

Exploration on Wire Discharge Machining Added Powder for Metal-Based Diamond Grinding Wheel on Wire EDM Dressing and Truing of Grinding Tungsten Carbide Material

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Abstract. In this paper, the effects of material removal rate and abrasive grain protrusion on the metal-based diamond grinding wheel were studied to find the optimal parameters for adding powder and wire discharge. In addition, this kind of electric discharge method to add powder on the metal-based diamond grinding wheel on line after dressing and truing will be applied on tungsten carbide to study the grinding material removal rate, grinding wheel wear, surface roughness, and surface micro-hardness.

1. Introduction

It is important that grinding wheel surface abrasive to maintain the appropriate amount of protrusion in order to have a good processing quality. Grinding process will produce high temperature, adhesion and other effects and abrasive will wear, loss of the original geometry and size; due to high-speed grinding of the grinding debris is extremely small and easy to block the surface of the grinding wheel. In order to make the diamond grinding wheel to maintain a good grinding state, it is necessary for grinding wheel dressing and truing after the abrasive wear. The shaping and repairing principle of the grinding wheel is to remove the metal bonding agent from the surface of the grinding wheel, so that the abrasive grains are prominent to increase the grinding performance. In order to make the diamond grinding wheel to maintain a good grinding state, it is necessary for grinding wheel dressing and truing after the abrasive wear. The shaping and repairing principle of the grinding wheel is to remove the metal bonding agent from the surface of the grinding wheel, so that the abrasive grains are prominent to increase the grinding performance. Wire EDM is often used conductive material as a binding agent for grinding wheel dressing and truing which is employing a forming conductive electrode to grind wheel for dressing and sharpening [1-3]. Diamond grinding wheel hardness, wear resistance, compressive strength and thermal conductivity and other characteristics, known as super abrasive, when the processing components required ultra-precision, diamond grinding wheel has gradually replaced the silicon carbide wheel, alumina wheel [4]. The metal method is a powder metallurgy with a metal powder as a binder. Metal-based diamond grinding



wheel has good abrasive adhesion、thermal conductivity, and excellent abrasion resistance, can maintain a sharp shape after grinding. It can be applied to the ultra-precision grinding like mirror grinding, non-ferrous metal or non-metallic cutting difficult materials, high-performance ceramic high-speed grinding and forming grinding [5].

2. Experimental method

In this study, the electric discharge method to add powder on the metal-based diamond grinding wheel on line after dressing and truing will be applied on tungsten carbide to study the grinding material removal rate, grinding wheel wear, surface roughness, and surface micro-hardness. Experimental procedure is shown in Figure 1. Taguchi method is applied to analyse and conduct the experiment by assigning the grinding parameters shown Figure 1, then L18 experimental array will be used to conduct the experiments and the optimal level combination will be found out.

