Surface ruggedness processing of cylindrical Cu-Zn wire with wet blasting

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Abstract

To reduce the machining cost and energy, the higher removal rate has been required on the wire cut electrical discharge machining (WEDM) method. Some experimental trials have been applied to improve the machining properties on the WEDM using the coated and/or the rugged wire materials. As the appropriate technology has not been established on the rugged wire machining method, the expected results have not been obtained yet. In this paper, we propose a new method of the wet blasting technology that was designed and made by ourselves. In this method the ZrO_2 abrasives were exhausted from the three nozzles with the compressed water jet on the feeding wire surface. The cylindrical Cu-Zn wire surface was deformed and the rugged shapes depended on the compressed air pressure, the abrasive size and shape, and the feeding speed of wire electrode material. The relation between the wet blasting condition and the formed ruggedness shape was discussed. In addition, the mechanical properties of the rugged wire were investigated by the tensile test.

Keywords: wire cut electrical discharge machining, wet blast, cemented carbide.

1 Introduction

On the wire electrical discharge machining (WEDM) method, to obtain better discharge machining properties of removal rate and surface roughness, many experimental trials have been carried out. Some researcher reported that when the discharge machining was carried out with the rough surface of the workpiece or tool electrode, the electrical discharge delay time became shorter than the

WIT Transactions on Engineering Sciences, Vol 62,
www.witpress.com, ISSN 1743-3533 (on-line)
doi:10.2495/SECM090131

smooth surface [1]. The removal rate could be improved within a few percent [2–4]. In these reports, the effect was discussed with the difference of surface roughness level. Recently, we have succeeded in making the new machining machine of constant rugged surface on the wire tool electrode. This is called the wet blasting method.

The electric discharge machining characteristic improves by using the wire that gives the ruggedness by the wet blasting method [5]. The reason is that it becomes difficult for the wire to be broken, and the electrical discharge machining by a high current becomes possible. On the WEDM, two dimensional complex arbitrary shapes were made by the controlled system that was attached onto the machine with the feeding wire. The discharged point on the wire surface moved with the constant speed and dispersion accordance with the machining direction.

To obtain the precise shape, the vibration motion must be avoided. The wire was pulled with a moderate tensile force between the tension roller. Considering the used condition of wire on the WEDM, the rugged creator must be impressed on the whole surface constantly and continuously. The mechanical properties of rugged wire must be bigger than the pulled force. When the discharge occurred at a high current condition, the wire was melted at the local region and elongated to breaking point. The authors have reported before that the broken limit current value expanded bigger zone using the rugged wire [6].

In this paper, to clarify the effects of the wet blasting method as a new machining technology of rugged surface on Cu-Zn wire, the machining condition and the mechanical strength was investigated with a variation of experimental factors.

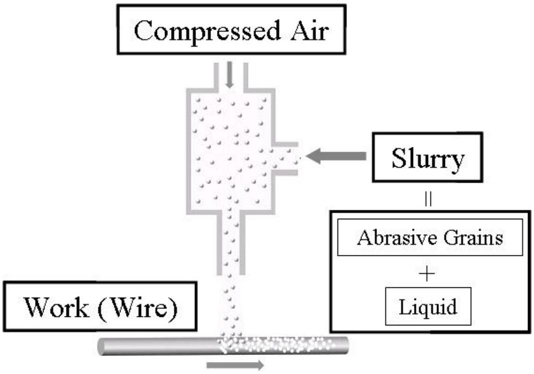

Figure 1: Wet blasting method.

