International Journal of Innovation Engineering and Science Research
(ISSN: 2581-4591)

www.ijiesr.com

Effect of dressing parameters when external cylindrical grinding 90CrSi on wheel life time

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ABSTRACT

This paper studies the influence of the dressing parameters on the external cylindrical grinding process on wheel life time to achieve the maximum grinding wheel life time. In this study, six dressing parameters were investigated, including depth of rough dressing, rough dressing time, depth of fine dressing, fine dressing time, non-feeding dressing time, and dressing speed. The study used the response surface method to design the experiment and ANOVA method to analyze the effect of input parameters on response. This study propose the regression equation describes the relationship between the dressing parameters and grinding wheel life time and the optimal dressing condition to achieve the maximum wheel life time was determined.

Keywords*—external grinding; dressing condition; surface roughness;*

I. Introduction

Grinding process is one of the most important final process in manufacturing. This process could processing the high accuracy and high surface quality of workpiece. But this is also a high-cost manufacturing process. Therefore, there are many researches to reduce the processing cost and increase the grinding performance.

The previous researches presented there are many processing parameter affect on the performance of grinding process as grinding condition, cooling condition and dressing condition… these processing parameters may affect on the quality of workpiece and grinding[1]. In the study of Sandeep Kumar presented the workpiece speed, grinding wheel speed and feed rate has more significant effect for surface roughness in external cylindrical grinding when grinding EN15 AM steel[2]. The study of Ja-Seob Kwak in grinding hardened SCM440 steel indicated the depth of cut has more effect on surface roughness than traverser speed [3].The grinding processing parameter on material removal rate in external cylindrical grinding EN45 steel also is mentioned in the research of Dersse [4]. The effect of the different cutting fluid on grinding performance have been study by Talon [5], and the minimum quantity lubricant (MQL) method also has been applied to improve the grinding quality and reduce grinding cost [6-8].

In the grinding process, not only improving the surface quality of the workpiece, but also improving productivity and reducing costs is also focused on research. The different study method have been applied to optimum the grinding condition as Taguchi method, response surface method, neural network and genetic algorithm[9, 10]. The exchanged grinding wheel to obtain the lowest grinding cost have been studied also [11, 12].

In addition to the effect of grinding condition, the dressing condition also has a great influence on the productivity and quality of the grinding process. Because the dressing condition determine the profile of the grinding wheel[13, 14]. But very few researchers investigate the effect of dressing condition on the grinding wheel life time [15]. Therefore, this study focus on the influence of dressing parameter on wheel life time when external cylindrical grinding the 90CrSi harden steel. Moreover, by applying the ANOVA method to find out the optimum dressing condition to maximum the wheel life time.

II. Experimental Design

In this study, an experiment design using response surface Box-Behnken method was applied to investigate the effect of six dressing parameters including depth of rough dressing, rough dressing time, depth of fine dressing, fine dressing time, non-feeding dressing time, and dressing speed on surface roughness when external cylindrical grinding 90CrSi. The investigated levels of input factors were shown in table 1.

TABLE 1.INPUT PARAMETERS AND INVESTIGATED LEVELS

No.	Input parameters	Symbol	Unit	Level of investigating	
				Low	High
1	Depth of rough dressing	a_r	mm	0.02	0.04
2	Rough dressing time	n_r	-	1	5
3	Depth of fine dressing	a_f	mm	0.005	0.015
4	Fine dressing time	n_f	-	0	4
5	Non-feeding dressing time	n_0	-	0	4
6	Feed speed	S_d	m/min	1	2

The experiments were conducted using the following fixed grinding conditions and equipment: The Cantext Aquatex 3810 with a concentration of 3% and a flow-rate of 10 l/min was used for coolant condition; the grinding condition is: feed rate at 1.8 m/min, depth per cut is 0.005 per single stroke, total depth of cut is 0.05 mm and the speed of grinding wheel is 29.3 m/s; Grinding machine: CONDO-Hi-5 HTS (Japan origin); grinding wheel: Ct80MV1-G 400x40x203 35m/2 (Vietnam origin); dressing tool: 3908-0088C type 2 (Russian origin); cutting force measurement: Kistler 5233A (German). The workpiece properties are described in table 2.

