THE GRINDABILITY OF STAINLESS STEEL USING ULID (ULTRASONIC IN-PROCESS DRESSING) METHOD

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Abstract

Because of the high toughness and low thermal conductivity, stainless steel is very difficult material to machine. It is also reported that the chemical interaction between stainless steel workpiece and alumina wheel causes the poor grindability. From these reasons, grinding time is larger and form accuracy is worse when the material ground with alumina wheel.

By applying CBN or diamond wheel, the cutting depth can be increased and the dressing interval can be expanded. However, the impurities at grinding can easily get attached to the wheel surface and caused clogging phenomena.

In this study, the Ultrasonic In-Process Dressing (ULID) method was suggested to prevent the clogging phenomena of the wheel surface and decrease the wheel wear. Finally, it can be found that the surface roughness with the ULID method is better than that without it. When stainless steel was ground with the CBN wheel, the wheel wear with ULID was about 36% less than that without it. The change of surface roughness and wheel wear is small with the use of ULID. The ULID is also effective to prevent clogging of wheel by removing the impurities among the grains.

Key words : Ultrasonic In-Process Dressing (ULID), Ultrasonic vibration, Clogging, Wheel wear, Surface roughness

1. Introduction

Improvements in surface integrity and productivity can be achieved by using appropriate grinding wheels and grinding conditions. For the precise grinding, the grinding characteristics of the wheel should always be kept consistent[1]. Many studies have been done in the field of grinding with the CBN and diamond wheels[2]. These wheels are good for keeping the shape as it has little wear. Because of the clogging phenomena, however, it is difficult to keep the fresh surface of the wheel. Finally, burning is caused on the surface of ground workpiece. To prevent all of these, a suitable dressing method should be used for the wheels. The ultrasonic vibration is used as one of the methods to get the high surface integrity. A lot of researches on the ultrasonic vibration are carried out to promote the grinding characteristics and surface integrity[3],[4],[5].

The Ultrasonic In-Process Dressing (ULID) is suggested to prevent the clogging phenomena and decrease wheel wear in the grinding process with the CBN & diamond wheels. It intends to decrease the wheel wear and get the high surface integrity. The surface integrity of ground workpiece and wheel wear in grinding with ULID is compared with that without it.

2. Principle of Ultrasonic Dressing

The ULID is a dressing method to prevent the clogging of the wheel by removing the impurities among the grains with the ultrasonic vibration.

Fig. 1 shows the ultrasonic unit and vibration mode. If high voltage by the ultrasonic generator is provided to the ultrasonic transducer, it changes to the vibration with the amplitude of about 2～3 ㎛. It will be amplified by a corn and horn. The desired amplitude in the tip of the horn can be obtained by optimal designing of the corn and horn. The ultrasonic unit using this experiment has the resonance frequency of 20 ㎑. The amplitude of the horn tip was 30 ㎛.

Fig. 2 shows the principle of the ultrasonic dressing. The vibration force by the up-and-down motion of the horn and the explosion force of the cavitation in the coolant are transmitted to the wheel surface and then the impurities are removed. These forces are extremely small but they are enough to eliminate the impurities among the wheel grains owing to the resonance frequency of the horn. In this way, the ULID method keeps the fresh wheel surface by preventing the clogging phenomena.

3. Experimentation

In this experiment, the resin bond diamond wheel and vitrified bond CBN one were used. For the workpiece, stainless steel (SUS420J2) and mold material (STD11) were used. The value of hardness after heat treatment were about H_{RC} 44～46 and H_{RC} 56～58, respectively.

Table 1
Experimental conditions

Machine	Surface grinder	
Wheel	Vitrified bond CBN wheel (B120H150V3, ϕ300×11×127)	
	Resin bond diamond wheel (TC400R125BG5, ϕ300×11×127)	
Dresser	Rotary diamond dresser (ϕ100, 2,500 rpm	
Workpiece	SUS420J2	After heat treatment, H_{RC} 44 ~ 46
	STD 11	After heat treatment, H_{RC} 56 ~ 58
Depth of cut	10, 20, 40 ㎛	
Gap(l)	0.05, 0.1, 0.15mm	
Coolant	Emulsion 4%	
Ultrasonic Unit	Power	1,500 W
	Frequency	20 ㎑
	Amplitude	30 ㎛
	Coolin	Air cooling
	Horn Material	Al 7075