2 Experimental method

Figure 1 shows the outline of the wet blasting method. It is composed of the slurry box in which the abrasives and the liquid was mixed, air compressor and jet nozzle. The mixed abrasives and liquid was exhausted by the compressor air to the jet nozzle. Figure 2 shows the outline of the wet blasting device used in this research. To deform the all wire surface constant condition the jet nozzles were arranged every 120° as shown in Fig. 3. The ruggedness could be detailed on all the wire surface area as shown in Fig. 4. The machining conditions were controlled by the following factors: (1) the compressed air pressure, (2) the size and shape of abrasive, and abrasive density, and (3) the wire feed speed. It is considered that the ruggedness and distribution of the deformed crater would be controlled by these experimental factors. Table 1 shows the wet blasting conditions. In this experiment, ZrO_2 powder was selected as the abrasive. The abrasives were filtered to the size region of 60 to 130 μm. As the Cu-Zn wire of ϕ 0.2 was used normally on the WEDM method, it was selected to the workpiece.

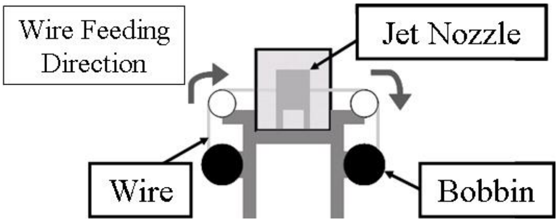

Figure 2: Schematic drawing of the wet blasting device.

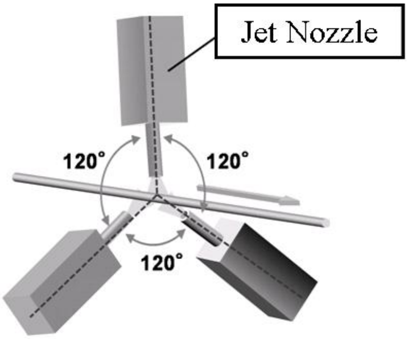

Figure 3: Triangularly arranged jet nozzles.

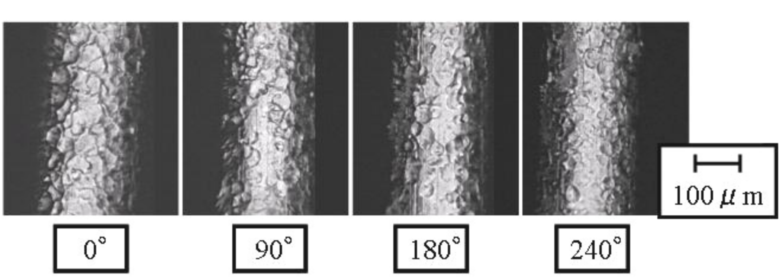

Figure 4: The images of all ruggedness wire surface.

3 Results and discussions

3.1 Influence of the wet blasting condition on the rugged surface shape

3.1.1 Wire feed speed

The effects of the feeding speed of wire electrode on the rugged shape of the wire were investigated. The wet blasting condition used for this experiment is shown in Table 1. The rugged surface shape of the wire was observed with the light microscope. The results are shown in Fig. 5.

The ruggedness of the deformed area by abrasive decreased with increasing the feeding speed of wire electrode material. On a fast feeding speed condition, the rugged crater could not cover the entire deformed surface. It indicated that the exhausted ZrO_2 abrasive could not collide with the feeding wire surface under high speed motion.

3.1.2 Compressed air pressure

To confirm the effects of the compressed air pressure on machining the rugged crater shape, the experiment was carried out using the condition of Table 2. The compressed air pressure changed from 0.1 to 0.4 MPa under the wire feeding speed of 250mm/min. The observation results using the microscope on the rugged surface are shown in Fig. 6. The indentation height was estimated with the focus depth method. The difference depth from the bottom to the raised part of the indentation was measured, show in Fig. 7. Figure 8 shows the measurement results on each compressed air pressure.

