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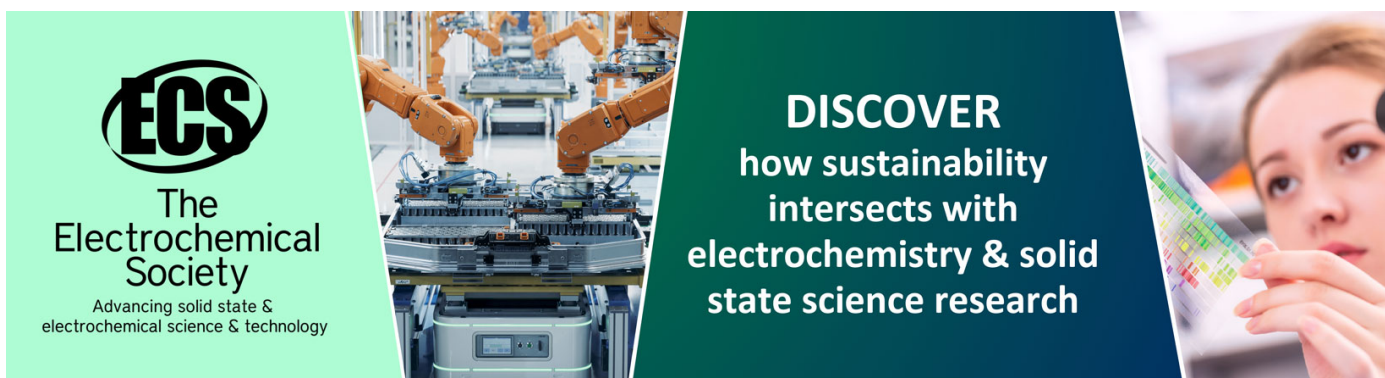
Study on design of light-weight super-abrasive wheel

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Study on design of light-weight super-abrasive wheel

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Abstract. Fixed-abrasive tool, also called a grinding wheel, is produced by furnacing abrasive compound which contains abrasive grains and binding powder such as vitrified materials or resins. Fixed-abrasive tool is installed on spindle of grinding machine. And it is given 1,800-2,000 min⁻¹ of spindle rotation for the usage. The centrifugal fracture of the compound of fixed-abrasive tool is one of the careful respects in designing. In recent years, however, super-abrasive wheel as a fixed-abrasive tool has been developed and applied widely. One of the most characteristic respects is that metal is applied for the body of grinding-wheel. The strength to hold abrasive grain and the rigidity of wheel become stronger than those of general grinding wheel, also the lifespan of fixed-abrasive tool becomes longer. The weight of fixed-abrasive tool, however, becomes heavier. Therefore, when the super-abrasive wheel is used, the power consumption of spindle motor becomes larger. It also becomes difficult for the grinding-wheel to respond to sudden acceleration or deceleration. Thus, in order to reduce power consumption in grinding and to obtain quicker frequency response of super-abrasive wheel, the new wheel design is proposed. The design accomplishes 46% weight reduction. Acceleration that is one second quicker than that of conventional grinding wheel is obtained.

1. Introduction

Fixed-abrasive tool, what we call grinding wheel, is produced by furnacing abrasive-compound which contains abrasive grains and binding powder such as vitrified materials or resins [4, 5]. Fixed-abrasive tool is installed on spindle of grinding machine. And it is given 1800~2000 min⁻¹ of spindle rotation for the usage. The centrifugal fracture of the compound of fixed-abrasive tool is one of the careful respects in designing. In recent years, however, super-abrasive wheel as a fixed-abrasive tool has been developed and applied widely. One of the most characteristic respects is that metal is applied for the body of grinding-wheel. The strength to hold abrasive grain and the rigidity of wheel become stronger than those of general grinding wheel, also the lifespan of fixed-abrasive tool becomes longer. The weight of fixed-abrasive tool, however, becomes heavier. Therefore, when the super-abrasive wheel is used, the power consumption of spindle motor becomes larger. It also becomes difficult for the grinding-wheel to respond to sudden acceleration or deceleration.

