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Development of Cylindrical Grinding Technology with Electrolytic In-process Dressing Method

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ABSTRACT

A highly efficient mirror surface grinding technology has been develpoed for hard and brittle materials various metal materials, by employing the ELID (electrolytic in-process dressing) grinding method using metal bonded grinding wheels. In this research, some typical applications of ELID-grinding for cylindrical grinding are introduced and the mirror grinding characteristics are investigated. Good results are obtained in the grinding of ceramics and tungsten carbide.

Key Words: ELID grinding, mirror surface, ceramics, tungsten carbide

1. Introduction

Advanced surface processing techniques which produce mirror surface quality, good surface accuracy and low surface damage are required for the efficient manufacturing of electronic parts or optical components made of hard and brittle materials.

Dr. Ohmori has proposed a new grinding method with Electrolytic In-Process Dressing(ELID) method using a super abrasive metal bonded wheel with high bonding strength and rigidity. Significant advantages of this new grinding technique, named "ELID-Grinding", has been proved by comparison with conventional fine grinding and.or loose abrasive lapping processes.

It is possible to make a efficient precision machining of hard materials such as ceramic, hard metals, and quenched steels. We have built up an ELID grinding system through the international cooperative work with Dr. Ohmori, and attempted for applications to the machining and finishing processes of cylindrical structural components and mirror surface grinding for cylindrical surface.

And, we try to develop the cylindrical grinding technique with ELID dressing for mirror finishing of ceramics, tungsten carbide and stainless steel, and to develop the high efficiency grinding technologies for some mecahnaical parts, for example, ball screw shaft. Fig. 1 shows the various examples of cylindrical grinding types.

2. Principle of ELID grinding

The ELID-grinding method is a new precision machining technique with the assistance of a special electrolytic in-process dressing. The metal bonded wheel is set as the +Ve pole through the application of a brush smoothly contacting the surface: the electrode fixed oppositely to the wheel surface is set as -Ve pole. In the small clearance of approximately 0.1mm between the -Ve and the +Ve, electrolysis occurs through the supply of the grinding fluid and

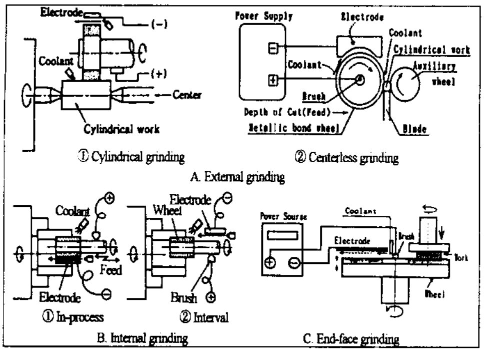

Fig. 1 Example of ELID grinding

electrical current. The ELID grinding system is easily constructed on conventional system. All that needs are as followings: a negative electrode, a brush, a power supply, a specific metal bonded wheel and chemical solution type grinding fluid as a medium.

3. Experimental Equipment

In these experiments, a cylindrical external finish grinding was conducted on a conventional grinder with ELID method. The specifications of experimental equipment are shown in Table 1.

Table 1. Experiment of Mirror Cylindrical Grinding

Grinding Machine : TOYODA GUX100 3.75kW		
ELID	Grinding Wheel	Metal Bonded Dia.Wheel, ϕ 305xW10, Grain Size : #325, 2000, 4000
	Power Supply	TRUELID PULSER
	Coolant	Noritake, AFG-M 2% Solution
Work	SCM22H	ϕ 35 x L400, 100rpm
	Ceramics	ϕ 55 x L110, 100rpm, ZrO_2

3.1. Grinding Machine

A conventional cylindrical grinding machine was used for mirror surface ELID-grinding. An electrode and a rotary connector for the ELID-system were specially designed. This machine has two hydrostatic bearing unit for grinding wheel spindle and infeed sliding. An infeed resolution is below the 0.5μm. Fig. 2 shows the ELID cylindrical grinding system which consists of grinding machine, power supply, grinding wheel and electrode. To construct a ELID system, an electrode and a rotary connector for the ELID system were specially designed.