On the lower pressure condition of 0.1MPa, a few shallow craters could be observed. On the other hand, with higher pressure condition, over 0.2MPa, many clear-cut craters could be observed on each deformed surface. Many types of creator shape and size were recognized on each machined condition. The mean crater depth became large with increased compressed air pressure. However, the deviations of indentation length values were so large that it was difficult to discuss the dependency of pressure over the 0.2MPa. The abrasive diameter range spread over a wide area from 63 to 126 μm. The rugged crater shape and size was changed with the following on the collision direction and the abrasive size. As the collusive energy was controlled by the mass and velocity of abrasive, the deviation of the abrasive size and the impact direction with the wire affected the rugged crater size and shape. The mechanism is summarized in Fig. 9.

3.2 Machining condition of the whole rugged surface

Considering the EDM processing, it is assumed that better machining properties would be obtained under dispersed discharge generation condition. When many rugged craters were impressed on the surface of the wire, the probability of the discharge generation would be increased. The electrical discharge is assumed to occur in the concentrating area in the electric field. The electrical discharge is distributed to this area uniformly. The rugged crater must be deformed on the whole wire surface. To machine the constant rugged crater on the tool wire

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Table 1: Wet blasting conditions.

Experiment No.	1-1	1-2
Wire feed speed [mm/s]	50, 150, 250	250
Compressed air pressure [MPa]	0.3	0.1, 0.2, 0.3, 0.4
Abrasive substance	Globular ZrO_2	
Abrasive diameter [μm]	63 ~ 126	
Abrasive density [vol.%]	10	

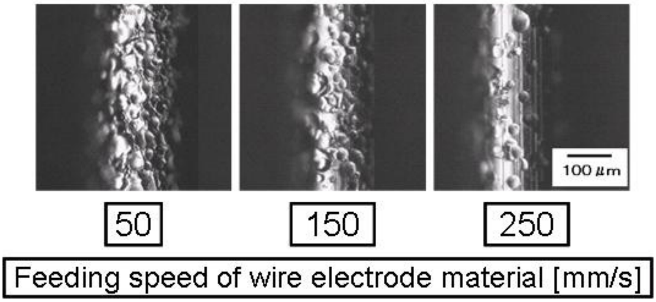

Figure 5: The images of the rugged wire surface with respective feeding speed.

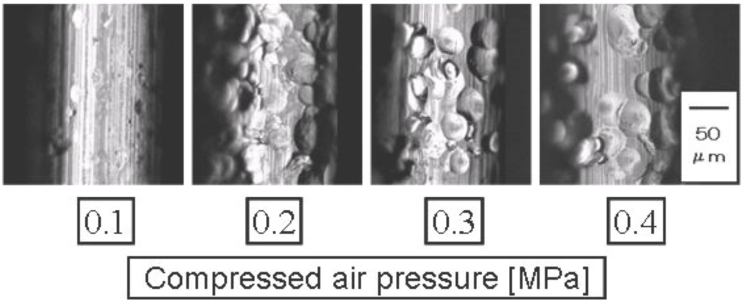

Figure 6: The images of rugged wire surface with respective compressed air pressure.

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electrode, the experimental factors of the abrasive size, constituent of the ZrO_2 abrasives in the machining water and the compressed pressure were investigated. In this experiment, the abrasive density of 20 vol.% was selected, as mentioned, the fine rugged crater couldn't be detailed on the feeding speed of 250 mm/s and the abrasive density of 10 vol.%. The experimental feeding speed of wire electrode material is 250 mm/s in consideration of productivity. But, when the feeding speed of wire electrode material was 250, the ruggedness could not be given to the whole wire surface. Consequently, the feeding speed of wire electrode material of 200 mm/s and the abrasive density of 20 vol.% was selected. The other conditions were selected as follows. The compressed air pressure is 0.2 and 0.4 MPa that is higher than 0.1 MPa. Abrasive has a diameter of 106–126 μm and 45–75 μm. Table 2 shows these wet blasting conditions. An unprocessed wire was called normal.

