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Analysis on the Effects of Cutting Parameters on Surface Roughness of Workpiece in Surface Grinding

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ABSTRACT

In this paper, the analysis on the effects of cutting parameters on surface roughness of workpieces in surface grinding has been conducted. Experimental SUJ2 steel grinding process is made with CBN grinding wheel. The tests is made on an APSG-820/2A surface grinder. The Box- Behnken method has been used to design experiments. Minitab 16 statistical software has been used to analyze ANOVA test results. The results show that the feed-rate has the greatest effect on surface roughness, followed by the least effects of velocity of workpiece, depth of cut on surface roughness. The interaction between velocity of workpiece and depth of cut has the greatest effect on surface roughness, followed by the effects of the interaction between the feed-rate and depth of cut, the interaction between velocity of workpiece and the feed-rate has insignificant effects on surface roughness. This study also shows the value range of some cutting parameters for processing surface of workpiece with small roughness. Finally, a regression model of surface roughness has been established in this study.

Keywords : Surface roughness, surface grinding, SUJ2 steel, CBN grinding wheel, ANOVA analysis.

I. INTRODUCTION

Studying the process of grinding to process surface of workpieces with small surface roughness has been carried out by many studies. In particular, the study of the effects of cutting parameters on the surface roughness of workpiece has been carried out with a large number of published works. The following table presents a summary of some contents that has been done in previous studies.

TABLE I. SUMMARY OF SOME PUBLISHED STUDIES

Discussions	Grinding wheel	Workpiece material	Grinding method	Ref.
The feed rate and depth of cut have significant effects on surface roughness values.	Al_2O_3 wheel	OHNS	cylindrical grinding	Deshmukh et al. (2016)
The depth of cut followed by flow rate and nozzle angle was most influencing parameters on surface roughness.	A60 M6 VCNM	SAE 8620 grade steel	cylindrial grinding	Hemant et al. (2014)
All of input parameters have a significant effect on surface roughness.	22A60L6V63L	9SMn28	centerless grinding	Krajnik et al. (2005)

The depth of cut has a greater effect on the surface roughness and feed has a medium effect while dressing depth of cut has minimal effect on surface roughness.	A60V5V	AISI 1080	surface grinding	Periyasamy et al. (2014)
- The depth cut was influenced the out range of surface roughness. When depth of cut is minimum the value of surface roughness is also minimum.	A60V5V	AISI 4140 Steel	cylindrical grinding	Radha Krishnan et al. (2018)
All of input parameters have a significant effect on surface roughness	SiC grain	AISI 4140 Steel	grinding and polishing process	Tao Zhao et al. (2014)
All of input parameters have a significant effect on surface roughness.	green silicon carbide with grit size of 120 microns	D2 steel	work roll grinding	Mohanasundararaju et al. (2008)
- The feed rate and depth of cut had significant effects on surface roughness during the micro-grinding process.	CBN grinding wheel with grain size of 270	SK-41C tool steel	micro-grinding process with compressed air	Lee et al. (2011)
All of input parameters have a significant effect on surface roughness.	A460L5V20	SS430 Material	cylindrical grinding	Saravanakumar et al. (2016)
All of input parameters have a significant effect on surface roughness.	Cn80.TB1.G.V1.500.150.305x35m/s	20X-carbon infiltration steel	plunge centerless grinding	Khoi et al. (2014)
- The surface roughness increases with an increase in feed and depth of cut. When the feed and depth of cut are increased, the increase in material removal rate and the increase in chip thickness account for the increase of surface roughness - Surface roughness decreases with an increase in wheel speed.	metallic bonded diamond grinding wheel	OFSiC advanced ceramic material	surface grinding	Binu Thomas et al. (2014)
All of input parameters have a significant effect on surface roughness	CBN wheel	AISI 1045 steel	cylindrical grinding	Mamun et al. (2012)
All of input parameters have a significant effect on surface roughness	CBN wheel	En15AM steel	centerless grinding	Durairaj et al. (2017)
Traverse speed and the depth of cut are significant factors that affect the surface roughness.	CBN wheel	Inconel 718 material	surface grinding	Nurul Afizan et al. (2017)

In this paper, carrying out the experimental study and analysis of the effects of cutting parameters on surface roughness when grinding SUJ2 steel with CBN wheel.

II. EXPERIMENTAL STUDY

A. Grinder, grinding wheel and materials

The test grinder used in this study is an APSG-820/2A surface grinder (Taiwan). CBN grinding wheel, HY-180x13x31.75-100 # (Korea) have been used for the testing process. The components used in this study is SUJ2 steel with the length x width x height of 50 mm x 50 mm x 10 mm respectively, and the component is heat-treated to reach the hardness of 62HRC.

B. Measurement instrument

The SJ201 roughness tester (Mitutoyo - Japan) is used to measure the roughness with a standard length of 0.8mm. At each workpiece, the surface roughness is measured at least 3 times, the roughness value at each experiment is the average value of successive measurements.