Thus, the purpose of this research is to design lighter grinding wheel while maintaining the rigidity, and to evaluate the effects on grinding performance, especially energy consumption.



2. Wheel design

2.1. Considered aspects in designing

In designing light-weight wheel, the following aspects are considered:

- (1) Lower weight, same rigidity
- (2) Wheel balance
- (3) Avoiding centrifugal destruction
- (4) Economical cost for manufacturing

Inasaki et al. [1-4] proposed a sensor-integrated grinding wheel where various sensors such as an acceleration sensor are installed on its carbon-composite body. Although it is an ambitious experimental proposal, from practical view point, utilizing carbon-composite is too expensive and possibility of delamination is one of the concerning aspects for durability.

Therefore, utilization of conventional super-abrasive wheel and weight reduction of the wheel are considered. Figure 1 and table 1 show a picture of utilized super-abrasive wheel and its specifications, respectively. Cubic Boron Nitride (CBN) as abrasive is selected for steel grinding, and resin as binder is selected to prevent centrifugal breakage of wheel.

Figure 2 shows the design of lightened super-abrasive wheel. 6-spoke design is selected according to the balance within production cost budget, strength and the result of FEM analysis. Round shape is also applied to connection between spokes, rim, and hub to avoid stress concentration.

Table 1. Specifications of experimented super-abrasive wheel

Abrasive material	Granularity	Coupling	Concentration	Binder
CBC	120	N	50	BW4
	Wheel diameter [mm]	Wheel thickness [mm]	Hole diameter [mm]	Abrasive layer thickness [mm]
	200.00	20.00	50.80	5.00

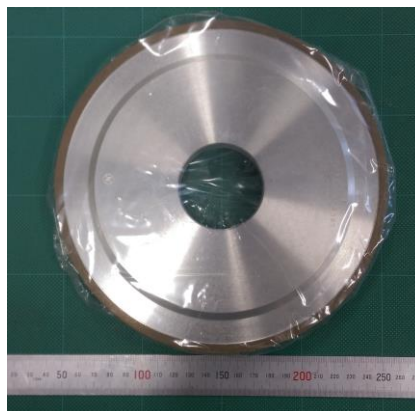


Figure 1. Utilized wheel

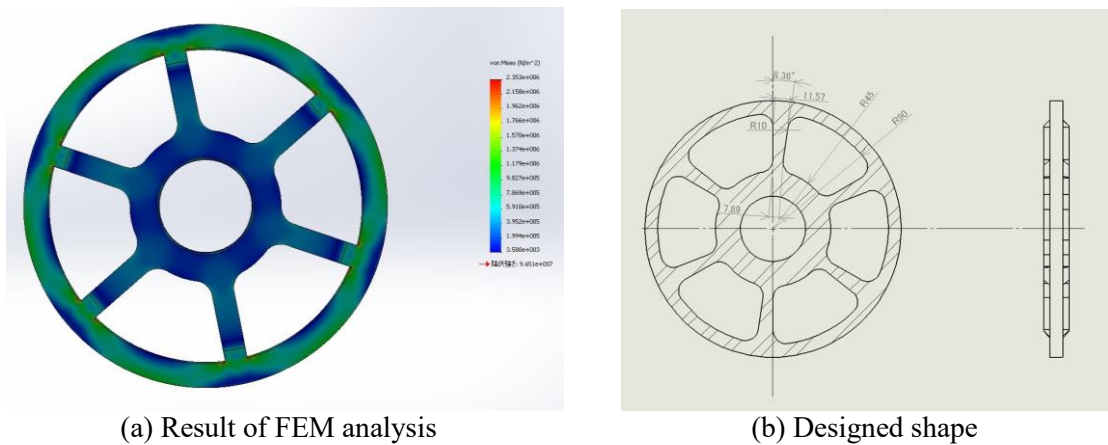


Figure 2. Design of light-weight wheel

2.2. Manufacturing strategy

There are three methods to fabricate the designed shape in figure 2 from the raw shape in figure 1. They are milling, electro-discharge machining, and wire electro-discharge machining. In case of milling, the cost of the fixing tool of the work piece (jig) is a problem. In case of applying Electro- Discharge Machining (EDM), the cost of making carbon pole is a problem. On the other hand, in case of Wire Electro-Discharge Machining (WEDM), fixing the work piece is not needed, and wire pole has sufficient flexibility to trace complicated tool trajectory. Thus, wire electro discharge is selected to fabricate the light-weight wheel.

