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Optimization Of Parameters In The SCM400 Steel Centerless Grinding Process

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***Abstract*—This paper presents a study to determine the optimal values of some parameters the SCM400 steel centerless grinding process. The machining parameters investigated in this study include the plunge feed rate, the dressing feed rate and the regulating wheel velocity. Test matrix in the form of Box – Behnken was applied to design tests. With three input parameters, the matrix has been designed with 15 tests, including 3 test points at the central points. From the test results, the influence of the plunge feed rate, the dressing feed rate and the regulating wheel velocity on surface roughness was analyzed. Surface roughness model in quadratic polynomial form was established in this study. Genetic algorithms have been used to determine the optimal values of the three parameters mentioned above. Finally, the direction for further research is proposed in this paper.**

Keywords—centerless grinding, SCM400 steel, surface roughness, optimization, genetic algorithm

1. Introduction

Centerless grinding is a machining method with high productivity and precision. This method is especially effective in the form of mass production. Surface roughness has a great influence on the workability and longevity of machine parts. Therefore, surface roughness has been interested by many scientists when studying centerless grinding technology. With the expectation that the machining surface has a small roughness, many studies have been conducted to adjust and select the values of the plunge feed rate, the dressing feed rate and the guide stone speed [1, 2]. Tables 1, 2 and 3 show the values of these parameters in several studies.

From the data in tables 1, 2 and 3, it is shown that for different cases of machined materials and the type of grinding wheel, the values of the plunge feed rate, the dressing feed rate and the regulating wheel velocity in the published studies are relatively different. Their values in such studies have been investigated over a relatively wide range. Surface roughness values in each study were also relatively different and also distributed in a relatively wide range. Thus, in order to reach small values of surface roughness, it is necessary to determine the values of the number of the plunge feed rate, the dressing feed rate and the regulating wheel velocity in each specific case. In this study, we will determine the optimal values of the three parameters above to ensure the smallest value of surface roughness in the SCM400 steel grinding process.

***Table 1**. Value of plunge feed rate in articles*

No.	S (μm/s)	Ra (μm)	Workpiece	Grinding wheel	Ref.
1	1÷21	0.44÷0.72	20X-carbon infiltration steel	Cn80-TB_1-G	[3]
2	33.33÷166.67	0.41÷0.79	EN52 steel	A80-N5-V45	[4]
3	8.33÷33.33	0.61÷0.94	-	-	[5]
4	16.67÷66.67	0.16÷0.36	EN52 steel	A100-L5-V45	[6]
5	20÷40	0.67÷1.34	9SMn28 steel	22A60L6V63L	[7]
6	0.83÷6.67	0.08÷0.58	Si_3N_4 ceramic and ZrO_2 ceramic	#2000SD and #4000SD	[8]

***Table 2**. Value of dressing feed rate in articles*

No.	*F (mm/min)*	Ra (μm)	Workpiece	Grinding wheel	Ref.
1	50÷550	0.32÷1.34	20X-carbon infiltration steel	Cn80-TB_1-G	[9]
2	5÷10	0.41÷0.79	EN52 steel	A80-N5-V45	[4]
3	100÷500	0.16÷0.36	EN52 steel	A100-L5-V45	[6]
4	200÷400	0.67÷1.34	9SMn28 steel	22A60L6V63L	[7]

***Table 3**. Value of regulating wheel velocity in articles*

No.	V (m/min)	Ra (µm)	Workpiece	Grinding wheel	Ref.
1	10.3÷53,2	0.4÷0.73	20X-carbon infiltration steel	Cn80-TB_1-G	[10]
2	48÷57.4	0.67÷1.34	9SMn28 steel	22A60L6V63L	[7]
3	43.2÷62.2	0.35÷1.33	9SMn28 steel	22A60L6V63L	[11]
4	25.1	0.26÷0.3	-	A-46-K6-VX	[12]

2. Grinding test

2.1. Test sample

The test sample is the SCM400 steel grade, which is often used to machining workpieces working under the conditions of abrasion and heat resistance. After heat treatment, the sample has a hardness of 54 ÷ 56HRC. Before the grinding test, the sample was lathed and pregrinded. The length and diameter of the grinding surface are 80 (mm) and 30 (mm), respectively. The chemical composition of the test sample is shown in Table 4.