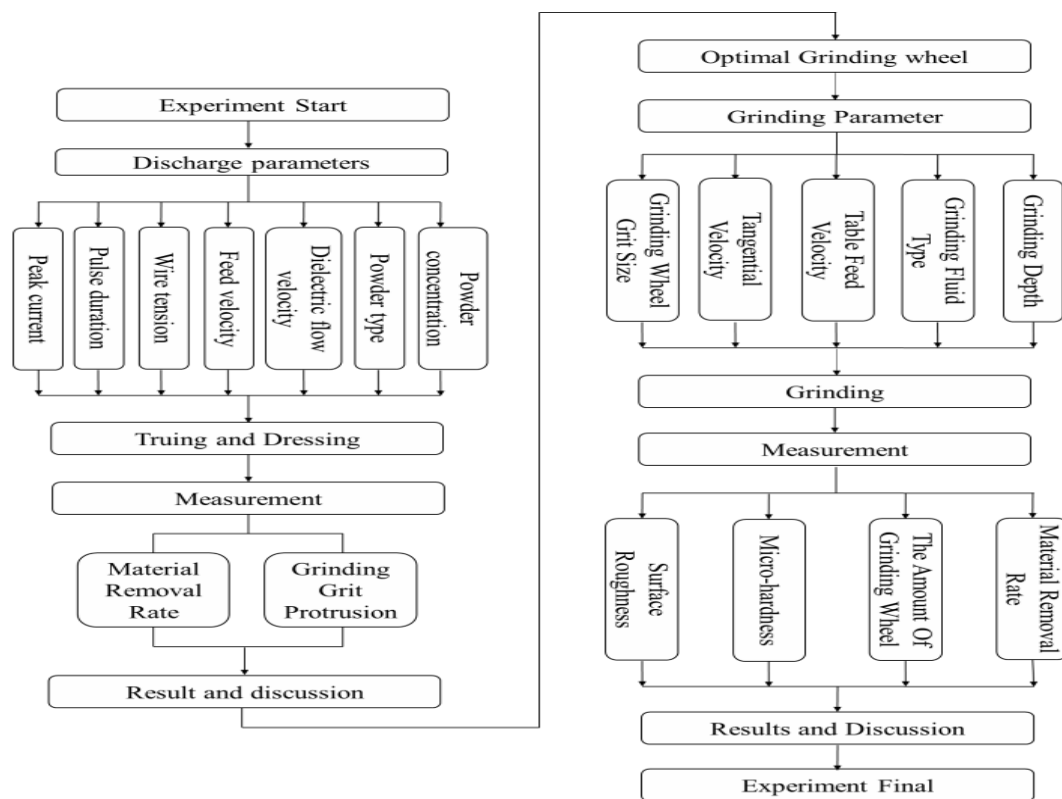


Figure 1. Experimental architecture flowchart

2.1 Experimental materials

Table 1 Powder characteristics

	Aluminum	Silicon carbide	Chromium
Particle size	1~3 μm	1~3 μm	1~5 μm
Bulk density g/cm ³	1.143	1.254	1.775
Purity	99.5%	99.5%	99%
1.75cm ³ /L	2.000g	2.194g	3.106g
3.5cm ³ /L	4.000g	4.389g	6.212g
7cm ³ /L	8.000g	8.778g	12.425g

The consumable equipment used in this study contains metal-based diamond wheels, copper electrodes, aluminum powder, silicon carbide powder, chromium powder, and tungsten carbide blocks shown in Table 1.

2.2 Adding powder to the EDM experiments

The parameters are discharge current, pulse time, feed rate, wire tension, dielectric fluid flow rate and the concentration of three kinds of powder processing fluid shown in Table 2. The 18 sets of experimental models are established to obtain the optimal combination of discharge parameters shown in Table 3. In this study, there are two characteristic points observed, large the better (LTB) material removal rate (MRR) and nominal the better (NTB) abrasive grain (Grinding Grit Protrusion, GGP). As the diamond abrasive particles in the binder is irregularly distributed and dispersed, so each combination before the experiment carbon steel blocks must be grounded and the new datum plane can be defined in the modification of the experiment to avoid interference between the experiments.

In this study, the removal rate and the amount of protrusion were calculated by the average roughness (R_a) and ten point roughness (R_z), respectively. From the Taguchi experiment, a better set of discharge parameters and factor responses are obtained. Then the confirmation of the experiments will be conducted. To prove that this experiment is suitable for the diamond wheel of each particle size, the # 100 diamond grinding wheel with a particle size of about 150 and # 1000 diamond grinding wheel particle size is about 13 were chosen. And then to explore the different diameter of the grinding wheel processing methods and parameters. The center line as a benchmark to the bottom of the curve refraction shown in Figure 2, and then calculate the center line above the full curve after the curve covered by the area, and then divided by the measured length, the resulting value in μm units, that is, the length of the processing surface within the measurement center line average surface roughness value shown in Figure 3.

