In-Process Electrical Dressing of Metal-Bonded Diamond Grinding Wheels

A. Sudiarso and J. Atkinson

***Abstract*— A new development of hybrid in-process electrical dressing of metal-bonded diamond grinding wheels is proposed in this paper. The electrical dressing method is used for overcoming the limitations of the conventional dressing methods available in relation to a super-abrasive wheel because of the hardness of its abrasive grains and the durability of its bonding material. The proposed hybrid in-process electrical dressing method consists of electro-discharge and electro-chemical processes and is implemented with twin copper electrodes and alternating power supplies. The results show that with properly maintained process conditions, a better surface finish is produced by the proposed method compared with traditional rotating SiC wheel dressing.**

***Index Terms* — Electro-chemical, electro-discharge, in-process dressing, metal-bonded diamond grinding wheel.**

I. INTRODUCTION

To restore its cutting ability, a grinding wheel needs a dressing process to remove dulled grains from the cutting face and then to disclose new and sharp grains. An advanced grinding process, which uses a super-abrasive wheel with metal bonding material, requires an advanced method of dressing. Using a conventional method to dress the wheel has been proved to be ineffective and uneconomical because of the high hardness of the abrasive grains and the bonding material durability [1]. Since electro-chemical and electro-discharge machining are capable of dealing with conductive materials, such as metals, then application to dressing of metal-bonded super-abrasive grinding wheels has already been tried. However, the existing electro-chemical and/or electro-discharge dressing techniques are generally implemented with a Direct Current (DC) power supply and single electrode.

In this paper, a new approach to electrical dressing of a metal bonded diamond wheel is proposed. Both electro-chemical and electro-discharge technique are applied to dress a metal-bonded diamond wheel using twin copper electrodes and Alternating Current (AC) power supplies. The machining occurs on both the wheel and the electrode, leaving the electrode shape to dynamically change to follow the shape of the wheel. Moreover, the AC power supply used eliminates the need for a carbon brush as a means to deliver the current to the wheel during a dressing process.

A combination of electro-chemical and electro-discharge dressing has been developed by Schopf *et al.* [2] and Ohmori *et al.* [3]. It suggested that the electro-chemical dressing is assisted by the thermal erosive effect of electrical discharge. The application is implemented for centreless grinding with single electrode supplied with a DC power supply via a pair of brushes.

A further improvement is proposed here. The use of twin electrodes [4] and in-process dressing using AC power supplies are implemented. This approach allows electro-chemical and electro-discharge dressings to be performed individually as required, rather than conducted alternating on single electrode. The gap could be set differently according to the requirement of each process.

II. EXPERIMENTAL PROCEDURES

Twin electrodes were used during the dressing process. One electrode was for electro-discharge dressing and the other one for the electro-chemical dressing (see Figure 1). The electro-discharge method is responsible for macro-geometrical removal whereas the electro-chemical method is required to produce sufficient grit protrusions. The block diagram of the dressing system is shown in Figure 2. An Acoustic Emission (AE) sensor was used for monitoring the grinding wheel condition [5].

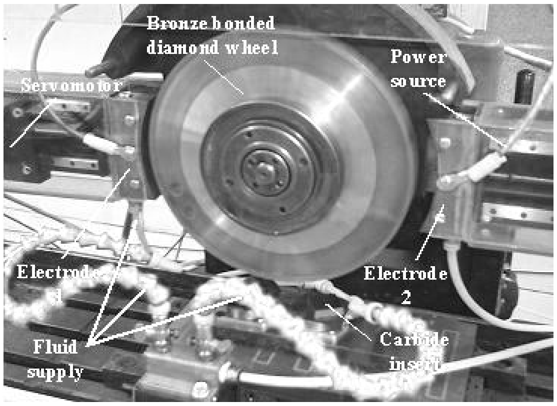

Figure 1. Experimental set-up for the hybrid electrical dressing process

The grinding wheel used was a bronze-bonded diamond wheel D107 C75, the workpieces were tungsten carbide inserts and the electrodes were made from copper. The fluid used was P16-35, which is especially designed by Blaser Swisslube, with an electrical conductivity of 0.002 S/cm and

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pH value of 9.20. Ideally, the fluid has to meet requirements as a coolant and lubricant for the grinding process, as an electrolyte for electro-chemical dressing and as a dielectric for electro-discharge dressing.

