Truing and Dressing of Diamond Wheels for High Speed Grinding of Brittle Materials

Han HUANG
Gintic Institute of Manufacturing Technology, Singapore 638075

1 Introduction

Wheel preparation generally includes truing and dressing. The truing and dressing efficiency strongly influences the grinding efficiency as it is often required during the course of a grinding process to keep the cutting grains sharp to maintain a consistent material removal rate [1-3]. To achieve an efficient and appropriate truing and dressing for diamond wheels, (i) the effect of truing and dressing conditions on the truing and dressing efficiency and wheel surface topography and (ii) the effect of truing and dressing conditions on the subsequent grinding process must be taken into accounted. This requires systematic investigations of various truing and dressing methodologies and their effects on the subsequent grinding process. In the present paper, we report a systematic study of two types of truing and dressing methods, motor driven mild steel and silicon carbide rollers, for preparing vitrified diamond wheels. After truing and dressing wheels were then used to grind ceramics at ultra high speeds to examine the corresponding grinding performance. The two types of rollers are compared in terms of truing or dressing efficiency and grinding performance.

2 Experimental Set-up

The truing and dressing system is illustrated in Fig. 1. During truing/dressing, a mild steel or silicon carbide (GC80M7V) roller was traversed across a grinding wheel at a feed rate with a down feed per pass. The vitrified diamond wheel (SD120J100C2) has a diameter of 200 mm and a width of 6 mm. Down-cut truing/dressing was adopted. The truing/dressing force was measured by a dynamometer. The run-out was measured by a capacitance sensor. The truing/dressing conditions for studying the truing/dressing efficiency are listed in Table 1. It should be noted that the truing/dressing was carried out using the same motor driven device for either steel or SiC rollers. The difference between them is only the values for each condition. In this experiment, a reasonably wide range for each condition was selected to cover both truing and dressing. Thus, unless particularly mentioned, 'dressing' is used to represent both truing and dressing to simplify the terminology. Grinding tests was conducted to examine the wheel performance after dressing. During grinding the creep rate was fixed at 320 mm/min. Various speeds from the conventional speed of 30 m/s to a high speed of 120 m/s were applied. The truing and dressing conditions for studying the wheel grinding performance are listed in Table 2.

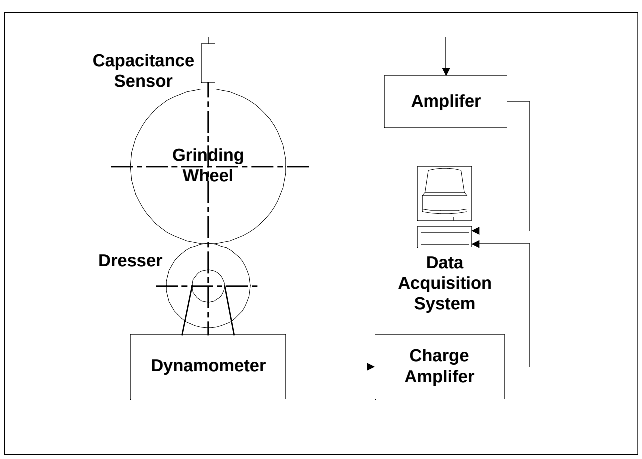

Figure 1: Schematic of the truing and dressing system.

Table 1: Truing/dressing conditions for studying truing/dressing efficiency.

Conditions	Sign	Unit	Variation Range	
			SiC	Steel
Wheel Speed	V_w	m/s	6.28	10-30
Roller Speed	V_r	m/s	2-4	5
Cross feed rate	f_d	mm/min	100-300	100-300
Down feed per pass	a_d	μm	0.2-30	0.2-3

Table 2: Truing/dressing conditions for grinding partially stabilized zirconia (PSZ).

Wheel preparation		Roller type	V_r/V_w (m/s/m/s)	f_d (mm/min.)	a_d (μm)	Dressing passes
Truing (dry)		Steel	5/10	200	2	40
Dressing (with dropping coolant)	1	SiC	3.8/15.2	100	2	200
	2	SiC	3.8/11.2	200	20	40
	3	Steel	5/30	100	2	80
	4	Steel	5/15	100	2	80

3 Results and Discussion

3.1 *Effect of Truing/Dressing Conditions on Wheel Run-out and Topography*

In Fig. 2, the run-out of the wheel is plotted as a function of the truing time for both SiC and steel rollers. It is seen that the run-out decreases more rapidly when using the steel roller than using the SiC roller, corresponding to a higher truing rate. The run-out reaches a saturated value for both rollers, with the SiC roller having a smaller run-out.

