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Performance of small diameter grinding wheel with coolant supplying from its inner side

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Abstract

Small diameter grinding has difficulties to achieve both high efficiency and high accuracy. A new tool for small and deep holes grinding which is capable of supplying grinding fluid from the inner side of the grinding wheel was developed. Grinding temperature and grinding force were measured on the straight part and the corner part of the workpiece in order to change the contact arc length between the grinding wheel and workpiece. Conventional coolant supply from external nozzle was also compared. It was cleared that the grinding temperature was lower when the proposed internal coolant supply was employed. Supplied coolant from inner side of the grinding wheel can also remove the grinding chips from the wheel surface and the clogging was prevented, then grinding force became lower and the finished surface roughness was smaller.

Key words: grinding, coolant, small and deep holes, temperature, grinding force

1. Introduction

On small and deep holes grinding, the difference of diameters of the hole and the grinding wheel is small to keep higher stiffness of the tool. It leads to longer contact arc length between the grinding wheel and the workpiece. In addition, it is difficult to supply the grinding fluid from outside to the grinding point locating at deep inside of the hole. Then some troubles such as the grinding burn or clogging of the grinding wheel often arise. In order to solve these problems, a new tool for small and deep holes was developed in our previous report [1]. Grinding fluid can be supplied from the inner side of the grinding wheel utilizing the spindle through system of the machining centre [2]. Then it is expected that the grinding fluid can reach at the actual grain-workpiece contact point effectively even if it is a small and deep hole grinding. In order to validate the effect of the coolant supplying from inner side of the grinding wheel, grinding point temperature, grinding force and surface roughness were examined in this report.

2. Experimental method

Figure 1 shows a schematic of the developped tool holder for supplying the grinding fluid from the inner side of the small diameter grinding wheel. The center shaft is a pipe made of tungsten carbide, its outer and inner diameter are 8 mm and 1.5 mm respectively. The grinding fluid flows though the shaft. The dimensions were designed according to the internal diameter of the target hole. A grinding wheel is mouted on a small-diameter section at the end of the shaft. At this end section, two holes were made to supply the coolant to the grinding wheel.

Size of the sylindrical grinding wheel was 9 mm in diameter, 10 mm in hight and 4 mm in inner diameter as shown in Fig.2. Fine ceramics bonded CBN grinding wheel (Nitolex, Cera Bora) was used. Its grain size and grade are #200 and K respectively.

Figure 3 shows the experimental setup to measure the grinding force and workpiece surface temperature during the

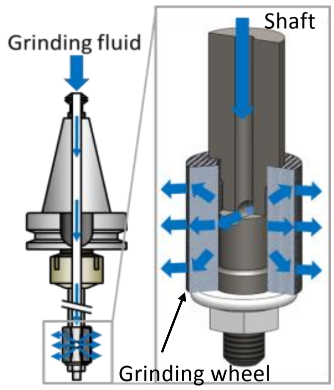


Figure 1. Schematic of tool holder.

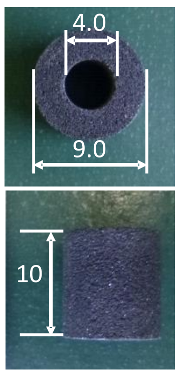


Figure 2. Grinding Wheel.

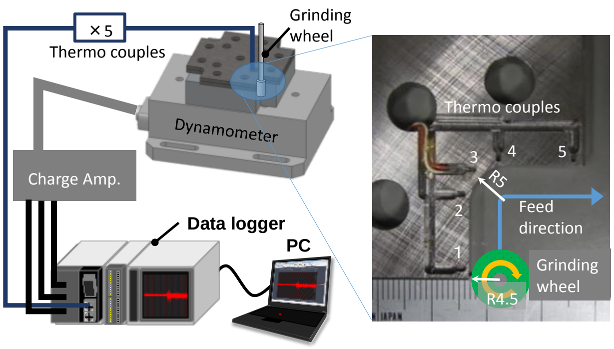


Figure 3. Experimental setup for measuring grinding force and temperature at straight and corner.

straight and corner grinding. A workpiece was mounted on the piezo-electric dynamometer (Kistler 9257B) to measure the grinding forces. Five sets of thermocouples #1 to #5 were embedded in thin grooves between two workpieces, then the two pieces of workpiece were combined. Right side of the Fig. 3

shows the location of the measurement points. Measurement point #1 and #5 are located on the straight part, and #2, #3 and #4 are located on entry, centre and exit of the corner part respectively. Distance between the temperature measurement junction and the grinding surface were precisely set. The contact arc length between the grinding wheel and the workpiece drastically increases even if the radial depth of cut *d* is constant in this experimental setup, then the grinding force and the temperature increases accordingly.

A conventional coolant supply from external nozzle was also compared with the internal coolant supply. Amount of the supplied grinding fluid was 2.0 L/min and 28 L/min for the internal and external supply respectively. Other grinding conditions are shown in Table 1.