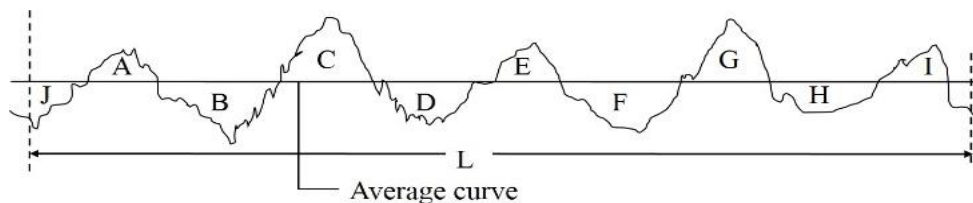


Figure 2 Curve average line

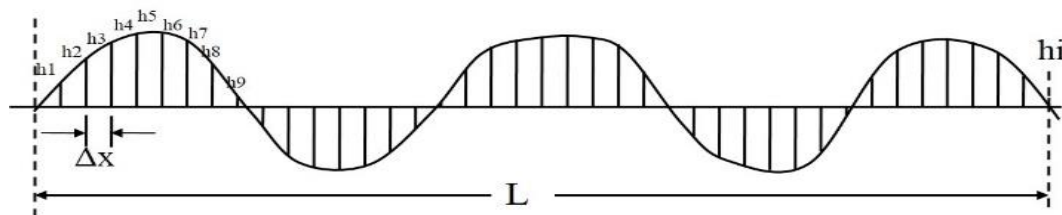


Figure 3 Central line average surface roughness (R_a)

Table 2 Discharge experimental factors and levels

Factor	A	B	C	D	E	F	G
Level	Peak current (Amp)	Pulse time (μs)	Feed rate (mm/min)	Line tension (kgf)	Dielectric flow rate (mm/s)	Powder type	Powder Concentration (g/l)
I	1	10	0.5	1	0.05	AL	1.75
II	3	20	1	3	0.10	SiC	3.5
III	5	30	2	5	0.15	Cr	7

Table 3 $L_{18}(3^7)$ experiment parameters and levels

Exp	A	B	C	D	E	F	G
	Peak current (Amp)	Pulse time (μ s)	Feed rate (mm/min)	Line tension (kgf)	Dielectric flow rate (mm/s)	Powder type	Powder concentration
1	1	10	0.5	1	0.05	Al	1.75
2	1	20	1	3	0.1	SiC	3.5
3	1	30	2	5	0.15	Cr	7
4	1	10	0.5	1	0.1	Cr	7
5	1	20	1	3	0.15	Al	1.75
6	1	30	2	5	0.05	SiC	3.5
7	3	10	1	3	0.05	SiC	7
8	3	20	2	5	0.1	Cr	1.75
9	3	30	0.5	1	0.15	Al	3.5
10	3	10	1	5	0.15	SiC	1.75
11	3	20	2	1	0.05	Cr	3.5
12	3	30	0.5	3	0.1	Al	7
13	5	10	2	3	0.15	Cr	3.5
14	5	20	0.5	5	0.05	Al	7
15	5	30	1	1	0.1	SiC	1.75
16	5	10	2	5	0.1	Al	3.5
17	5	20	0.5	1	0.15	SiC	7
18	5	30	1	3	0.05	Cr	1.75

2.3 Tungsten carbide grinding experiment

In order to obtain the optimal parameter combination, the parameters for the wheel size, tangent speed, bed feed, cutting fluid and grinding depth are selected to conduct experiments shown in Table 4. There are three types of quality characteristics such as small the better (STB), large the better (LTB), and nominal the better (NTB). In this experiment, four observations were roughness (STB), micro hardness (STB), abrasion (STB), and material removal rate (LTB). The Taguchi experiment array is shown in Table 5.

