Methodology,” IJRMET, 3 (2), 2013, pp. 245-252.

[4] Hemant S. Yadav, R. K. Shrivastava, “Effect of Process Parameters on Surface

Roughness and Mrr in Cylindrical Grinding using Response Surface Method,” International Journal of Engineering Research & Technology, 3 (3), 2014, pp. 1384-1388.

[5] N. Mohanasundararaju, R. Sivasubramanian, N. Alagumurthi, “Optimisation of work roll grinding using Response Surface Methodology and evolutionary algorithm,” Int. J. Manufacturing Research, 3 (2), 2008, pp. 236-251.

[6] Nguyen Hong Son, Do Duc Trung, “Analysis on the Effects of Cutting Parameters on Surface Roughness of Workpiece in Surface Grinding,” International Journal of Scientific Research in Science, Engineering and Technology, 6 (5), 2019, pp. 277-282.

[7] Nguyen Hong Son, Do Duc Trung, “Investigation of The Effects of Cutting Parameters on Surface Roughness When Grinding 3X13 Steel using CBN Grinding Wheel,” Journal of Multidisciplinary Engineering Science and Technology, 6 (10), 2019, pp. 10919-10921.

[8] Nguyen Hong Son, Do Duc Trung, “Optimization the Cutting Parameters when Grinding SKD11 Steel using CBN Grinding Wheel,” American Journal of Engineering Research, 8 (10), 2019, pp. 77-80.