

# Effect of Grinding Wheel Tooth Thickness on Grinding Force Distributions in Face Grinding of Cemented Carbide with Constant Processing Efficiency

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**Abstract:** Cemented carbide is very hard and suitable for molds and tools, although because of its high hardness and strength, both high precision and high efficiency processing methods have not been established yet. Then in this paper, in order to establish accurate grinding technology of the cemented carbide, also to clarify the grinding mechanism we carried on this research using with two different tooth thickness grinding wheel. Because of workpiece support stiffness is higher than grinding wheel stiffness, system stiffness is affected by the wheel stiffness. Furthermore, grinding wheel stiffness of thick tooth thickness is higher than thin tooth. In the face grinding of the cemented carbide is carried out with the parameter of the wheel setting depth of cut and feed rate of wheel head with constant processing efficiency. Grinding force is larger with increase of the feed rate. Furthermore, grinding force distribution peak becomes low and broad. This is measured by the difference of rise up part of grinding force when the grinding wheel starts to interfere with cemented carbide which was transcribed a wheel envelope shape. Furthermore, in the case of the thick tooth, the grinding force and the grinding force distribution become lower than the thin tooth.

**Key words:** cup type electroplated diamond grinding wheel, cemented carbide, grinding force, grinding force distribution, surface integrity of grinding wheel working surface

## 1. Introduction

This study aims to establish both high precision and high quality face grinding technique for cemented carbide with cup type single layer electroplated diamond wheel. An idea of grinding force distribution is introduced into an analysis of grinding process. A peak of the grinding force distribution becomes low and broad, when the same depth of cut and rise up the feed rate<sup>1)</sup>. With increase of the depth of cut, a peak position of the grinding force distribution hardly changed when the large depth of cut, which is another approach to efficiency processing<sup>2)</sup>. In this paper, two wheel which has different tooth thickness are examined.

## 2. Grinding wheel

The wheel has an outer corner radius  $R1\text{mm}$ , and grinding fluid feed ports are located inner part of a wheel working surface. The tooth thickness are  $3.5\text{mm}$  and  $7.0\text{mm}$ . Wheel support stiffness is  $k_s=103.1\text{N}/\mu\text{m}$  for thickness  $3.5\text{mm}$ , and also  $k_s=142.1\text{N}/\mu\text{m}$  for thickness  $7.0\text{mm}$ , and then wheel support stiffness of the thickness  $7.0\text{mm}$  is 40% improved. While a stiffness of work support system is  $k_w=468.1\text{N}/\mu\text{m}$ , then system stiffness becomes  $k_{sy}=84.5\text{N}/\mu\text{m}$  for thickness  $3.5\text{mm}$  and  $k_{sy}=108.5\text{N}/\mu\text{m}$ , it is made clear that the system stiffness of thickness  $7.0\text{mm}$  which is 28% improved by thickness  $3.5\text{mm}$ .

## 3. Experimental apparatus

Figure 1 shows an experimental apparatus. A quartz dynamometer is settled on a machine table, and a precision vice is fixed on it. And a workpiece is mounted on the vice, so the grinding forces can be measured. A cup type electroplated diamond grinding wheel is fixed to a wheel holder, and an axis of the grinding wheel rotates, furthermore the setting depth of cut is fed in  $z$  direction, a feed rate is fed in  $y$  direction, and the face grinding is done in  $x$ - $y$  plane. Note that sufficient spark-out grinding is done previously.

A grinding fluid is fed by both eight spindle through type nozzles which has a center hole in order to gush out to the bottom part of the wheel, and external feed nozzle. Main experimental conditions are as follows. Grinding wheel: SD80P (mean grain size is  $177\mu\text{m}$ ). Tooth Thickness: (1) $3.5\text{mm}$ , (2) $7.0\text{mm}$  in a base metal of the wheel. Workpiece: Cemented carbide G5 (particle size of WC is  $\phi 1.0$ - $8.0\mu\text{m}$ , contents of Co is 8.0%, HV=1250). A rotation speed of the spindle:  $N_s=2500\text{rpm}$ . A processing efficiency is maintained  $15\text{mm}^3/(\text{mm} \cdot \text{min})$ , A feed rate of the grinding wheel:  $V_f=18.75$ - $500.0\text{mm}/\text{min}$ . A setting depth of cut:  $\Delta=30$ - $800\mu\text{m}$ . A grinding fluid feed rate:  $G_f=7.0\text{L}/\text{min}$  (soluble

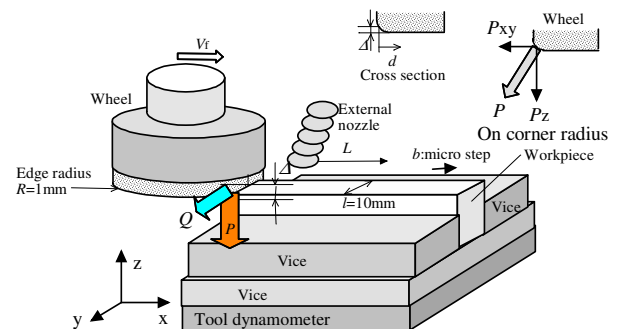


Fig. 1. An Experimental apparatus.