Table 4. Chemical composition of SCM400 steel

C	Si	Mn	P	S	Cr	Mo	Ni	Cu
0.41%	0.25%	0.72%	0.03%	0.03%	1.1%	0.23%	0.25%	0.3%

2.2. Grinding machine, grinding wheel and regulating wheel

The tests were conducted on CNC centerless grinding machine with the symbol STC-2410.

The grinding wheel used in this study is an aluminum oxide stone with the symbol Cn100 TB_2 G V_1. The outside diameter, thickness and inside diameter of the grinding wheel are 480 (mm), 150 (mm) and 320 (mm), respectively.

The regulating wheel is made of rubber with the outside diameter, thickness and inside diameter of 250 (mm), 150 (mm) and 120 (mm), respectively.

2.3. Measuring devices

The roughness of machined surface is measured by SJ-200 machine. At each test, at least three steel samples will be grinded, the roughness of each sample will be measured three times, the roughness value for each test will be the average of successive measurements.

2.4. Design of experiment

The Box - Behnken test matrix was used to design tests in this study. Three input parameters to design the test matrix include the plunge feed rate, the dressing feed rate and the regulating wheel velocity. The values of these parameters at the encryption levels are shown in Table 5. Box-Behnken test matrix with 15 tests is shown in Table 6.

Table 5.Value of input parameters

Input parameter	Symbol	Unit	Value at levels		
			-1	0	1
Plunge feed rate	S	µm/s	2	6	10
Dressing feed rate	F	mm/min	100	300	500
Regulating wheel velocity	V	m/min	12	30	48

Table 6. Experimental matrix and result

	Code value			Actual value			Surface roughness
No.	S	F	V	S (µm/s)	F (mm/min)	V (m/min)	Ra (µm)
1	-1	1	0	2	500	30	1.42
2	-1	-1	0	2	100	30	0.34
3	1	0	1	10	300	48	1.32
4	0	-1	1	6	100	48	0.50
5	1	-1	0	10	100	30	0.90
6	0	1	1	6	500	48	1.58
7	0	0	0	6	300	30	1.16
8	0	0	0	6	300	30	1.22
9	0	1	-1	6	500	12	1.82
10	-1	0	1	2	300	48	0.76
11	0	-1	-1	6	100	12	0.74
12	0	0	0	6	300	30	1.24
13	-1	0	-1	2	300	12	1.00
14	1	0	-1	10	300	12	1.56
15	1	1	0	10	500	30	1.98

2.5. Grinding conditions

In addition to the input parameters for each experiment as shown in Table 6. The testing process is carried out with the following conditions: grinding wheel velocity: 34 (m/s), height of workpiece center: 12 (mm), machining stock according the radius: 0.05 (mm), The regulating wheel is rotated in the vertical plane at an angle of 0.5^0 and rotated in the horizontal plane at an angle of 0^0, grinding fluid is emusil (TOTAL firm), concentration of 6.5%, flow of 8 liters/min.

3. Results and discussion

Conducting tests according to the matrix in Table 6, the surface roughness at each test was also included in this table. From the data in this table, minitab 16 statistical software was used to analyze the data. Surface roughness model is expressed by the regression equation as in formula (1). In this model, the input parameters (S, F, V) are taken in encrypted form. This model has a determination coefficient R^2 = 0.9988, this value is very close to 1. This confirms that the rough surface model is very consistent with the test data.

$$Ra = 1.2067 + 0.28 * S + 0.54 * F - 0.12 * V - 0.0233 * (S^2 + F^2 + V^2) \quad (1)$$

Also from the data in Table 6, the graph showing the influence of the input parameters on surface roughness is presented in Figure 1. Observation of this figure shows that the dressing feed rate is the parameter that has the most influence on surface roughness, followed by the influence of the plunge feed rate, the regulating wheel velocity is the parameter that has the least influence on surface roughness. If increasing the dressing feed rate and the plunge feed rate, the surface roughness will increase rapidly. Meanwhile, if increasing the regulating wheel velocity, the surface roughness decreases slowly.