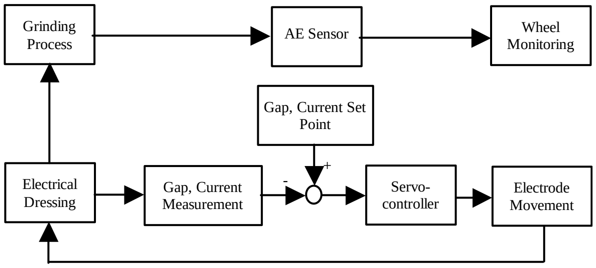

Figure 2. Block diagram of the in-process electrical dressing system

Two different power supplies were used in the experiments. One power supply was capable of delivering voltage up to 55 VAC at normal mains frequency (i.e. 50 Hz). Another power supply was capable of delivering a high frequency supply up to 20 kHz, but had a limited voltage of up to 15 VAC. The gap width is maintained in the range of 20-200 µm during the dressing period.

III. RESULTS AND DISCUSSIONS

A. *Current and Voltage Characteristics*

Typical current characteristics during an electrical dressing process mainly depend on the electrode movement, i.e. whether it is static or dynamic, and the status of the dressing process i.e. offline or online (in-process). During an in-process electrical dressing, a typical observed current characteristic is shown in Figure 3. A period called pre-dressing occurs at the beginning of the dressing process. During this period, more current is drawn and a series of sparks can occur. Following the pre-dressing period, re-dressing cycles are employed with relatively smaller amount of current drawn. These cycles appear periodically during the grinding process. A copper oxide layer is formed on both the electrodes and the wheel as a result of the AC supply used.

The voltage characteristics show different spark durations at different applied frequencies during the dressing process. A higher frequency supply tends to create shorter spark duration but of a greater spark/wave duration ratio compared with a lower frequency power supply. An example of a voltage characteristic during a discharge is shown in Figure 4.

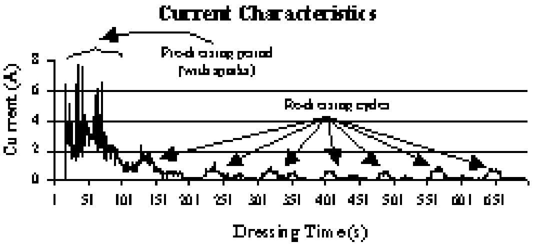

Figure 3. Current characteristics during in-process electrical dressing

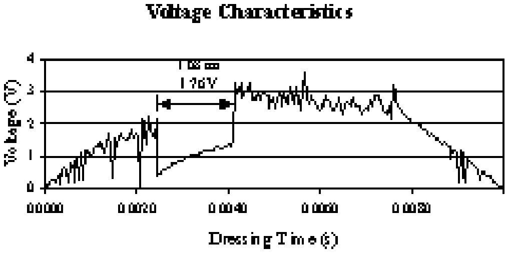

Figure 4. Voltage characteristics during a discharge

B. *Wheel Profile and Roundness*

Results of the electrical dressing on the wheel profile and roundness indicate better properties compared with the result from the traditional rotating SiC wheel dressing method. The wheel profile produced by the electrical dressing method has more sharp profiles and protrusions as shown in Figure 5 whereas the wheel profile produced by the traditional SiC wheel dressing shows a flatter profile and less protrusions.