The wheel topography after dressing was examined using the Scanning Electron Microscope (SEM). The SEM examination revealed that there exist some differences between the wheel topographies dressed by the two rollers. On the wheel dressed by the SiC roller diamond grains with micro-cutting edges were more frequently observed than the wheel dressed by the steel roller. For the wheel dressed using the steel roller, larger and sharper cutting edges were easily observed.

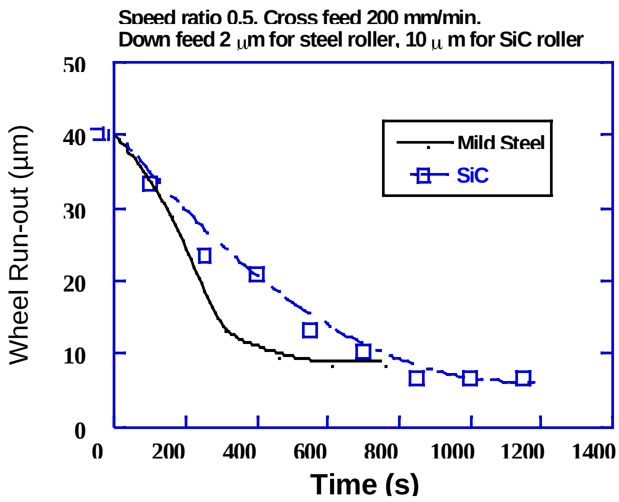

Figure 2: The run-out decreases with the progress of truing.

3.2 *Effect of Dressing Intensity on Dressing Efficiency*

Dressing ratio and rate are used to evaluate the dressing efficiency. The dressing ratio is the ratio of the material removal volume between the wheel and the roller. The rate equals to the material removal volume of the wheel over the dressing time. The dressing intensity, which is defined as the resultant force acting on an individual grain, is used to characterize the dressing process. The dressing ratio and rate for various conditions listed in Table 1 are plotted as a function of the intensity in Fig. 2 and 3. It is seen that when using the SiC roller, all the data almost lie on a common curve for various dressing conditions, indicating that the intensity does give a good measure of the dressing efficiency. The data obtained using the mild steel roller are not dropping on one common curve. However, when classifying those data into two categories according to their speed ratios, both the ratio and rate exhibit good relationships with the intensity, regardless of the other dressing conditions. In summary, for 'truing' the speed ratio between the wheel and the roller should be larger than 0.5 for both mild steel and SiC rollers in order to achieve a sufficiently large removal rate. For 'dressing', the speed ratio should be decreased to reduce the removal volume of the wheel.

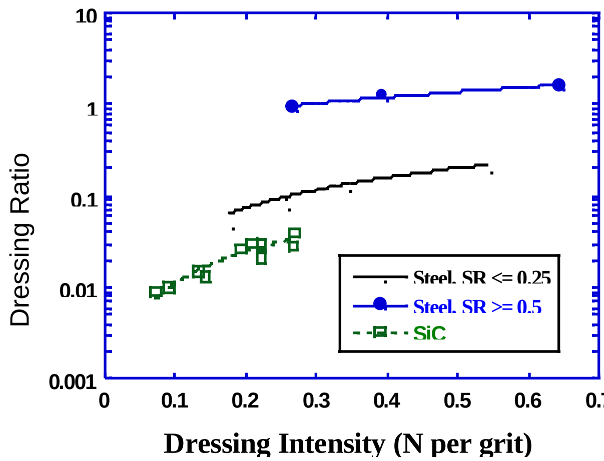

Figure 2: Dressing ratio against dressing intensity.