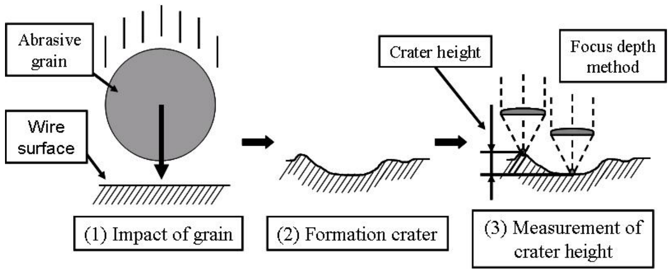

Figure 7: Schematic illustration of crater formation process and measurement of the crater height.

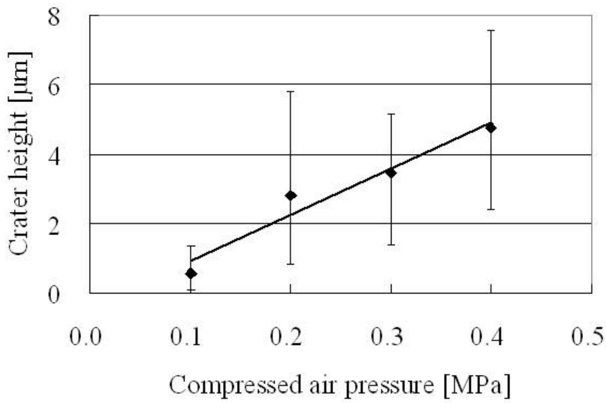

Figure 8: Relationship between compressed air pressure and crater height.

The surface of the rugged wire was observed with the laser microscope, and the results are shown in Fig. 10. The deviations of indentation over the length were too large to discuss. In this experiment, surface roughness of rugged wire is discussed by the surface roughness Ra, the result are shown in Fig. 11. Surface roughness Ra is calculated from the surface profile measured by the laser microscopy. As a result, there is not so much deviation on each pressure point.

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The surface roughness Ra of the rugged surface was increases by the compressed air pressure. The diameter of the indentation increases when the abrasive diameter is large and the distribution of the ruggedness changes. It appeared that average rugged crater depth was related to the compressive pressing under the conditions.

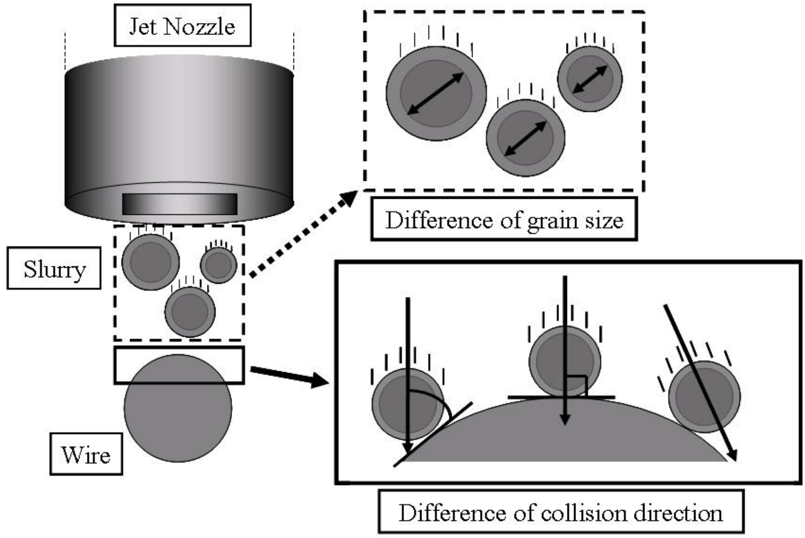

Figure 9: Disturbances in crater height control.

Table 2: Wet blasting condition with various wire feed speed and compressed air pressure.