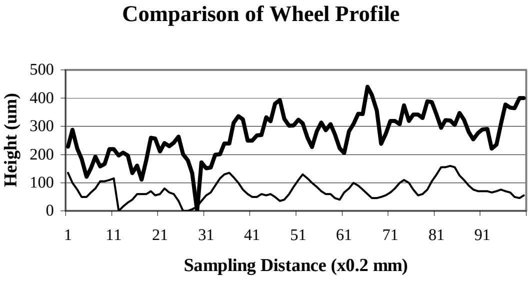

Figure 5. Wheel profile as a result of dressing process

The wheel roundness is measured by a laser sensor. The result indicates a good overall roundness as shown in Figure 6. A deviation of 0.37% of the radius of the wheel is found.

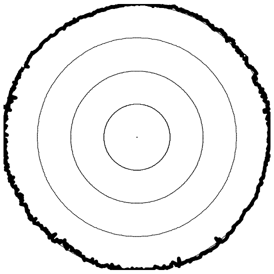

Figure 6. Wheel roundness produced by electrical dressing

C. Surface Roughness

From the experiments, it is possible to compare the results based on the average surface roughness produced on the carbide inserts ground as shown in Table 1. The average surface roughness produced, in term of Ra and Rz values, during the grinding of carbide inserts is considerably better than the Ra and Rz values produced by the traditional rotating SiC wheel dressing method. The best result so far was produced by twin electrodes hybrid in-process electrical dressing using 50 VAC and 50 Hz supplied voltage for the electro-discharge dressing at 200 μm gap width and 15 VAC and 500 Hz voltage for the electro-chemical dressing at 50 μm gap between the wheel and the electrode. A summary of the surface roughness produced during the experiments is shown in Appendix 1.

Table 1. Surface roughness produced using the traditional SiC wheel and the hybrid electrical dressing

Surface Roughness (μm)	SiC Wheel Dressing	Hybrid Dressing
Minimum value		
• Ra	0.24	0.20
• Rz	1.75	1.40
Average value		
• Ra	0.31	0.22
• Rz	2.31	1.65

In most cases, an online or in-process electrical dressing method produces a better surface roughness than for offline dressing. This condition is likely caused by a continuously maintained wheel condition due to the in-process dressing. Moreover, a slow feedrate tends to produce a better surface finish than the high feedrate grinding, but more time is needed to complete the grinding process.

IV. CONCLUSION

With properly maintained process conditions, it is possible to produce a better surface roughness on the workpiece ground with a hybrid electrical dressing method than with the traditional rotational SiC dressing method. The best result so far is achieved from an online or in-process hybrid electrical dressing with twin electrodes using two different AC power supplies.

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APPENDIX

Appendix 1. Summary of the surface roughness produced by electrical and traditional dressing methods

Surface Roughness (Ra, μm)	Electrode Used, Dressing Status	Power Supply Type and Rating	Gap Width (μm)	Workpiece Feedrate (cm/s)
0.22	Twin, online	AC, 50V 50 Hz (ED) AC, 15V 500 Hz (EC)	200 (ED) 50 (EC)	4.7
0.24	Twin, offline	AC, 50V 50 Hz (both electrodes)	100 (ED) 200 (EC)	4.7
0.25	Twin, offline	AC, 50V 50 Hz (ED) AC, 15V 500 Hz (EC)	200 (ED) 50 (EC)	4.7
	Twin, online	AC, 50V 50 Hz (both electrodes)	100 (ED) 200 (EC)	4.7
0.26	Single, online	AC, 10V 50 Hz	50	4.7
	Twin, offline	AC, 50V 50 Hz (both electrodes)	100 (ED) 200 (EC)	15.8
0.27	Twin, online	AC, 50V 50 Hz (both electrodes)	100 (ED) 200 (EC)	15.8
0.28	Twin, online	AC, 50V 50 Hz (ED) AC, 15V 500 Hz (EC)	200 (ED) 50 (EC)	15.8
	Single, online	AC, 10V 5000 Hz	50	4.7
0.29	Twin, offline	AC, 50V 50 Hz (ED) AC, 15V 500 Hz (EC)	200 (ED) 50 (EC)	15.8
0.30	Single, online	AC, 25V 50 Hz	200	4.7
0.31	**SiC Wheel (Traditional)**	**n/a**	**n/a**	**4.7**