Table 4 Grinding experiment factor and level

Factor Level	A	B	C	D	E
	Grain size	Grinding Wheel rate(m/s)	Feed rate(mm/s)	Cutting fluid	Grinding depth(mm)
I	100#	27.1	12	water	0.005
II	1000#	31.6	24	Emulsifier	0.010
III	None	36.1	36	oil	0.015

Table 5 $L_{18}(3^5)$ experimental parameter array

Exp	A Grain size	B Grinding wheel rate(m/s)	C Feed rate(mm/s)	D Cutting fluid	E Grinding depth(mm)
1	100	27.1	12	water	0.01
2	100	27.1	24	Emulsifier	0.015
3	100	27.1	36	Oil	0.02
4	100	31.6	12	Water	0.015
5	100	31.6	24	Emulsifier	0.02
6	100	31.6	36	Oil	0.01
7	100	36.1	12	Emulsifier	0.01
8	100	36.1	24	Oil	0.015
9	100	36.1	36	Water	0.02
10	1000	27.1	12	Oil	0.02
11	1000	27.1	24	Water	0.01
12	1000	27.1	36	Emulsifier	0.015
13	1000	31.6	12	Emulsifier	0.02
14	1000	31.6	24	Oil	0.01
15	1000	31.6	36	Water	0.015
16	1000	36.1	12	Oil	0.015
17	1000	36.1	24	water	0.02
18	1000	36.1	36	Emulsifier	0.01

3. Result and discussion

3.1 Large particle size diamond grinding wheel dressing

The results showed that the experimental combination with the optimal material removal rate was 17, the removal rate was 5.921 mm³ / min, and the optimal removal rate of Taguchi experiment was 5.76 mm³ / min. The experimental combination with the optimal protrusion is the 14th combination and the abrasive grain protrusion is 74.711 μm. The experimental results are 75.478 m shown in Table 6. Figure 4 shows the large diameter diamond wheel before and after dressing from SEM photos.

Table 6 Removal rate of abrasive material and abrasive grain protrusion

EXP (100)	A Peak current (Amp)	B Pulse time (μs)	C Feed rate (mm/min)	D Line tension (kgf)	E Dielectric flow rate (mm/s)	F Powder type	G Powder concentration	GGP (μm)	MMR (mm ³ /min)
L1	1	10	0.5	1	40	Al	1.75	68.716	4.757
L2	1	20	1	3	50	SiC	3.5	66.675	5.062
L3	1	30	2	5	60	Cr	7	62.358	5.310
L4	3	10	0.5	3	50	Cr	7	65.434	5.075
L5	3	20	1	5	60	Al	1.75	75.779	4.407
L6	3	30	2	1	40	SiC	3.5	68.304	5.776
L7	5	10	1	1	60	SiC	7	71.337	5.563
L8	5	20	2	3	40	Cr	1.75	68.429	5.059
L9	5	30	0.5	5	50	Al	3.5	77.929	5.162
L10	1	10	2	5	50	SiC	1.75	66.573	4.798
L11	1	20	0.5	1	60	Cr	3.5	69.769	5.167
L12	1	30	1	3	40	Al	7	70.245	4.836
L13	3	10	1	5	40	Cr	3.5	65.984	5.194
L14	3	20	2	1	50	Al	7	74.711	5.153
L15	3	30	0.5	3	60	SiC	1.75	71.859	4.817
L16	5	10	2	3	60	Al	3.5	78.833	5.733
L17	5	20	0.5	5	40	SiC	7	69.154	5.921
L18	5	30	1	1	50	Cr	1.75	70.077	4.871
Best GGP	3	20	1	1	60	Al	7	75.478	
Best MMR	5	10	2	1	40	SiC	3.5		5.760