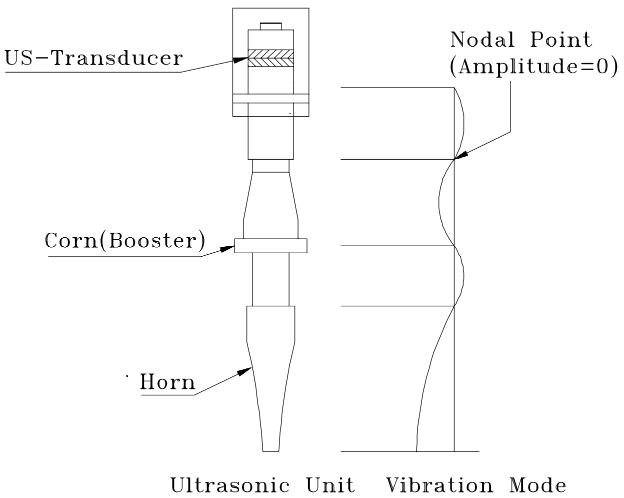


Fig. 1 Schematic of ultrasonic unit and vibration mode

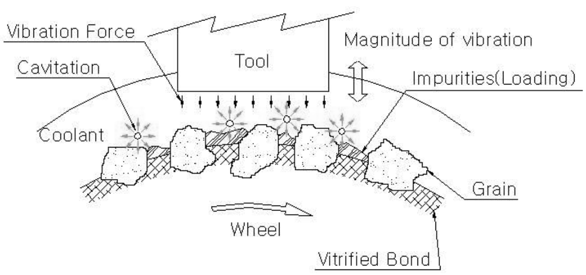


Fig. 2 Principle of Ultrasonic In-Process Dressing (ULID)

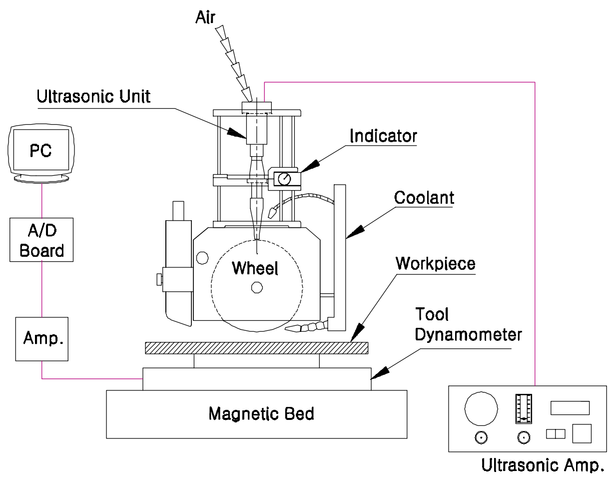


Fig. 3 Schematic of experimental equipment

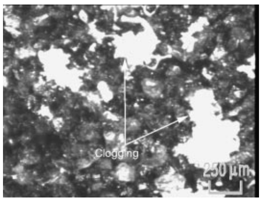
The ultrasonic dressing unit was attached to the upper part of the spindle housing of the surface grinder (Fig. 3). To control the gap between the horn and wheel, a height gauge was used. The tip of the horn was shaped similar to the profile of the wheel. The compressed air was used to cool down the ultrasonic transducer and the coolant was provided into the tip of the horn.

The wheel wear and the surface integrity of ground workpiece were compared in the case with and without ULID. It was also observed that the ultrasonic dressing removed the impurities, which took place on the wheel surface. The experimental conditions are shown in Table 1.

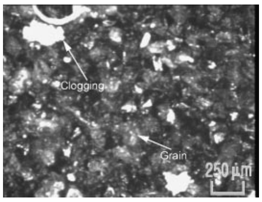
4. Experimental results

4.1 Photograph of wheel surface

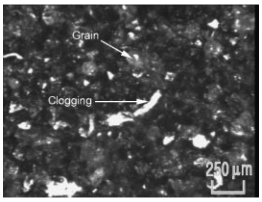
The wheel surface was observed to find the clogging phenomena. Fig. 4(a) is the photograph of the wheel surface ground up to V_w'= 20,000mm^3/mm without ULID. It shows that the clogging phenomena were generated by the impurities of the workpiece. The white part in the photograph indicates that the clogging was generated.



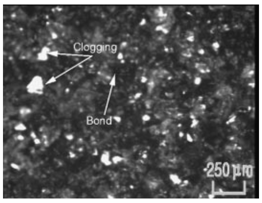
(a) Without ULID



(b) With ULID(1min)



(c) With ULID(2min)

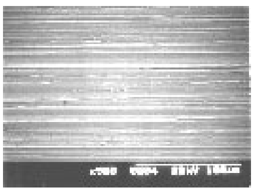


(d) With ULID(5min)

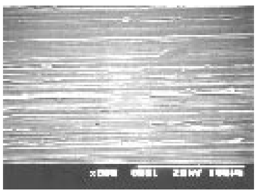
Fig. 4 Photograph of CBN wheel surface

The photograph of the wheel in cases of ultrasonic dressing time of 1, 2, and 5 minutes, respectively, are shown in Fig. 4(b), (c), and (d). The impurities are not removed completely though the ultrasonic dressing time increases. The reason is that the ultrasonic dressing is an indirect dressing method without contact between horn and wheel.