TABLE 2.90CrSi STEEL PROPERTIES

Steel grade: 90CrSi						
C	Si	Mn	Cr	P	S	Co
0.85-0.95	12-1.6	0.3-0.6	0.95-1.25	≤0.03	≤0.03	≤1

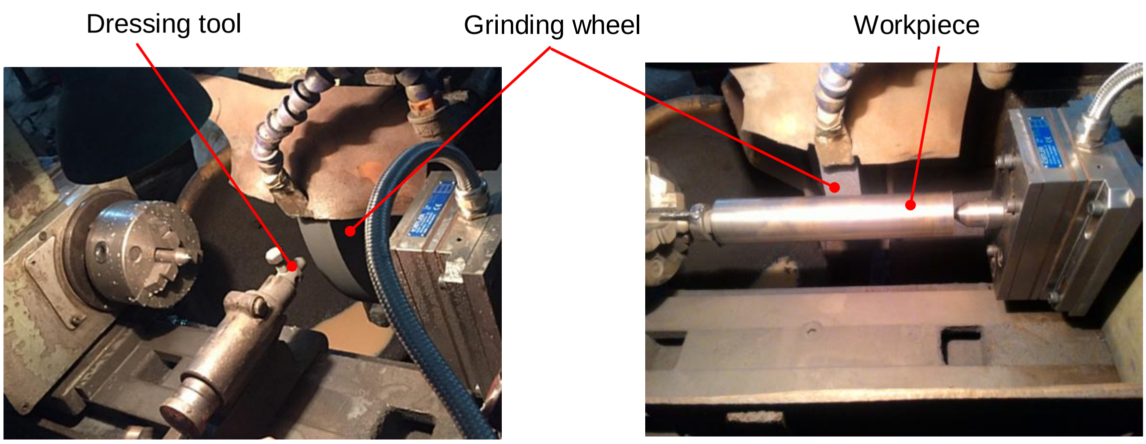

Fig 1. Experiment setup

According to the response surface method, the experiment design is calculated based on the input data in table 1. By using Minitab R19, the experiment design table with 54 experiments is listed in table 3. The wheel life time is determined by cutting force measurement. The experiment result is described in table3 either.