Wire name	PB02L1	PB04L2	PB02A	PB04A
Wire feed speed [mm/s]	200			
Compressed air pressure [MPa]	0.2	0.4	0.2	0.4
Abrasive substance	Globular ZrO_2			
Abrasive diameter [μm]	106 ~ 126		45 ~ 75	
Abrasive density [vol.%]	20			

3.3 Mechanical properties of ruggedness wire

After the wet blasting machining, the mechanical properties of the wire would be varied with the generation of work hardening, residual stress and the stress concentration on the rugged area. If the tensile strength of the rugged wire became less than the pulling stress, the wire could not be applied for WEDM process. In this paper, the tensile strength of the rugged wire was investigated. It was well-known that almost all the breakage occurred out of the gage length area on the tensile test of thin wire. More than 90%, the failure was detected around the chuck zone. It indicated that many specimens were needed to evaluate the accurate tensile strength value of wire. In this experiment, the tensile test is carried out with the Instron type tensile machine as shown in Fig. 12. The following conditions were selected: gauge length of 10 mm, and crosshead speed of 1mm/min. The new chucking system was designed with the O-ring. The estimated wires were PB02A and PB04A and normal wire. Using the O-ring as the chucking attachment material, the breakage position was detected at the centre of gage length at least more than 10% with small deviation. Figure 13 shows the breaking stress and the breaking strain obtained from the tensile test. Fracture pattern of the pulled out wire is observed with the light microscope, and the result is shown in Fig. 14.

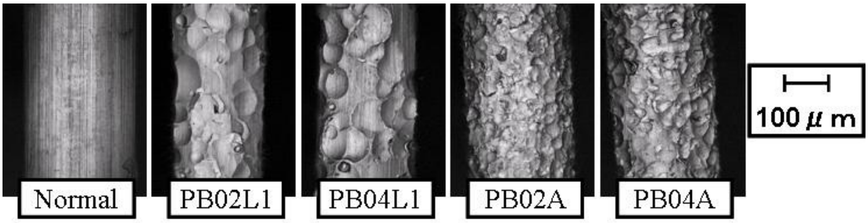

Figure 10: The image of rugged wire surface with respective compressed air pressure and abrasives diameter.

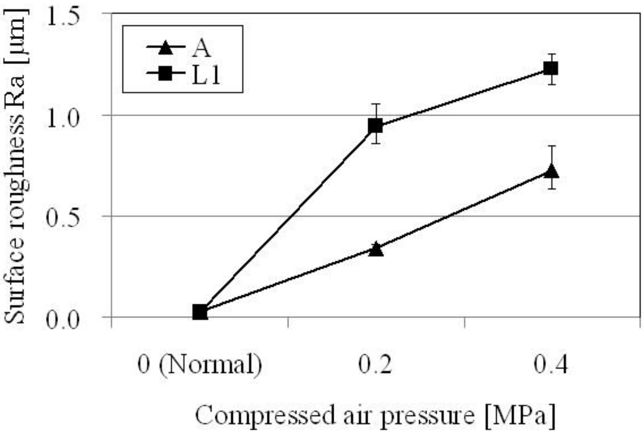

Figure 11: Relationship between compressed air pressure and surface roughness Ra.

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The fracture stress and the strain of the rugged wire decreased with increasing the compressed air pressure. The fracture pattern of normal wire showed the ductile fracture with the necking, but on the rugged wire it turned to the shear type failure. It was assumed that on account of the work hardening and the residual stress, the tensile strength of rugged wire became smaller than the normal wire. However, tensile strength of a rugged wire was enough higher than the pulled stress on the WEDM machine of 300 to 400 MPa.

In addition, the shear fracture was observed on the rugged wire as shown in Fig. 14. As the breakage generated from the damage surface zone, it indicated that the rugged crater was deformed on the limited thin surface area. It was considered that the rugged surface was impressed constantly and continuously without large residual stress by the wet blasting method on the thin Cu-Zn wire.