C. Grinding conditions and experiments

The experiments are conducted with cutting speed of 26 (m/s), dressing depth of cut of 0.01 (mm), dressing feed-rate of 150 (mm/min), emulsion 10% oil used for cooling, method of overflow irrigation, with a flow of 4.6 (liters/min). The test matrix is built with 3 input parameters of cutting parameters including velocity of workpiece, feed-rate and depth of cut. Each parameter received 3 levels of value during the experiments (Table II). The testing matrix is presented in Table III. Testing results are also included in Table III.

TABLE II. FACTORS AND THEIR LEVELS

Factor	Level 1	Level 2	Level 3
v: Velocity of workpiece (m/min)	5	10	15
f: Feed-rate (mm/stroke)	3	4	5
t: Depth of cut (mm)	0.01	0.015	0.02

TABLE III. DESIGN MATRIX WITH RESPONSES

Run	v (m/min)	f (mm/stroke)	t (mm)	Ra (µm)	v*v	f*f	t*t	v*f	v*t	t*t
1	5	3	0.015	1.12	25	9	0.000225	15	0.075	0.045
2	15	3	0.015	1.42	225	9	0.000225	45	0.225	0.045
3	5	5	0.015	1.16	25	25	0.000225	25	0.075	0.075
4	15	5	0.015	1.55	225	25	0.000225	75	0.225	0.075
5	5	4	0.010	1.34	25	16	0.000100	20	0.05	0.04
6	15	4	0.010	1.16	225	16	0.000100	60	0.15	0.04
7	5	4	0.020	1.11	25	16	0.000400	20	0.1	0.08
8	15	4	0.020	1.16	225	16	0.000400	60	0.3	0.08
9	10	3	0.010	1.14	100	9	0.000100	30	0.1	0.03
10	10	5	0.010	1.20	100	25	0.000100	50	0.1	0.05
11	10	3	0.020	1.13	100	9	0.000400	30	0.2	0.06
12	10	5	0.020	1.37	100	25	0.000400	50	0.2	0.1
13	10	4	0.015	0.92	100	16	0.000225	40	0.15	0.06
14	10	4	0.015	0.98	100	16	0.000225	40	0.15	0.06
15	10	4	0.015	1.02	100	16	0.000225	40	0.15	0.06

D. Result analysis

The Minitab 16 statistical software is used to analyze the testing results in Table III. The results are presented in Tables IV, V and Figures 1 to 5.

TABLE IV. REGRESSION ANALYSIS SURFACE ROUGHNESS

Term	Coef	SE	T	P
Constant	5.69	1.90	2.997	0.030
v (m/min)	-0.17	0.10	-1.727	0.145
f (mm/stroke)	-1.54	0.68	-2.255	0.074
t (mm)	-130.59	115.45	-1.131	0.309
v*v	0.01	0.00	2.079	0.092
f*f	0.18	0.08	2.280	0.072
t*t	2365.12	3115.59	0.759	0.482
v*f	0.00	0.01	0.311	0.768
f*t	2.35	2.99	0.784	0.468
f*t	8.58	14.97	0.537	0.591

TABLE V. ANOVA OF SURFACE ROUGHNESS

Source	DF	Seq SS	Adj SS	Adj MS	F
v (m/min)	1	0.040440	0.087100	0.087100	4.06
f (mm/stroke)	1	0.028684	0.152299	0.152299	7.10
t (mm)	1	0.000685	0.046645	0.046645	2.18
v*v	1	0.287816	0.287816	0.095939	4.47
f*f	1	0.108844	0.136029	0.136029	6.34
t*t	1	0.149641	0.159091	0.159091	7.42
v*f	1	0.029331	0.029331	0.029331	1.37
f*t	1	0.023300	0.023300	0.007767	0.36
f*t	1	0.002164	0.002164	0.002164	0.10
Error	5	0.112003			
Total	14	0.782908			

