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Novel designing of super abrasive wheel for dynamic motion control in grinding

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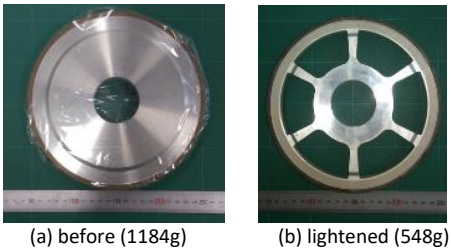
Abstract
Dynamical control of velocity between grinding wheel and workpiece has great potential. Our previous studies clarified that It can't only supress regenerative chatter vibration but also fabricate texture on surface of workpiece in cylindrical grinding. If, however, dynamic revolution control of grinding wheel is attempted, wheel breakage induced by change of centrifugal force must be considered, because general grinding wheel is produced by furnacing abrasive-compound which contains abrasive grains and binding powder such as vitrified or resins.
Meanwhile super abrasive wheel was developed and widely used in recent years. This wheel consists of thin abrasive layer whose thickness is from 5 to 10mm as an outer layer of the wheel, and simple shape of a metal disk as an inner layer of that. The inner metal layer is basically heavy. One of the functions of metal inner can be to maintain a level of moment of inertia. If we realize dynamic control of wheel, the weight and the moment of inertia must be lightened. Therefore, we are researching on the designing of grinding wheel with lightweight and aesthetic sense. In this paper, our newly designed grinding wheel, and the effect is introduced.

Keywords: Grinding, Super-abrasive wheel, wheel designing

1. Introduction

Dynamical control of velocity between grinding wheel and workpiece has great potential. So far, our studies clarified that controlling relative speed between grinding wheel and workpiece can not only supress regenerative chatter vibration but also fabricate texture on surface of workpiece in cylindrical grinding.[1]
In cylindrical grinding, there are three ways to control relative speed between wheel and workpiece. The 1st, 2nd, and 3rd is control of wheel rev., workpiece rev., both revs, respectively. If, however, we change wheel rev., current wheel design which is heavy weight and moment of inertia must become problem. Lighter wheel with high rigidity is desired for dynamic control of the relative speed. Also, it must be a great advantage to reduce power consumption of machine tool.
Thus, we develop new designs of super abrasive wheel. Our previous reports [2] introduced the light weight super abrasive wheel as shown in Figure1. The wheel proved that reduction of energy consumption and acceleration time. The proposed wheel, however, has too much safety ratio yet and improvement in aesthetic sense.



(a) before (1184g) (b) lightened (548g)
Figure 1. utilized super abrasive wheel

Therefore, for the realization of dynamic motion control of grinding wheel, new design concepts of super abrasive wheel are attempted.

2. Design

2.1. Considered respects in designing

Table 1 is specifications of utilized super-abrasive wheel as shown in Figure 1(a). Wheel is redesigned and machined with milling machine to reduce the weight and the moment of inertia. In the redesigning, requested function and constraint condition are discussed and listed as shown in table 2.

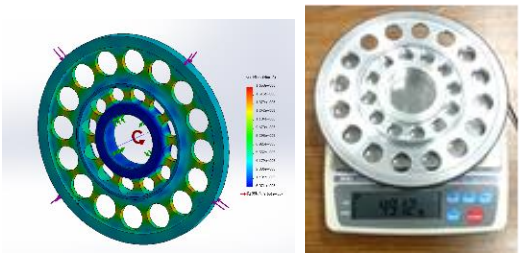
Table 1 wheel specifications to be designed.

Abrasive Spec.			CBC120N50BW4	
Shape	**Wheel dia.** [mm]	**Wheel th.** [mm]	**Hole dia.** [mm]	**Layer th.** [mm]
14A1	200	20	50.8	10.0

Table 2 requested function V.S. constraint condition

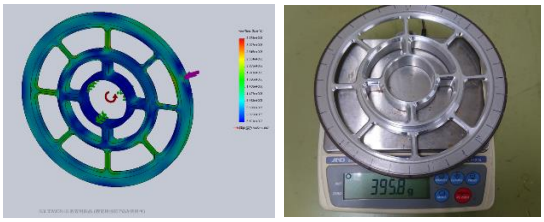
Requested function	**Constraint condition**
Lighter	Higher rigidity
Not fractured by centrifugal force	Available to install on spindle of grinder
Aesthetic design	Available to fabricate designed shape

According to table 2, two types of wheels, type A, type B, are designed, as shown in figure 2, figure 3 respectively.
The design concept of type A is combination of stress dispersion and easiness of machining. The wheel achieves 491.2g of weight; 58% reduction.
The design concept of type B is combination of ultimate light weight and high rigidity. The wheel also achieves 395.8g of weight; 66.7% reduction.