Table1. Grinding conditions.

Grinding method	Up cut		
Work material	0.45% carbon steel		
Tool diameter [mm]	9.0		
Feed rate *f* [mm/min]	100		150
Radial depth of cut *d* [mm]	0.03	0.06	0.03
Grinding velocity [m/s]	9.5		
Method of coolant supply	Internal	External	
Amount of coolant supply [L/min]	2.0	28	

3. Results and discussions

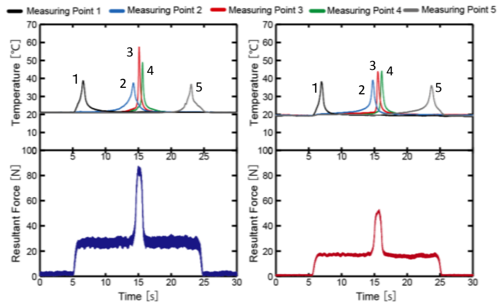
3.1. Grinding force and temperature

Figure 4 shows the transitions of the resultant grinding force and the measured temperature at five measurement points. It can be seen that the temperature rapidly rises when the grinding wheel passes through each measuring point. When the coolant was supplied externally, the peak temperatures at #1 and #5 are almost same on the straight part. While, on the corner part, the peak temperature at #3 is remarkably high. It is because the contact arc length between the grinding wheel and the workpiece increases from 0.74 mm to 2.46 mm at the corner part. On the other hand, when the coolant was supplied from inner side of the grinding wheel, temperature at the measuring point #3, which is the centre of the corner, is lower than the case with external coolant supply as shown in Fig. 4 (b) even if the amount of the coolant is much smaller in this case.

Temperature rise is resulting from the amount of the grinding energy generated at the grinding point and the amount of the heat removal by the supplied coolant. Grinding force with external coolant supply is larger than that with internal coolant supply. Then the amount of heat generation is smaller on the internal coolant supply. In addition, as the coolant is directly supplied to the grinding point from the inner side of the grinding wheel, the friction between the grain and the workpiece will decrease and the heat will be removed efficiently by the coolant on the internal coolant supply. It works very effectively even though the amount of the coolant is small.

3.2. Surface roughness

Figure 5 shows the effect of coolant supply on surface roughness. It can be seen that the roughness on the case of internal supply is smaller than that of external supply especially when *f* is 100 mm/min. When *f* was 150 mm/min, difference of the roughness was small. Supplied coolant from the inner side of the grinding wheel can also evacuate the grinding chips from the wheel surface and then the clogging can be avoided as shown in Fig.6. Adhered chips on the grinding wheel surface are shown with hatching in this figure. Then the grinding force became lower and the surface roughness was smaller. In addition, it is expected that the affected layer of the ground surface will be smaller because the grinding force is small and temperature is low. As a result, the developed grinding wheel is expected to achieve higher accuracy and integrity for small and deep holes grinding.



(a) External coolant supply (b) Internal coolant supply

Figure 4. Effect of coolant supply on grinding temperature and force (*d*=0.06 mm, *f*=100 mm/min).

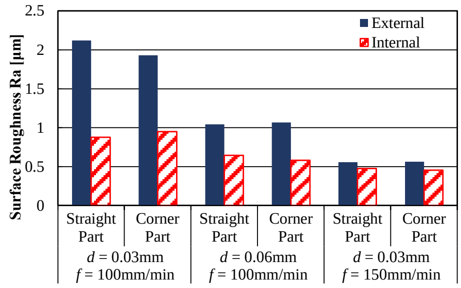
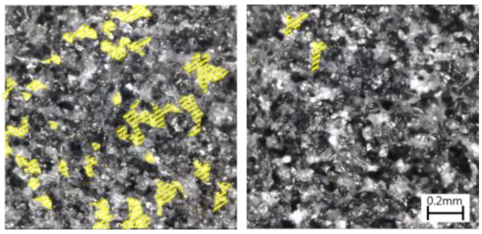


Figure 5. Measured surface roughness.



(a) External coolant supply (b) Internal coolant supply

Figure 6. Microscopic images of the grinding wheel surface (*d*=0.03 mm, *f*=100 mm/min, after 25th path).

4. Summary

A new tool for small and deep holes grinding which is capable of supplying grinding fluid from the inner side of the grinding wheel was developed. Grinding temperature and grinding force were measured on the straight part and the corner part of the workpiece in order to change the contact arc length between the grinding wheel and workpiece. It was found that the grinding temperature was about 20°C lower at the corner part when the internal coolant supply was employed. Supplied coolant from inner side of the grinding wheel can also remove the adhered grinding chips from the wheel surface and the clogging was prevented, then grinding force became lower and the surface roughness could be less than 0.5 μmRa.

Acknowledgement

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