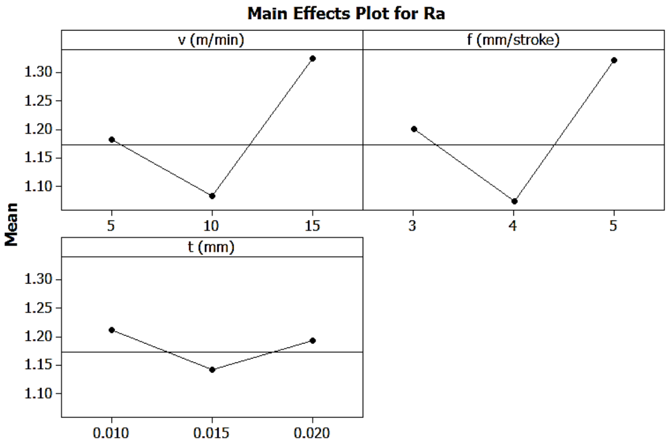

Figure 1: Main Effects Plot for surface roughness

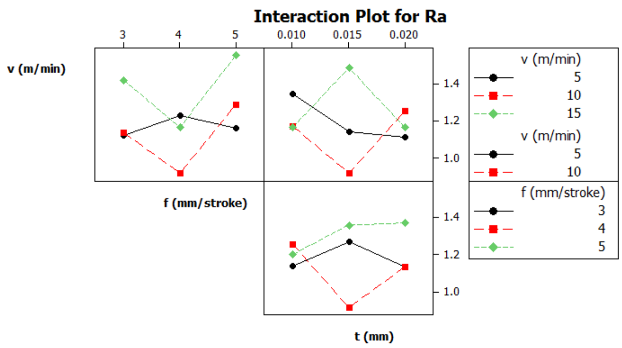

Figure 2: Interaction Plot for surface roughness

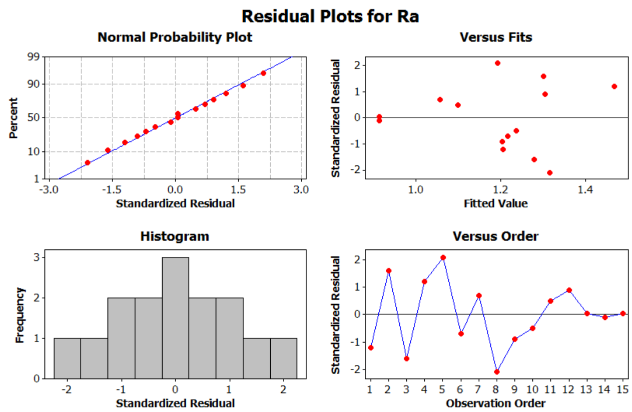

Figure 3: Residual Plot for surface roughness

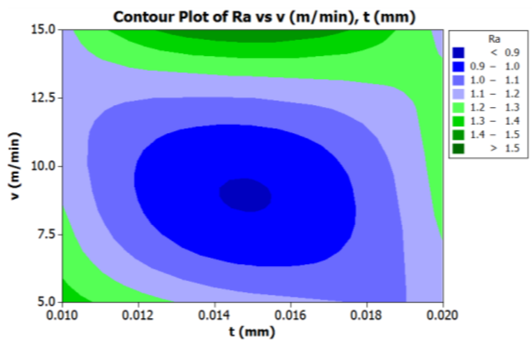

Figure 4: Contour Plot interaction v and t for surface roughness

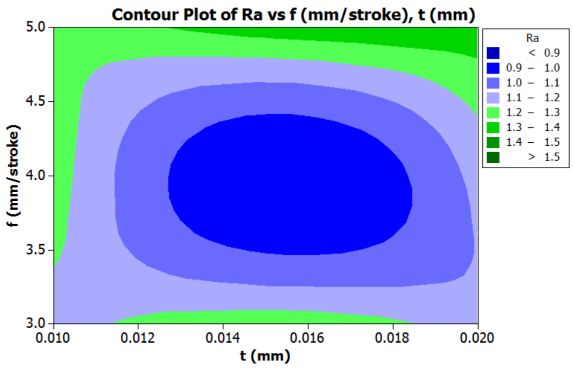

Figure 5 : Contour Plot interaction f and t for surface roughness

From the illustrations in figures and tables above, it can be seen that the feed-rate has the greatest effect on surface roughness, followed by the effects of velocity of workpiece, the depth of cut has the lowest effect. This can also be clearly seen in Figure 1. The interaction between the velocity of workpiece and depth of cutting has the greatest effect on surface roughness, followed by the effect of interaction between the feed-rate and depth of cut, the interaction between the velocity of workpiece and feed-rate has insignificant effect on surface roughness. Also from Table IV and Table V, the regression model of surface roughness is presented in formula (1). The observation in Figure 3 shows that the relevance of the model is above the acceptable limit. Therefore, this regression equation can be used to control the processing course when grinding SUJ2 steel with CBN grinding wheel. The observation in Figure 4 and Figure 5 shows that when the depth of cut is about 0.15 (mm), the velocity of workpiece is about 9 (m/min) and the feed-rate is within 3.5 ÷ 4.3 (mm/stroke), then the surface roughness will have the smallest value.

$$R_a = 5.69 - 0.17 * v - 1.54 * f - 130.59 * t + 0.01 * v^2 + 0.18 * f^2 + 2356.12 * t^2 + 2.35 * v * t + 8.58 * f * t \quad (1)$$

III.CONCLUSION

This experimental study has carried out for grinding SUJ2 steel with CBN grinding wheel. After analyzing the test results, this study has determined the effects of velocity of workpiece, the feed-rate, the depth of cut, the interaction among parameters on the surface roughness of workpiece. The value of velocity of workpiece, feed-rate and depth of cut has also been determined to ensure that the processed surface of workpiece has with a small roughness. Finally, the regression equation showing the relation between the surface roughness of workpiece and the cutting parameters has been developed. This model allows to predict the surface roughness when grinding, contributing to reduce the time to adjust machines, test processing time and to improve the efficiency of the grinding process.

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