Figure 3 shows fabricated light-weight super-abrasive wheel. The wheel weight before processed is 1,183.7 g. Meanwhile, the weight after processed is 547.6 g that is 46% reduction, as shown in figure 4.

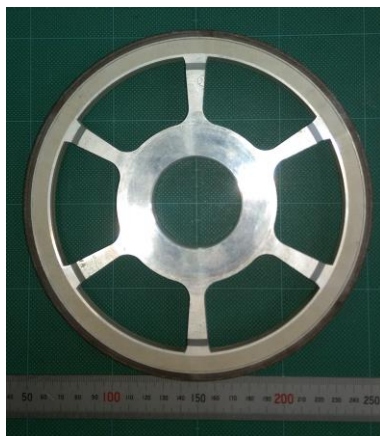


Figure 3. Light-weight concept

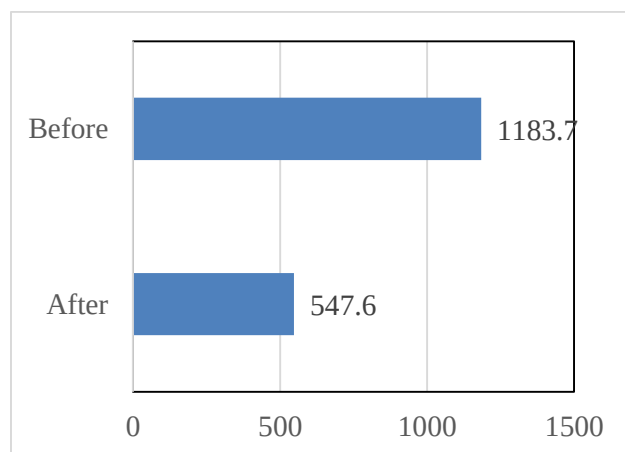


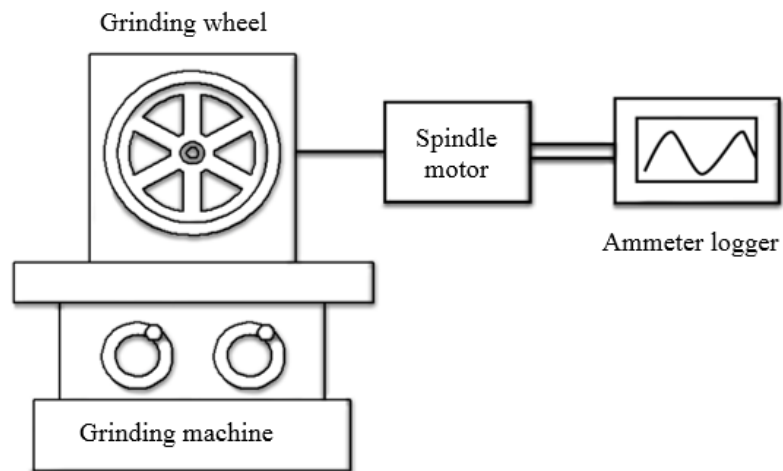
Figure 4. Comparison of wheel weight

3. Grinding Performance

3.1. experimental setup

Figure 5 shows the installation of the developed wheel. The evaluation of the fabricated light-weight wheel is executed with the experimental setup as shown in figure 6.

The specification of the grinder is shown in table 2. In order to monitor power, an ammeter logger (Fluke 120B) is installed on the spindle motor of the grinder.