(a)FEM analysis (b)shape

Figure 2. Design of type A wheel



(a)FEM analysis (b)shape

Figure 3. Design of type B wheel

Centrifugal force that can affect safety of each body of wheel is analyzed under the condition of constant spindle revolution of 2000 min^{-1}. In analysis of type B, safety ratio of 28.5 is confirmed. The result shows that each wheel has enough static strength against centrifugal force.

3. Experimental set-up

Figure 4 shows the installation of the developed wheel. The evaluation of the fabricated light-weight wheel is executed with the experimental set-ups as shown in figure 5.
The experimental condition and specification of grinder are shown in Table 3.

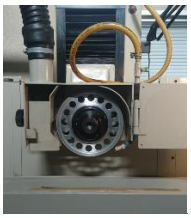


Figure 4. installation

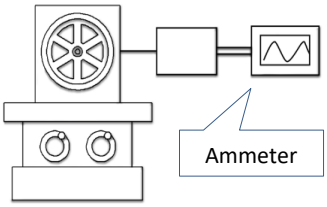


Figure 5. illustration of experiment

Table 3 condition of grinding experiment

Grinder	OKAMOTO PSG52DX
Table size	550×200 mm
Grinding wheel rotation speed	1800 min^{-1}
Ammeter logger	Fluke Scope meter 120B

In order to monitor power, an ammeter logger (Fluke 120B) is putted to spindle motor of the grinder. The current of the spindle motor is measured to evaluate how reduction of weight and moment of inertia effect.

4. Result & discussion

Figure 6 shows the measured spindle motor currents when the spindle with type A wheel is started from 0 min^{-1} and accelerated to 2000 min^{-1}.

The Spindle motor is vector-controlled AC-servomotor. The motor is controlled by amplitude of current and frequency. Larger amplitude and lower frequency of the wave form is seen

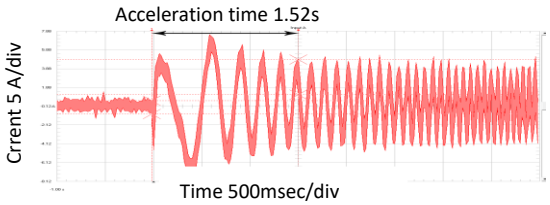


Figure 6. start-up current wave of spindle motor with Type A

as transfer response when the spindle starts the rotation. Then amplitude and frequency become constant as steady state response. In order to evaluate the effect of weight lightened, the duration time of transfer response is measured, and results in table 4.

Type A and B both demonstrate quicker acceleration than normal. they also have better frequency response. Principally, the power-consumption becomes larger in proportion to the duration of current waveform. It means that the light-weight wheel is effective in not only improvement of frequency response of wheel rotation but also reduction of power consumption.

Meanwhile, despite of weight reduction ratio between A and B is different, acceleration times of both wheels is same. As one of the reasons, the moment of inertia of the spindle itself is heavier than that of each wheel, and it can absorb effect of weight reduction between A and B.

Also, it is found that weight lightening of wheel helps reduction of operator's loads when they handle a wheel and adjust static wheel balancing, as another advantage.

Table 4 results

Type	**Weight [g] After/Before**	**Reduction ratio** [%]	**Calculated Inertia** [kg/m^2]	**Acceleration time**[s]
Normal	1158/1158	-	0.0057	4.72
Type A	491.2./1158	58	0.0025	1.52
Type B	395.8/1187	66.7	0.002	1.52

5. Conclusion

In order to realize dynamic speed control between grinding wheel, new designs of weight lightened, and high rigid super abrasive wheel is proposed. The findings from this study are following:

1) Two types of new design concept are proposed. The lightest wheel achieves 395.8g of weight; 66.7% reduction ratio and it shows feasibility of faster frequency response.

2) Despite of weight reduction ratio between A and B is different, acceleration times of both wheels are same. As one of the reasons, the moment of inertia of the spindle itself is heavier than that of each wheel.

3) Weight lightening of wheel helps reduction of operator's loads when they handle a wheel and adjust static wheel balancing.

Acknowledgement

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