TABLE 3.EXPERIMENT DESIGN AND MEASUREMENT RESULTS

StdOrder	RunOrder	PtType	Blocks	a_r	n_r	a_f	n_f	n_0	S_d	Wheel life time T(min)
16	1	2	1	0.03	5	0.015	2	4	1.5	39.82
28	2	2	1	0.04	3	0.010	4	0	1.5	44.54
24	3	2	1	0.03	3	0.015	4	2	2.0	39.39
44	4	2	1	0.04	3	0.015	2	2	1.0	44.15
26	5	2	1	0.04	3	0.010	0	0	1.5	43.56
21	6	2	1	0.03	3	0.005	0	2	2.0	38.95
27	7	2	1	0.02	3	0.010	4	0	1.5	38.44
49	8	0	1	0.03	3	0.010	2	2	1.5	45.89
10	9	2	1	0.03	5	0.005	2	0	1.5	40.03
2	10	2	1	0.04	1	0.010	0	2	1.5	43.05
32	11	2	1	0.04	3	0.010	4	4	1.5	44.97
35	12	2	1	0.03	1	0.010	2	4	1.0	38.55
20	13	2	1	0.03	3	0.015	4	2	1.0	38.63
30	14	2	1	0.04	3	0.010	0	4	1.5	43.05
42	15	2	1	0.04	3	0.005	2	2	1.0	45.23
8	16	2	1	0.04	5	0.010	4	2	1.5	44.94
3	17	2	1	0.02	5	0.010	0	2	1.5	41.62
53	18	0	1	0.03	3	0.010	2	2	1.5	45.92
40	19	2	1	0.03	5	0.010	2	4	2.0	39.73
6	20	2	1	0.04	1	0.010	4	2	1.5	44.04
51	21	0	1	0.03	3	0.010	2	2	1.5	45.88
54	22	0	1	0.03	3	0.010	2	2	1.5	45.74
29	23	2	1	0.02	3	0.010	0	4	1.5	40.88
43	24	2	1	0.02	3	0.015	2	2	1.0	41.79
50	25	0	1	0.03	3	0.010	2	2	1.5	45.95
12	26	2	1	0.03	5	0.015	2	0	1.5	39.62
48	27	2	1	0.04	3	0.015	2	2	2.0	44.26
15	28	2	1	0.03	1	0.015	2	4	1.5	38.97
5	29	2	1	0.02	1	0.010	4	2	1.5	40.86
38	30	2	1	0.03	5	0.010	2	0	2.0	39.04
17	31	2	1	0.03	3	0.005	0	2	1.0	39.79
31	32	2	1	0.02	3	0.010	4	4	1.5	42.14
36	33	2	1	0.03	5	0.010	2	4	1.0	42.68
9	34	2	1	0.03	1	0.005	2	0	1.5	39.15
33	35	2	1	0.03	1	0.010	2	0	1.0	39.26
22	36	2	1	0.03	3	0.015	0	2	2.0	39.22
14	37	2	1	0.03	5	0.005	2	4	1.5	40.15
4	38	2	1	0.04	5	0.010	0	2	1.5	43.88
37	39	2	1	0.03	1	0.010	2	0	2.0	38.81
45	40	2	1	0.02	3	0.005	2	2	2.0	41.54
1	41	2	1	0.02	1	0.010	0	2	1.5	40.88
34	42	2	1	0.03	5	0.010	2	0	1.0	39.23
18	43	2	1	0.03	3	0.015	0	2	1.0	40.37
52	44	0	1	0.03	3	0.010	2	2	1.5	45.66
19	45	2	1	0.03	3	0.005	4	2	1.0	40.84
23	46	2	1	0.03	3	0.005	4	2	2.0	40.49
7	47	2	1	0.02	5	0.010	4	2	1.5	42.25
41	48	2	1	0.02	3	0.005	2	2	1.0	43.26
25	49	2	1	0.02	3	0.010	0	0	1.5	42.13
47	50	2	1	0.02	3	0.015	2	2	2.0	41.96
39	51	2	1	0.03	1	0.010	2	4	2.0	38.96
13	52	2	1	0.03	1	0.005	2	4	1.5	39.27
46	53	2	1	0.04	3	0.005	2	2	2.0	44.68
11	54	2	1	0.03	1	0.015	2	0	1.5	39.15

III. RESULT AND DISCUSSIONS

In order to investigate the effect of dressing parameters on wheel life time, the ANOVA method is conducted. The effect of input factor are described in the figure 2.