4. Optimization

The determination of the optimal values of the plunge feed rate, the dressing feed rate and the regulating wheel velocity is actually finding the values of these parameters in formula (1) to reach the smallest value of surface roughness. In the encrypted form of the input parameters, the optimal problem is written in the following form:

$$\begin{cases} Ra = f(S,F,V) \rightarrow min \\ Ra > 0 \\ -1 \le S,F,V \le 1 \end{cases} \quad (2)$$

The genetic algorithm has been applied to solve the problem (2) with the basic parameters of the algorithm including population number, hybrid probability, selected mutation probability with corresponding values of 150, 0.25, and 0.05 [13, 14]. The graph of the fitness function of surface roughness is presented in Figure 2. The results have determined the optimal values of the parameters of the plunge feed rate, the dressing feed rate and the regulating wheel velocity with the values of 2 (μm/s), 100 (mm/min) and 48 (m/min), respectively. It is interesting to note that the optimal values of the input parameters are located at the boundary of the surveyed ranges. When machining with this optimal value set of the plunge feed rate, the dressing feed rate and the regulating wheel velocity, the surface roughness has the smallest value of about 0.197 μm.

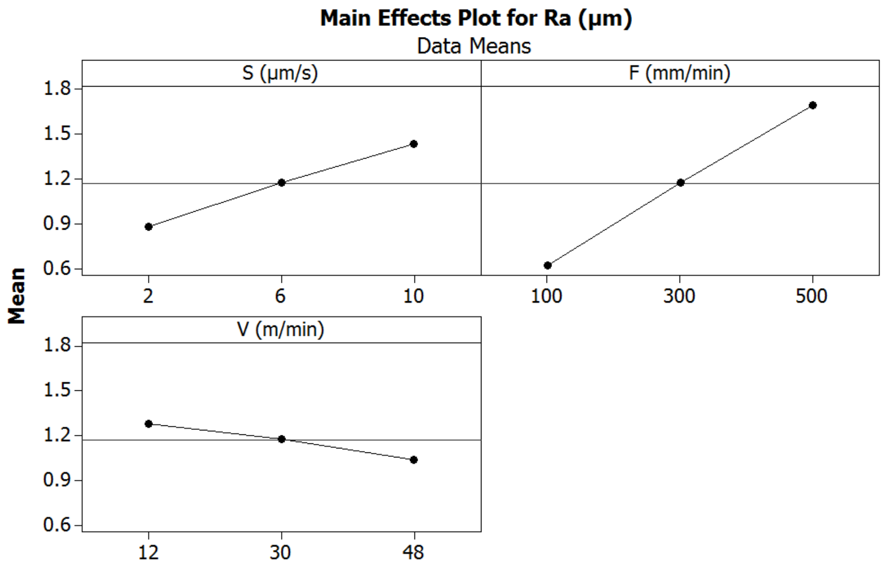

Fig 1. Main effects plot for Ra

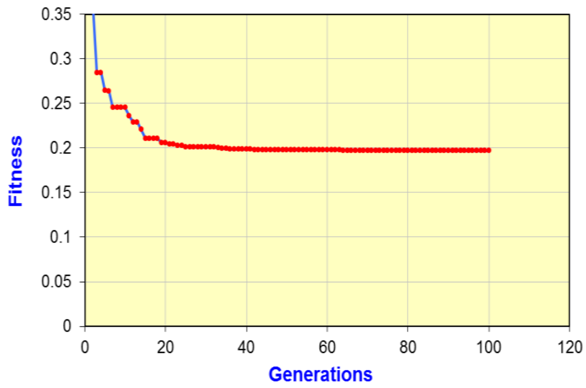

Fig 2. Graph of fitness function of surface roughness

5. Conclusion

Some conclusions drawn in SCM400 steel centerless grinding process are as follows:

✓ The dressing feed rate has a great influence on the surface roughness, when increasing the dressing feed rate, the surface roughness increases quickly. The feed rate also has a significant influence on surface roughness, and the roughness will also increase if the feed rate increases. When the regulating wheel velocity increases, surface roughness will decrease. However, the regulating wheel velocity affects the surface roughness less than the influence of the feed rate and the dressing feed rate.

✓ The optimal values of the plunge feed rate, the dressing feed rate and the regulating wheel velocity are 2 (µm/s), 100 (mm/min) and 48 (m/min), respectively.

✓ The study determined the optimal values of the plunge feed rate, the dressing feed rate and the regulating wheel velocity when considering the change of some other parameters (type of grind stone, stone speed, characteristics of the machined material), they are the directions for further studies.

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