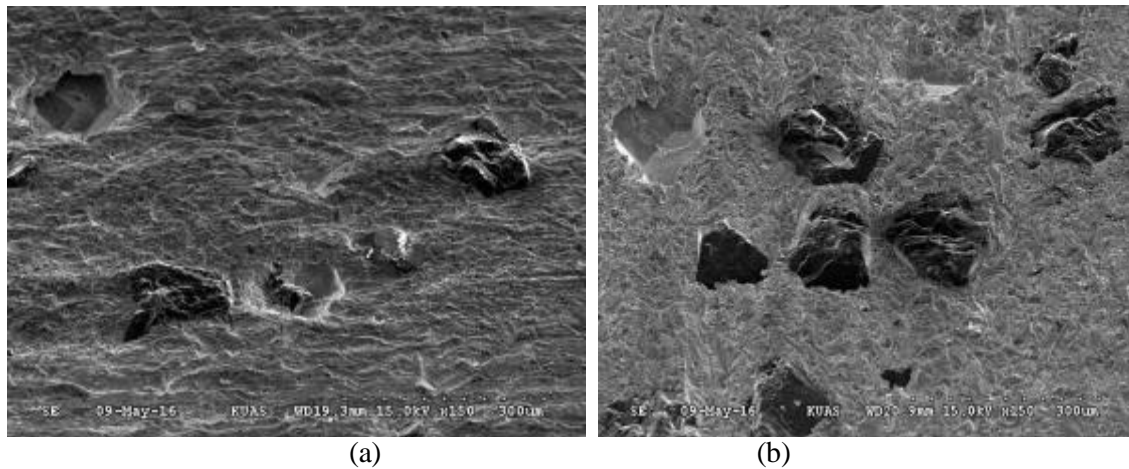


Figure 4 Large diameter diamond wheel (a) before dressing (b) after dressing

3.2 Small particle size diamond grinding wheel dressing

The results showed that the experimental combination with the optimal material removal rate was the seventh combination with the removal rate of 3.357 mm³ / min, and the optimal removal rate of Taguchi was 3.208 mm³ / min. The optimal experimental parameter combination is the fourth group, the protrusion is 8.621 μm, and the optimal experimental value of Taguchi is 8.478 μm in this study shown in Table 7. The SEM photos of small diameter diamond wheel before and after dressing are in the Figure 5.

Table 7 Removal rate and protrusion of small particle size wheel

EXP (1000)	A Peak current (Amp)	B Pulse time (μs)	C Feed rate (mm/min)	D Line tension (kgf)	E Dielectric flow rate (mm/s)	F Powder type	G Powder concentrat ion	GGP (μm)	MMR (mm ³ /min)
L1	1	10	0.5	1	40	Al	1.75	11.743	2.985
L2	1	20	1	3	50	SiC	3.5	10.624	3.017
L3	1	30	2	5	60	Cr	7	9.213	2.737
L4	3	10	0.5	3	50	Cr	7	8.621	2.804
L5	3	20	1	5	60	Al	1.75	11.570	2.864
L6	3	30	2	1	40	SiC	3.5	10.097	3.173
L7	5	10	1	1	60	SiC	7	13.123	3.357
L8	5	20	2	3	40	Cr	1.75	11.795	3.006
L9	5	30	0.5	5	50	Al	3.5	16.218	2.958
L10	1	10	2	5	50	SiC	1.75	9.845	3.120
L11	1	20	0.5	1	60	Cr	3.5	9.232	2.831
L12	1	30	1	3	40	Al	7	10.538	2.858
L13	3	10	1	5	40	Cr	3.5	10.753	2.901
L14	3	20	2	1	50	Al	7	11.623	2.985
L15	3	30	0.5	3	60	SiC	1.75	11.295	2.732
L16	5	10	2	3	60	Al	3.5	16.328	2.842
L17	5	20	0.5	5	40	SiC	7	11.661	3.130
L18	5	30	1	1	50	Cr	1.75	12.960	2.953
Best GGP	1	20	0.5	3	40	Cr	7	8.478	
Best MMR	5	10	2	1	40	SiC	7		3.208