3.2 Grinding Wheel

A cylindrical grinding wheels of #325, #2000 and #4000 grit were used. The #325 wheel is for the rough grinding and high removal rate grinding, and #2000, #4000 wheels are for the mirror surface grinding. The diameter of wheel is 305mm, width is 10 mm and thickness of metal bonded diamond layer is 3mm. Fig. 3 shows the metal bonded diamond wheel, electrode and coolant supply unit.

3.3 Power Supply

A specialized power supply was used for the cylindrical grinding. The open-circuit voltage E0 is 60V and the peak current Ip is 10A. Each on/off pulse width is 2 microsecond. Square wave pulses were used for the ELID-test, including the initial electrical dressing operation.

Fig 4. Shows the square wave pulses form used in these tests.

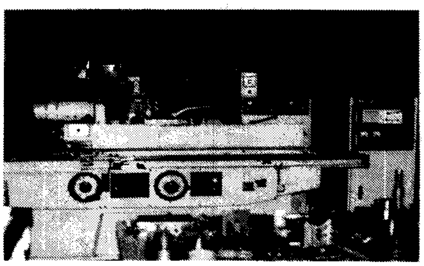

Fig. 2 ELID Cylindrical Grinding System

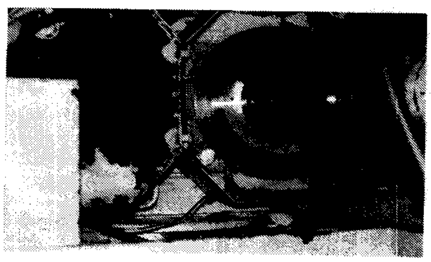

Fig. 3 Diamond wheel, Electrode, Grinding Fluid Supply Unit

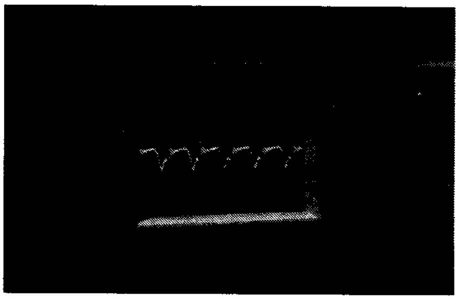

Fig. 4 Pulse Wave of Electric Power

3.4 Materials, Griding Fluid and Other items

The workpiece materials used in these test were ceramics (Al_2O_3, ZrO_2, SiC, Si_3N_4), tungsten carbide, and stainless steel.

The grinding fluid was a chemical-solution type, diluted with 2% of water.

To truing the metal bonded wheel, the #60 GC wheel mounted at brake truer was employed.

4. Experimental Procedure

The metal bonded grinding wheels were trued mechanically at first, as the same method as general super abrasive wheels. And after that, the wheel were pre-dressed using electric method.

After initial dressing, the ELID grinding experiments were conducted. To obtain the mirror surface, the #325, #2000, #4000 cast iron fiber reinforced metal bonded wheel were used successively. We monitored the current variations of electric power, and also measured the surface roughness and roundness of workpieces.

5. Results and Discussion

5.1 Predressing of Metal Bond Diamond Wheel

To use a metal bond wheel, truing and dressing operation are need for abrasive protrusions. In truing operation, GC stick or brake truer is generally used. In dressing operation, the Electrolytic In process Dressing (ELID) System is used to obtain isolating layer (oxide layer) for super smooth grinding. This isolating layer prevents the abrasive from over-protrusion. In super smooth grinding, a relatively thick oxide layer is needed. To develop the isolating layer rapidly, the wheel spindle has lower speed than actual grinding.

Fig. 5 and Fig. 6 show the current and voltage change of ELID system during predressing operation with various grit size. The just trued wheel surface has not isolating layer and there is high current between electrode and wheel. As the isolating layer grows on the wheel surface by electrical action, the current decrease slowly and approach to steady state. For the ideal condition of electrically dressed grinding wheel, the current is about 1.5A ~ 2.5A. In the figures, the finer grit size (#4000) takes less time to obtain a steady state than larger grit size(325). These features of pre-dressing are dependent on ELID-system.