**Figure 5.** Installed wheel**Figure 6.** Experimental setup**Table 2.** Specifications of utilized Grinder

Grinder	OKAMOTO PSG52DX
Table size	550×200
Wheel size	Φ205×25×Φ50.8
Grinding wheel rotation speed	1800 min ⁻¹
Feed stroke	500
Minimum preset-able depth of grinding	0.1μm

3.2. Comparison of spindle-motor current at the start-up

In order to evaluate how the reduction of wheel weight effect on grinding, the current of the spindle motor is measured.

Figure 7 shows the measured spindle motor currents when the motor is started from 0 min⁻¹ and accelerated to 2,000 min⁻¹. Figures 7(a) and 7(b) are cases of utilizing normal wheel and light-weight wheel, respectively.

The spindle motor is vector-controlled AC-servo-motor. The controllable parameters are current and frequency. The figures demonstrate almost the same maximum amplitude. However, the durations that the frequency becomes constant in utilization of each wheel are different. The duration of figure 7(b), which is 2.16 sec, is shorter than that of figure 7(a), which is 3.18 sec. The amplitudes of both the current plots do not decrease rapidly but slightly as shown in the figures. This means that the power consumption is large in proportion to the duration. Therefore the result shows that the light-weight wheel is effective in not only reduction of power consumption but also improvement of frequency response of wheel rotation.

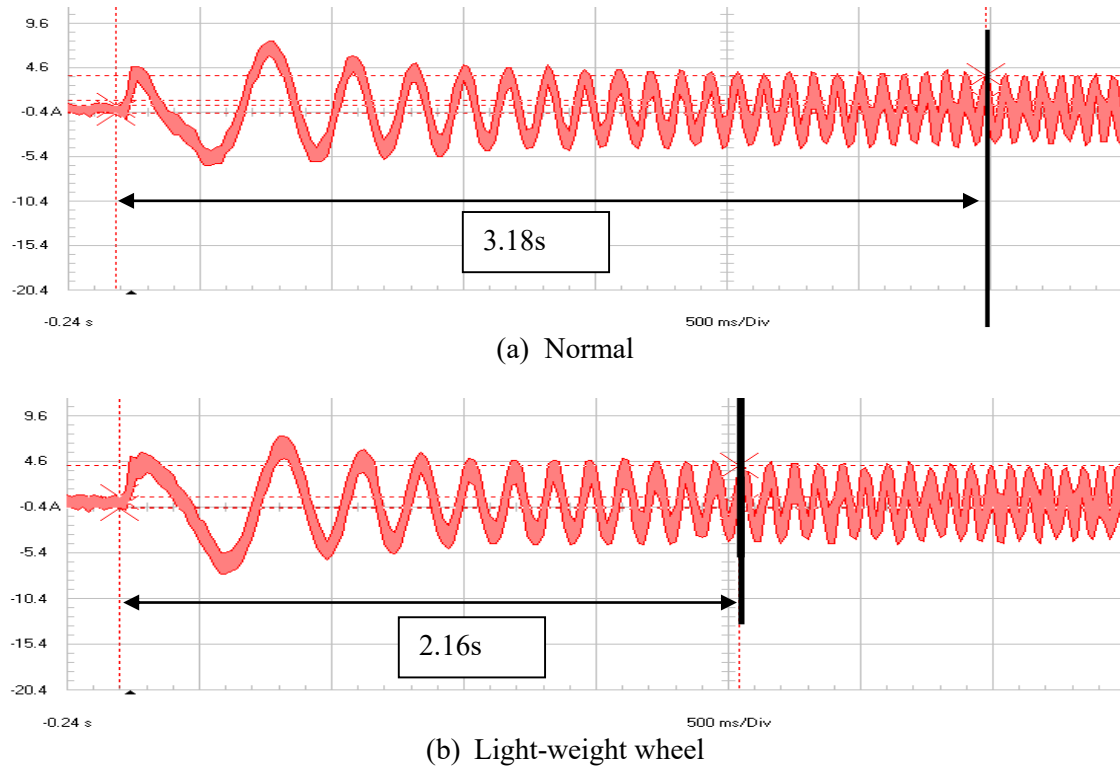


Figure 7. Comparison of waveform of spindle-motor current

4. Effects on processing

Reducing weight of grinding wheel can involve reduction of rigidity as fixed-abrasive tool. In this section, it is investigated how the reduction of the fixed-abrasive tool rigidity affects the ground surface.