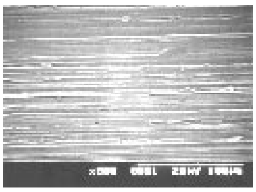
Fig. 5 shows the surface of the ground workpiece, in the cases with and without ULID. The stainless steel was ground with the diamond wheel when V_w'= 100mm^3/mm. The cutting depth was between 10 µm and 40 µm. Because of the toughness of stainless steel, the surface of ground workpiece with ULID was better than that without it.



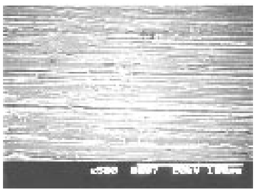
(a) With ULID(a=10 µm)



(b) Without ULID(a=1 µm)



(c) With ULID(a=40 µm)



(d) Without ULID(a=4 µm)

Fig. 5 SEM of ground workpiece surface

4.2 Photograph of ground workpiece

Fig. 6 shows the wheel wear, in the case with and without ULID when stainless steel was ground with the CBN and diamond wheels.

Fig. 6(a) shows the wear of CBN wheel until the material removal per unit active wheel width reached 20,000mm3/mm. The wheel wear with ULID was about 0.171mm and 0.269mm without it. Fig. 6(b) shows the results for the diamond wheel. The wheel wear was about 0.05mm without ULID and 0.044mm with it. The material removal was 1,200mm^3/mm. The wheel wear in grinding with ULID was less than that without it. The ULID method should be effective to prevent clogging of wheel.

4.3 Surface Roughness

Fig. 7 shows a graph of the surface roughness, depending on whether there is the ULID when the stainless steel was ground b the CBN wheel in the depth of cut of 2 µm. It is found that the surface roughness was deteriorated as V_w' increased. As found in this graph, the Rz value of the conventional grinding without the ULID was greater than that with the ULID by approximately 0.3 ~0.8 µm. The change of the surface roughness value without the ULID was about 1. µm while that with the ULID only was about 0.7 µm in the grinding of stainless steel with the V_w' ranging to 2,500mm^3/mm. Therefore, if the ULID is used, a fine grinding surface can be obtained.

As shown in Fig. 8, the depth of cut was set as 1 µm and the gap between the horn and wheel surface was changing from 0.05 through 0.1 to 0.15mm to investigate the effect of the ULID according to the gap.

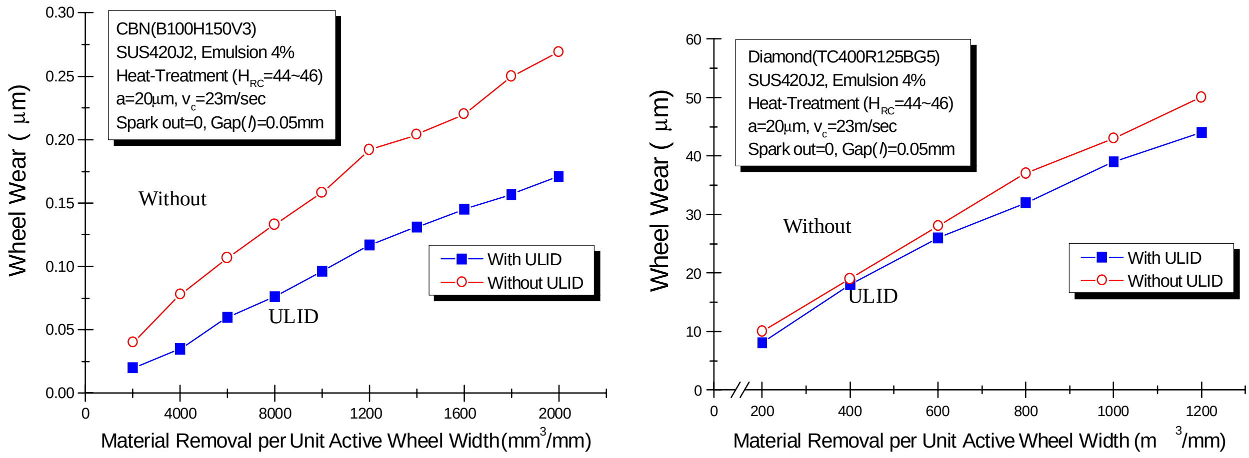
The most optimal surface roughness was came out when the gap was 0.05mm. The ULID is an indirect dressing method, removing the impurities among the grains by the vibration force of the horn and cavitation explosion force generated in the coolant. Therefore, in case the gap between the wheel surface and horn was great, their forces were so little that the effect of the ultrasonic dressing disappeared.