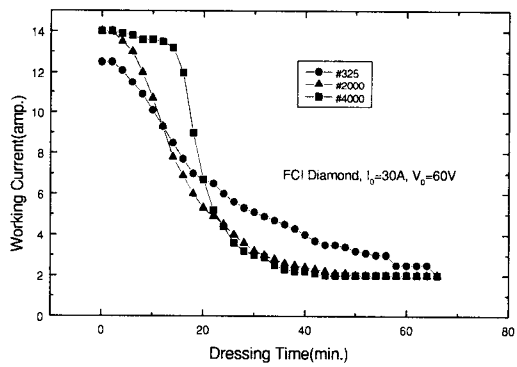

Fig. 5 Current Change of ELID System During Predresing with Various Grain Size

5.2 Cylindrical Ceramics Grinding

Cylindrical external finish grinding was conducted on a conventional grinder with ELID. Fig 7 and 8 show the obtained surface roughness and samples of Ceramics (Al_2O_3,ZrO_2,SiC). Wheel is #4000 metal bond Dia., Wheel speed is 900m/min, depth of cut is 1㎛/pass, traverse speed is 60mm/min.

5.3. Stainless Steel

The stainless steel was ground the same procedure as ceramics grinding. The surface roughness is 12.7nm Ra(Fig.9)

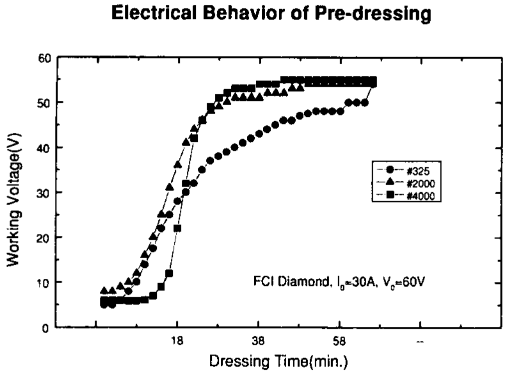

Fig. 6 Voltage Change of ELID System During Predresing with Various Grain Size

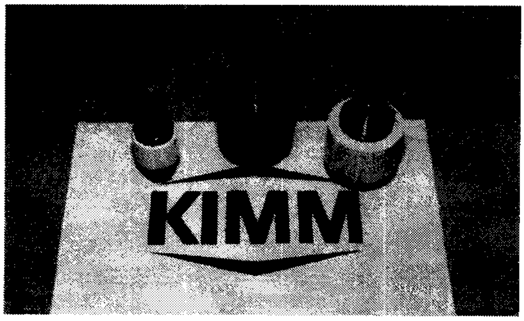

Fig. 7 Ceramic specimens (Al_2O_3, ZrO_2, SiC)

5.4 Tungsten carbide

The Tungsten Carbide workpiece were ground the same procedure as ceramics grinding. The #325, #2000, and #4000 cast iron fiber reinforced metal bonded specific wheel were used successively. Wheel speed is 1040m/min. The workpiece are shown in Fig. 11.

The workpiece rpm, traverse speed and depth of cut are changed. And the current variations of ELID system are checked. At start point, the current fluctuation is large, and then at steady state grinding the current become stable. If there is trouble like chatter, it also results to current fluctuation. Because the irregular contacts between the wheel and workpiece could damage the isolating layer.

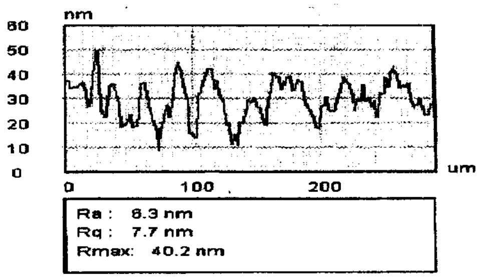

Fig. 8 Roughness of Zirconia

Fig. 9 Mirror finishing of stainless steel

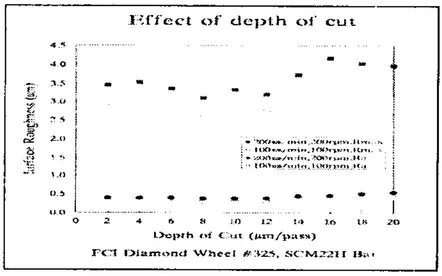

Fig. 10 The Effect of depth of cut

Fig. 11 WC(P10) testpieces (Ra 6.6nm, # 4000)