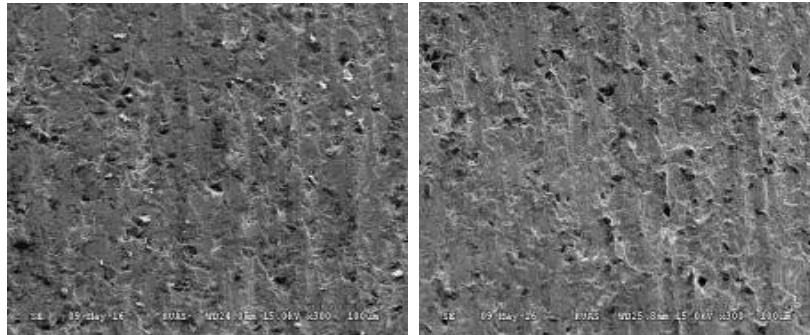


Figure 5 Small diameter diamond wheel (a) before the dressing (b) after finishing

3.3 Grinding results

The grinding results show that the roughness of the machined surface is optimal in the 14th combination, the roughness is 0.184 μm , the optimal roughness of Taguchi is 0.175 μm . The experimental combination with the optimal micro hardness of the machined surface is the fifth combination with the hardness value of 2046Hv and the optimal hardness of Taguchi is 1980Hv.

The optimal experimental combination of diamond grinding wheel wear is the seventh combination, the wear amount is 0.020 mm and the Tanaka is 0.020 mm. The optimal level for removal rate was 3, the removal rate was 3.1589.

3.4 Discussions

Large diameter diamond grinding wheel dressing in the addition of powder caused by excessive conductive particles easily interfere with the discharge phenomenon, so that the discharge is unstable and refer to surface roughness deterioration, simultaneously the material removal rate is low. After adding the powder, the amount of abrasive grains is increased because the conductive particles increase in the processing fluid, and both the discharge gap and the processing depth increases.

Small diameter diamond grinding wheel in the addition of powder due to the increase in conductivity which is easy to cause the phenomenon of bridge, the discharge gap increases, so that the processing depth increases, so the material removal rate increased. After adding the powder, the amount of protrusion is too large to cause the abrasive particles to fall off.

4. Conclusions

This study has the following four conclusions

(1) The results show that the optimal parameters of the surface roughness experiment are combination 14, the grinding wheel has a grain size of 1000, a tangent speed of 31.6 m / s, a bed feed of 24 mm / s, a cutting fluid of oil, a grinding depth of 0.01 mm, and a surface roughness of 0.184 μm . The optimal Taguchi parameters are grinding wheel size 1000, tangential speed 31.6 m / s, bed feed 36 mm / s, cutting fluid is oil, grinding depth 0.02 mm, roughness 0.175 μm .

(2) The results also show that the optimum parameters for micro hardness experiment are combination 5, the grinding wheel has a grain size of 100, a tangent speed of 31.6 m / s, a bed feed of 24 mm / s, a cutting fluid of water + oil, a grinding depth of 0.02 mm, a micro hardness of 2046 Hv. The optimal Taguchi parameters include a grinding wheel size of 1000, a tangent speed of 31.6 m / s, a bed feed of 24 mm / s, a cutting fluid of water + oil, a grinding depth of 0.02 mm and a micro hardness of 1980 hv.

(3) Then, the optimal parameters for abrasive test are combination 7, the grinding wheel has a particle size of 100, a tangent speed of 36.1 m / s, a bed feed of 12 mm / s, a cutting fluid of water + oil, a grinding depth of 0.01 mm, and a wear of 0.020 Mm. The optimal parameters of Taguchi are wheel size 100, tangent speed 31.6 m / s, bed feed 12 mm / s, cutting fluid is water + oil, grinding depth 0.01 mm.

(4) Finally, the best parameters for material removal rate was the third combination, the grinding wheel size was 100, the tangent speed was 27.1 m / s, the bed feed with was 36 mm / s, the cutting fluid was oil, the grinding depth was 0.02 mm, the material removal rate (MRR) of 3.15887. The optimal Taguchi parameters are wheel size 100, tangent speed 31.6 m / s, bed feed 36 mm / s, cutting fluid is water + oil, grinding depth 0.02 mm, material removal rate is 4.0034.

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