The surface roughness with the gap of 0.15mm between the horn and wheel surface was better than that of 0.1mm. This is the reason that the vibration force is transmitted through the wheel to the ground surface, but that the removal force of the impurities among the grains is small in case of 0.1mm. In case of 0.15mm, however, the better surface roughness was came out, as the vibration force became so small.

5. Conclusion

The conclusions are as follows

1. The ULID is effective to prevent clogging of grinding wheel b removing the impurities among the grains.
2. The surface roughness of ground workpiece with ULID was better than that without it.
3. When stainless steel was ground with the CBN wheel, the wheel wear with ULID was about 36% less than that without it.
4. The ULID had the best effect when the gap between ultrasonic horn and wheel surface was 0.05mm.
5. If the ULID is used, a fine surface can be obtained.



(a) The CBN wheel wear

(b) The diamond wheel wear

Fig. 6 Wheel wear according to material removal per unit active wheel width

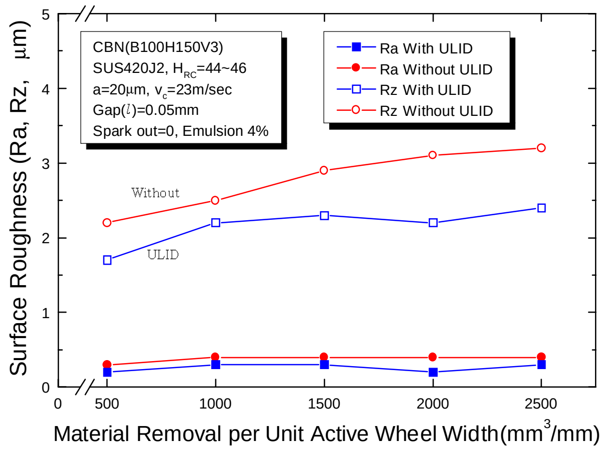


Fig. 7 Influence of Ultrasonic In-Process Dressing on surface roughness

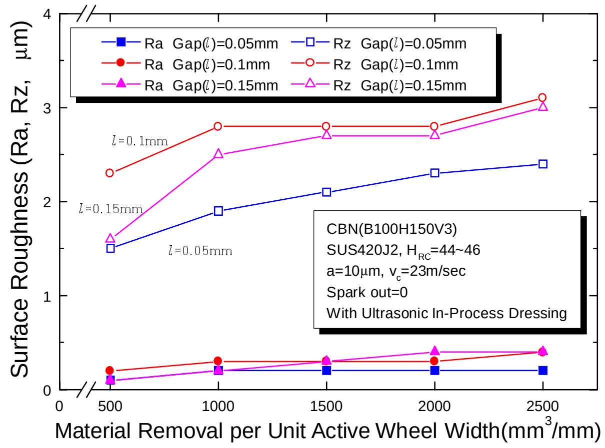


Fig. 8 Surface roughness for different gap(l)

6. Reference

[1] Komanduri, R., "A New Technique of Dressing and Conditioning Resin Bonded Superabrasive Grinding Wheel", Annal of CIRP, Vol.29, pp. 239～243, 1980.

[2] Choi, H. Z., Lee, S. W., and Park, S. I., "A Study the Grinding Technologies for Manufacturing Ball Screws", CIRP International Seminar on Improving Machine-Tool Performance, pp. 475～486, 1998.

[3] Yasushi Ikuse, Takeshi Nonokawa, Noritugu Kawabata, Takehiko Kamo, Yoshihiko Yuzawa and Kuniaki Unno, "Development of New Ultrasonic Dressing Equipment", J. of JSPE,Vol. 61, No. 7, pp. 986～990, 1995.

[4] Yeiji Iasui, Hiroshi Nakazono, Hideo Tsuwa, "Improvement of Grinding Performance by Ultrasonic Dressing", J. of JSME, Vol. 39, No. 10, pp. 54～59, 1973

[5] Berlyaev et al, B. V., "The Effect of Ultrasonic Wheel Dressing on the Grinding Process", Machines & Tooling, Vol. 49, No. 11, pp. 53～54, 1978.