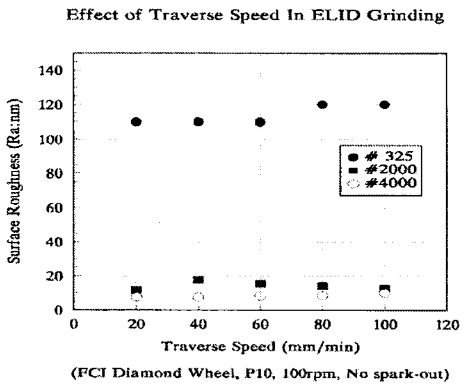

Fig. 12 Effect of Traverse Speed

Fig. 12 and Fig. 13 show the effect of grinding conditions on the surface roughness.

The traverse speed ranges are 20 ~ 100mm/min, rpm of workpiece is 50 ~ 250rpm. It is possible to grinding effectively for the wide range with ELID system.

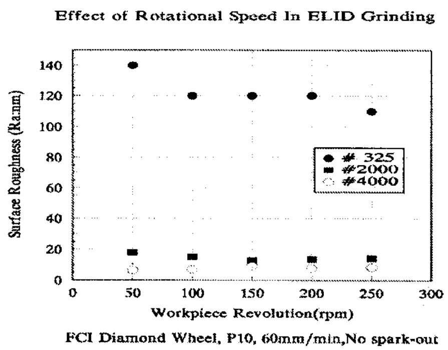

Fig. 13 Effect of Workpiece RPM

For the finer abrasive wheel, #2000 and #4000, there was a chattering under some conditions. In the case of chattering, the current are increase and surface roughness and roundness are worse.

Fig.14 and Fig.15 show the roundness of workpiece when the chatter is appeared or not.

6. Conclusion

This paper deals with some typical applications of ELID-grinding for cylindrical machining. We had conducted experiments with several kinds of materials to improve the surface roughness at the same time geometrical accuracy(roundness). This paper has provided a technique for mirror finishing using ELID-grinding. The suitable operation conditions, performances and characteristics on mirror surface grinding for external surface was surveyed.

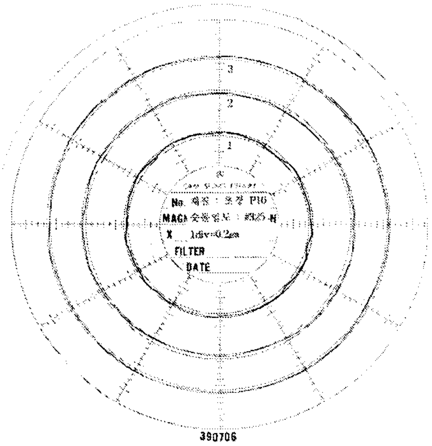

Fig. 14 Roundness of WC workpiece (# 325, 1div=0.2μm, Mitutoyo)

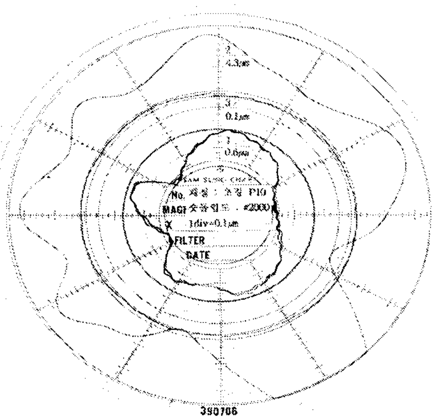

Fig. 15 Roundness of WC workpiece (Chattered, # 2000, 1div=0.1μm, Mitutoyo)

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