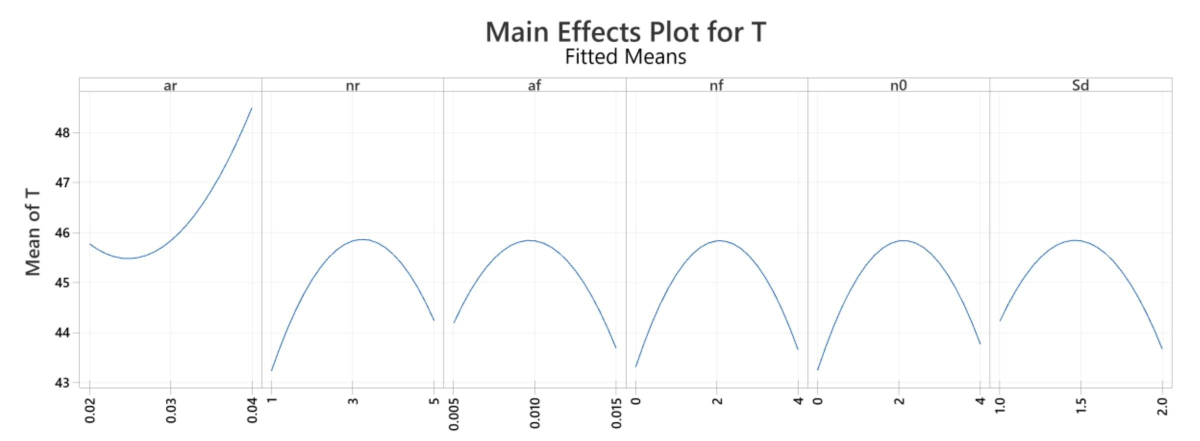

Fig 2.Effect of input factors on surface roughness

Observing the analysis result in figure 2 shows all of the input factors affect the output response in the quadratic form. This result indicated that investigated area has extreme value and the optimal value of the input parameter can be determined.

The influence degree of investigated parameter is described in the Pareto chart in figure 3. The factors which cross over the red reference line are significant factors.

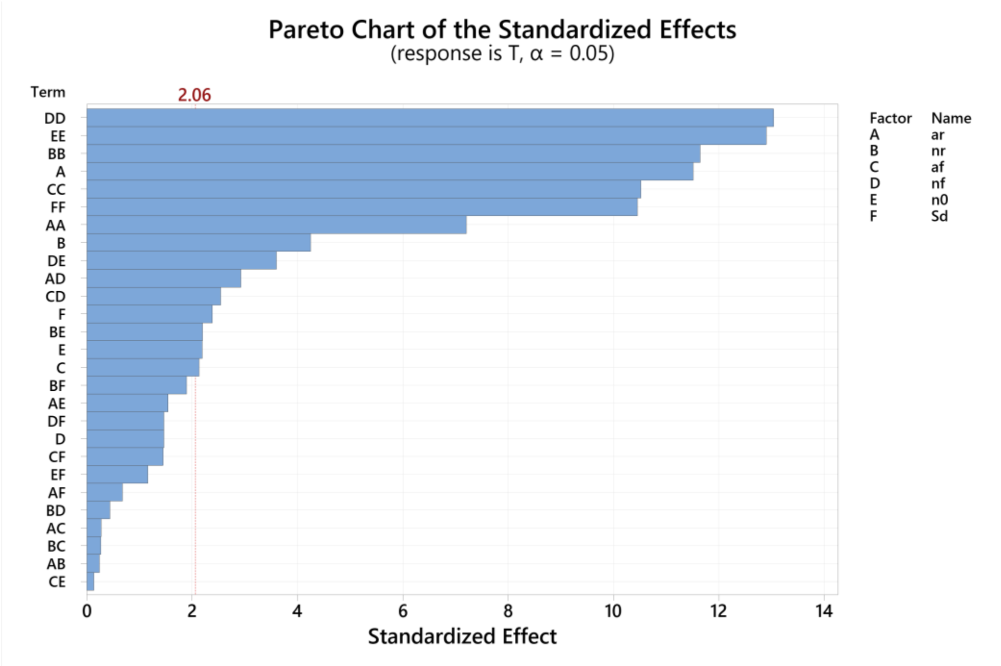

Fig 3. The influence degree of input factor on surface roughness

The figure 3shows clearly that the quadratic effect of DD (n_f*n_f) is largest, then followed by the effect of EE (n_0*n_0), BB (n_r*n_r), A (a_r), CC (a_f*a_f), FF (S_d*S_d), AA (a_r*a_r), B (n_r), DE (n_f*n_0), AD (a_r*n_f), CD (a_f*n_f), F (S_d), BE (n_r*n_0), E (n_0) and C (a_f).

The influence trend of the input factors is also determined and described in the figure 4.