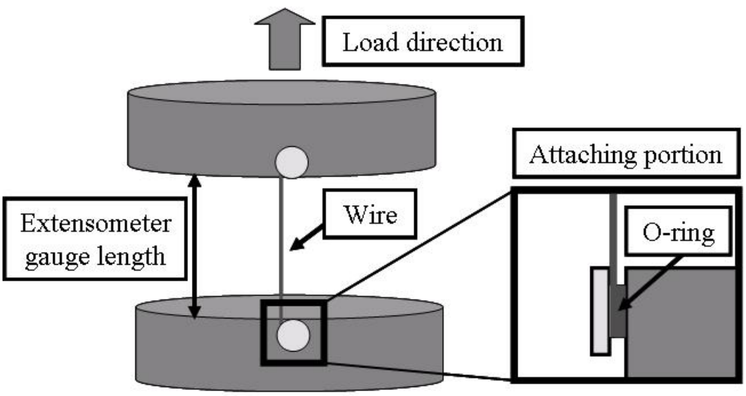

Figure 12: Schematic drawing of the tensile test.

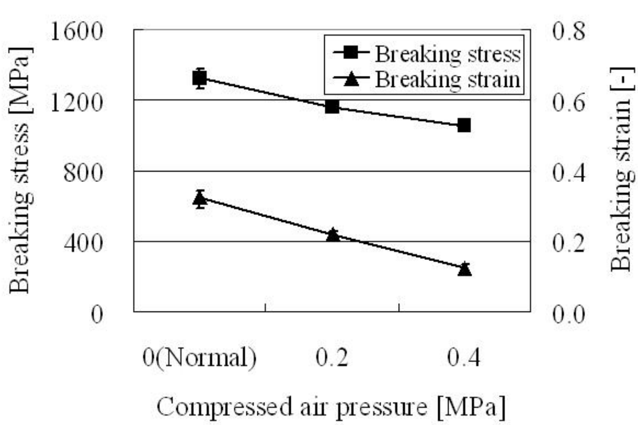

Figure 13: Fracture stress and strain obtained from tensile test.

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4 Conclusion

The new wet blasting method was proposed for making the rugged surface on the Cu-Zn wire. The effects of the machining conditions for making the rugged crater were investigated. The mechanical properties of the rugged wire were also discussed. The results were summarized as follows.

(1) The ruggedness can be impressed on the whole surface of the thin wire by the proposed wet blasting method.
(2) The size and distribution of the rugged craters can be controlled by changing the blast processing conditions.
(3) The breaking stress and strain of the rugged wire is smaller than the normal wire. The shear fracture occurred on the rugged wire for the tensile test.
(4) On the rugged wire, the stress concentration and residual stress of the damaged surface was not so large.

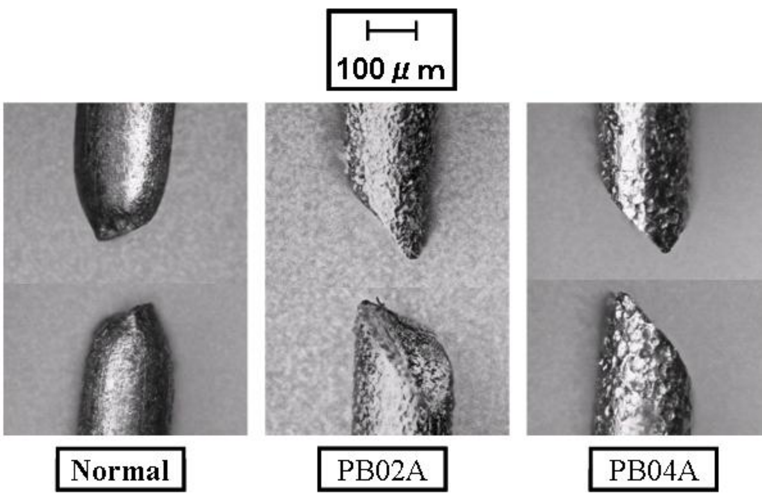

Figure 14: The image of the wire breakage region.

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