Figure 8 shows the ground specimen of S45C with light-weight wheel. Figure 9 shows the roughness curves of work-pieces which are ground with normal and light-weight wheel.

The mean roughness of normal and light-weight wheel is $0.74 \mu\text{m Ra}$ and $0.23 \mu\text{m Ra}$, respectively. It shows that reduction of wheel-weight in our design does not affect for wheel rigidity and grinding performance.

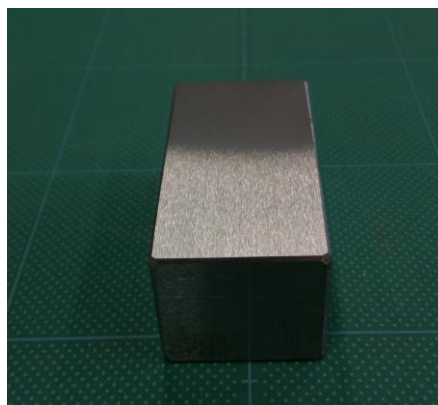
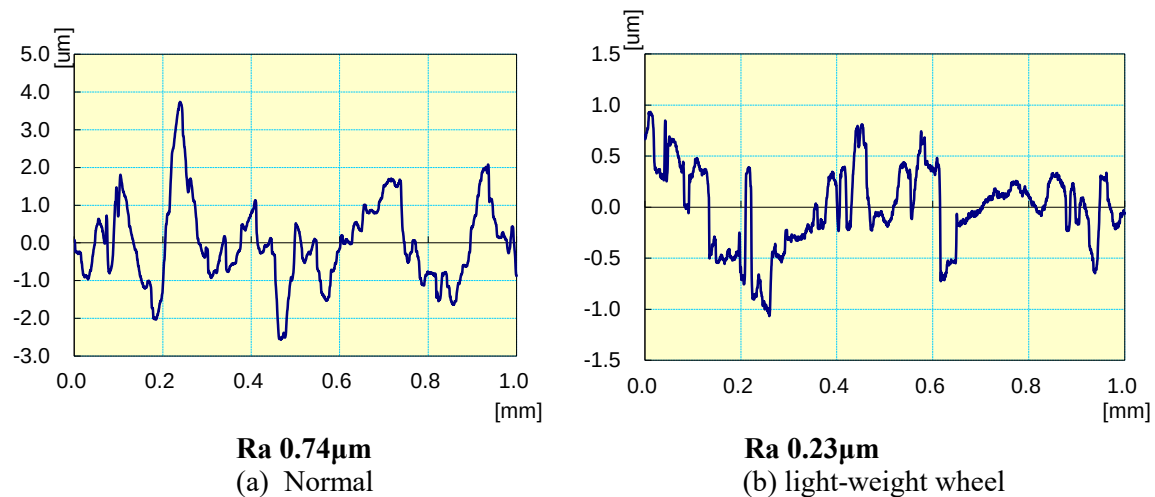


Figure 8. ground specimen

**Figure 9.** comparison of ground surface

5. Conclusion

In order to reduce power consumption and improve response of rotational acceleration or deceleration of spindle, reducing of weight of grinding wheel while maintaining the rigidity is investigated. Obtained conclusions from this study are as follows:

- 1) To realize a light-weight grinding wheel while maintaining high rigidity, six-spoke shape is designed with CAD. 46% weight-reduction has been accomplished.
- 2) To confirm the effect of this light-weight grinding wheel, verification experiment is conducted to accelerate the spindle from stop to 2,000 min^{-1} which is the operation speed without any wheel failure.
- 3) In the experiment, it is confirmed that the time until when the frequency becomes constant by the inverter control is shortened. Improvement of acceleration or deceleration and reduction of power consumption is confirmed.
- 4) The reduction of wheel weight does not affect wheel rigidity, surface integrity of ground surface, or grinding performance in the case of our design.

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