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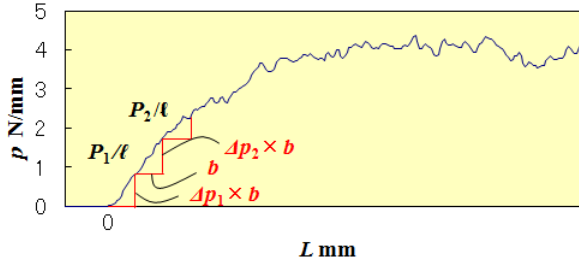


Fig. 2. Calculation method of grinding force distribution.

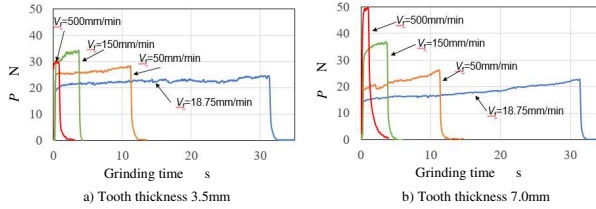


Fig. 3. Variations of normal grinding force.

type, 1.25% concentration). Before grinding test, WA stick grinding is done as a dressing process of SD grinding wheel. Dressing condition is  $50\mu\text{m} \times 6\text{pass}$  with wet grinding.

#### 4. Analysis of grinding force distribution

Figure 2 shows a calculation method of the grinding force distribution, where  $l$  is a grinding width,  $b$  is a micro step width of an interference along a grinding length  $L$  in Fig.1,  $\Delta p$  is the normal grinding force distribution. The normal grinding force distribution can be presented as an Eq. (1).<sup>1)</sup> It is obtained by a beginning part of the normal grinding force rise up section, when the grinding wheel approaches to a spark-out surface again.

$$\Delta p_n = (P_n - P_{n-1})(b \cdot l) \quad (1)$$

#### 5. Grinding force and grinding force distribution

Figure 3 shows variations of normal grinding force  $P$ . From the figure, it is clear that  $P$  increased with increase of the feed rate. And  $P$  was smaller in the case of tooth thickness 7.0mm. The wheel is electroplated, so the grain support stiffness is high, furthermore the wheel support stiffness is also high, the wheel rigidity becomes large, and a residual stock  $d_r$  becomes low mention below. Therefore, there is little number of simultaneous cutting edges as there are few escapes of the abrasive. And if the same force arises, the system stiffness is high, so the residual amount  $d_l$  becomes low, prepared to the case of  $d_l$  increases, real contact point of the workpiece and the grinding wheel. Because of these two reasons, in the real contact area, the simultaneous grain number became low, compared with the low stiffness wheel, then grinding forces might became decrease.

Figure 4 shows the variations of the normal grinding force distribution  $\Delta p$ . From the figure, as with increased of the feed rate, the peak value was decreased, and was made broad. Furthermore, the peak position was nearby the rise-up section of  $P$ , in another word, the peak occurred from a contact point of both wheel and workpiece, and it was understandable that the of most material removal were done in the corner radius  $R$ . That is to say, bottom of the wheel makes the surface roughness as if traverse grinding. The peak position moved toward inner part of the bottom of the wheel with increase of feed rate. And all values are smaller in the case of thickness 7.0mm wheel.

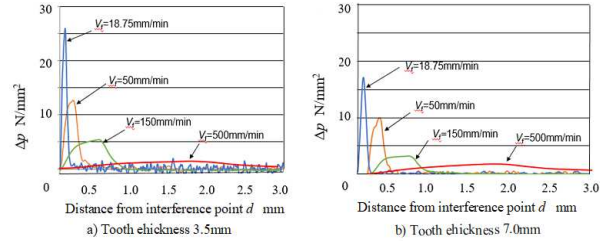


Fig. 4. Variations of normal grinding force distribution.

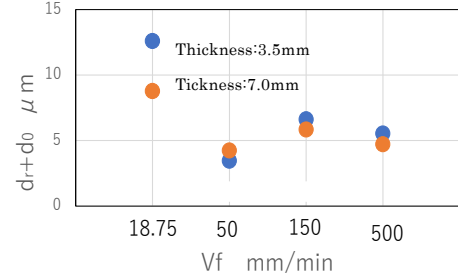


Fig. 5. Variations of residual amount ( $d_r + d_o$ ).

#### 6. Residual amount

Figure 5 shows variations of the residual amount ( $d_r + d_o$ ). From the figure, these values had decrease tendency with increase of the feed rate. The values were smaller in the case of thickness 7.0mm wheel.

#### 7. Conclusions

Main conclusions obtained in this study are as follows.

- 1) Grinding force and grinding force distribution of tooth thickness 7.0mm wheel became lower than that of the thickness 3.5mm wheel.
- 2) All residual stocks became low in the case of thickness 7.0mm wheel rather than the case of 3.5mm wheel.

#### Acknowledgement

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