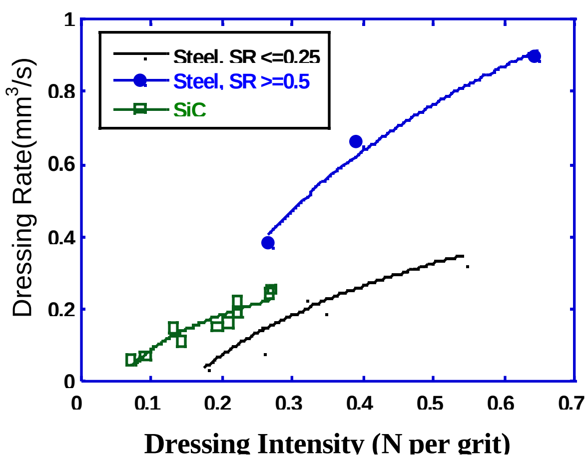

Figure 3: Dressing rate against dressing intensity.

3.3 *Effect of Dressing Intensity on Grinding Performance*

The normal force was measured during grinding and the surface roughness of the workpiece was measured as well. It was found that the grinding force decreases with the increasing dressing intensity for all the grinding speeds and the depths of cut, indicating that the dressing intensity also gives a measure of the wheel grinding performance. For high speed grinding, the influence of dressing intensity on the grinding force was not so significant as that for conventional grinding. Increasing the wheel speed also reduced the grinding force. As a result, the effect of the dressing intensity was relieved. It was also found that the smaller the dressing intensity is, the better the surface quality is achieved. To measure the wheel life after each dressing the wheel was used to continuously grind the zirconia until the normal grinding force was significantly increased. The grinding time before next dressing was recorded to represent the wheel life. In Fig. 4, the wheel life is plotted as a function of the dressing intensity. It is seen that the wheel life generally increases with the increasing intensity for either SiC or steel roller. It is apparent that the effect of the dressing intensity on the wheel life at the higher speed is more significant than that at the conventional speed. Apparently, sharper cutting edges produced by the larger intensity dressing are more suitable for high speed grinding of zicornia. It is also found in Fig. 4 that the wheel dressed using the steel roller with the largest dressing intensity didn't possess the longest life. This could be because the wheel dressed by different rollers has different wear mechanisms during grinding. Raman Microscopy revealed that the graphitization on diamond grains was caused during dressing using the steel roller. It is thus inferred that the small amount of graphite-type carbon existing on some of the abrasive grains may lead to the excessive wheel wear during grinding.

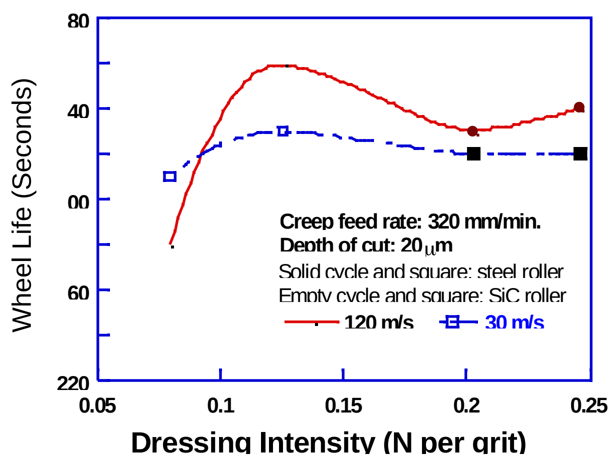

Figure 4: Wheel life as a function of dressing intensity.

4 Concluding Remarks

Truing/dressing intensity gives a good measure to evaluate the truing/dressing efficiency. A higher intensity can result in a higher efficiency. The steel roller generally gives a higher dressing intensity than the SiC roller. The surface topography is also influenced by the intensity. A higher intensity dressing produces more large cutting edges and a lower intensity dressing leads to more micro-cutting edges. Higher intensities should be used to dress the wheel for rough grinding as they can produce sharper cutting edges. This is of particular importance for high speed grinding of ceramics. On the other hand, lower intensities can be applied to achieve micro-cutting edges for fine grinding.

References:

[1] Inasaki, I., Dressing of resinoid bonded diamond grinding wheels, Annals of CIRP 38/1 (1989), 315-318.

[2] Klocke, F., O. Gerent & C. Schippers, High speed grinding of ceramics, Machining of Ceramics and Composites, Edited by Said Jahanmir, M. Ramulu and P. Koshy, Marcel Dekker, Inc. 1999, 119-137.

[3] Malkin, S., Grinding technology: theory and applications of machining with abrasives, John Wiley & Sons, 1982.

[4] Notter, A.T. & G.R. Shafto, A new truing and dressing technique for resin bond peripheral grinding wheels, Industrial Diamond Review, 6 (1979), 203-210.