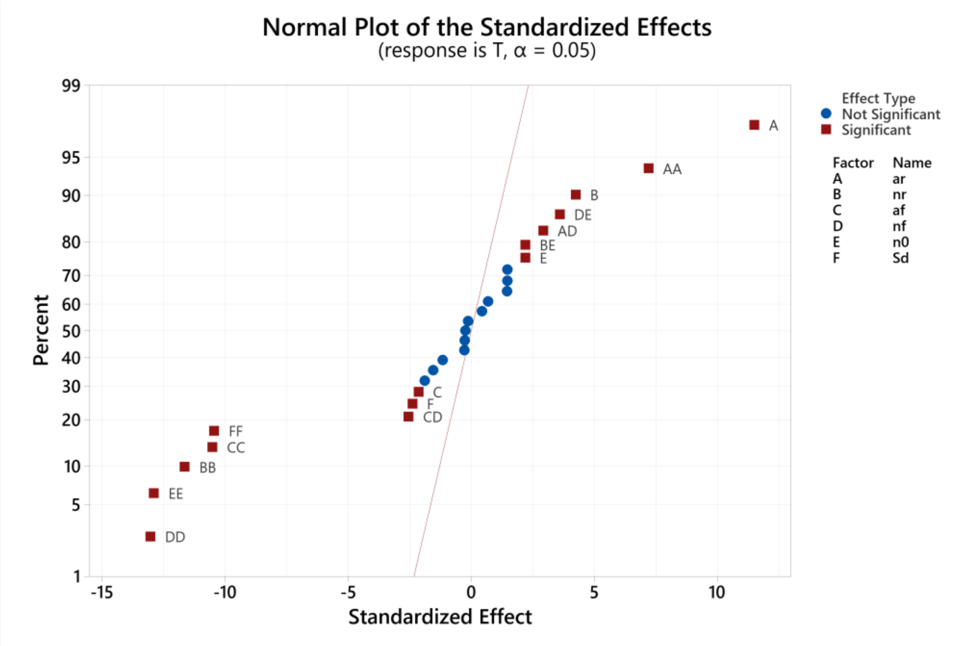

Fig 3. The normal plot of the standardized effects of input factors on wheel life time

The figure 4 indicated the following factors: A (a_r),AA (a_r*a_r),B (n_r),DE (n_f*n_0),AD (a_r*n_f),BE (n_r*n_0)E (n_0) have positive effect on the wheel life time. Otherwise, the factors DD (n_f*n_f),EE (n_0*n_0),BB (n_r*n_r), CC (a_f*a_f), FF (S_d*S_d), CD (a_f*n_f), F (S_d),C (a_f) have negative effect on the wheel life time.

The ANOVA method was applied to calculate the effect of input factors to output response. After remove the negligible influence factors, the analysis result is described in the table 4.

TABLE 4.ANALYSIS OF VARIANCE

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	16	311.649	19.4781	56.02	0.000
Linear	6	56.070	9.3450	26.88	0.000
ar	1	44.282	44.2817	127.36	0.000
nr	1	6.040	6.0401	17.37	0.000
af	1	1.525	1.5251	4.39	0.043
nf	1	0.718	0.7176	2.06	0.159
n0	1	1.607	1.6068	4.62	0.038
Sd	1	1.898	1.8984	5.46	0.025
Square	6	244.603	40.7671	117.25	0.000
ar*ar	1	17.349	17.3494	49.90	0.000
nr*nr	1	45.306	45.3060	130.31	0.000
af*af	1	36.985	36.9850	106.38	0.000
nf*nf	1	56.803	56.8029	163.37	0.000
n0*n0	1	55.601	55.6007	159.92	0.000
Sd*Sd	1	36.499	36.4990	104.98	0.000
2-Way Interaction	4	10.977	2.7443	7.89	0.000
ar*nf	1	2.865	2.8646	8.24	0.007
nr*n0	1	1.613	1.6129	4.64	0.038
af*nf	1	2.163	2.1632	6.22	0.017
nf*n0	1	4.337	4.3365	12.47	0.001
Error	37	12.864	0.3477		
Lack-of-Fit	32	12.799	0.4000	30.77	0.001
Pure Error	5	0.065	0.0130		
Total	53	324.514			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.589648	96.04%	94.32%	90.41%

The regression equation of wheel life time is described by the following model:

Regression Equation in Uncoded Units

T = 21.12 - 686 ar + 3.240 nr + 1571 af + 1.954 nf + 1.848 n0 + 22.04 Sd + 12988 ar*ar- 0.5247 nr*nr - 75850 af*af - 0.5875 nf*nf - 0.5812 n0*n0 - 7.535 Sd*Sd + 21.16 ar*nf+ 0.0794 nr*n0 - 52.0 af*nf + 0.1841 nf*n0

the optimal value of the input parameters to achieve the maximum wheel life time is determined by using Minitab R19 software base on the regression equation above.

TABLE 5.THE CALCULATED OF THE OPTIMAL VALUE OF THE INPUT PARAMETERS

Solution

Solution	ar	nr	af	nf	n0	Sd	T Fit	95% CI	Composite Desirability
1	0.04	3.2222	0.0094	2.2626	2.0202	1.4747	48.5840	(48.058,49.110)	1

From the optimal calculation results in table 5, an optimal set of dressing condition parameters can be obtained to achieve the longest wheel life time based on the adjustment range of the machine are a_r = 0.04 mm, n_r = 3 times, a_f = 0.01 mm, n_f = 2 times, n_0 = 2 times and S_d = 1.5 m/min. The predicted value of wheel life time corresponding to optimum dressing condition is 48.5840minutes. By the confident interval 95% the wheel life time is distributed in the range from 48.058 to 49.110 minutes.

IV. CONCLUSION

This study presents an investigation to determined the effect of dressing condition to wheel life time in external cylindrical grinding. The response surface method and ANOVA are applied to find the orthogonal array for the experimental plan. The following conclusions can be made:

- The effect of quadratic of DD (n_f*n_f) is largest, then followed by the effect of EE (n_0*n_0), BB (n_r*n_r), A (a_r), CC (a_f*a_f), FF (S_d*S_d), AA (a_r*a_r), B (n_r), DE (n_f*n_0), AD (a_r*n_f), CD (a_f*n_f), F (S_d), BE (n_r*n_0), E (n_0) and C (a_f).

- The influence trend of each parameter on the wheel life time has been determined also. The analysis result indicated that the parameters A (a_r),AA (a_r*a_r),B (n_r),DE (n_f*n_0),AD (a_r*n_f),BE (n_r*n_0)E (n_0) have positive effect on the wheel life time. Otherwise, the parameters DD (n_f*n_f),EE (n_0*n_0),BB (n_r*n_r), CC (a_f*a_f), FF (S_d*S_d), CD (a_f*n_f), F (S_d),C (a_f) have negative effect on the wheel life time.

- The regression equation for the relationship between dressing condition and wheel life time is determined as follows:

T = 21.12 - 686 ar + 3.240 nr + 1571 af + 1.954 nf + 1.848 n0 + 22.04 Sd + 12988 ar*ar- 0.5247 nr*nr - 75850 af*af - 0.5875 nf*nf - 0.5812 n0*n0 - 7.535 Sd*Sd + 21.16 ar*nf+ 0.0794 nr*n0 - 52.0 af*nf + 0.1841 nf*n0

- The optimum value of wheel life time is predicted in the range from 48.058 to 49.110 minutes with the confident interval up to 95% correspond to the optimal dressing condition isa_r = 0.04 mm, n_r = 3 times, a_f = 0.01 mm, n_f = 2 times, n_0 = 2 times and S_d = 1.5 m/min

Acknowledgment

The authors wish to thank Thai Nguyen University of Technology for supporting this work.

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