Evaluation of Wheel Life by Grinding Ratio and Static Force

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A degree of sharpness in wheel grains affects the surface roughness and dimensional accuracy in the grinding process. If a wheel with dull grains is used, the grinding force is increased and the surface roughness is deteriorated. In ovder to produce a precision component economically, the magnitude of the wear amount in the grinding wheel has to be limited. In this study, experimental evaluation of a wheel life varying with the grinding ratio and static grinding force was conducted. The grinding ratio and grinding force were measured to seek the grinding performance of the WA wheel. The relationship between the grinding ratio and static grinding force was presented.

Key Words : Grinding Ratio, Grinding Force, Wheel Life, Experimental Evaluation

1. Introduction

Recently, demand for machining ultra-precision parts has increased in metal removal processes. Since the grinding process is a final stage of the metal removal process and determines the product quality, the importance of the grinding process is increasing in the machinery industry. Especially, the state of a wheel has a significant effect on produced parts comparing with other metal removal processes such as turning and milling. Therefore, it must be accomplished to choose the correct wheel and to determine the adequate dressing time. In qeneral, however, the dressing time has been chosen subjectively by the skilled operators. It means that the decision of the wheel life or dressing time is very difficult and complex due to the action of multi-connected parameters that must be considered. Various methods were introduced to make the estimation of the wheel life and to determine the dressing time.

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The monitoring technique by a grinding force in plunge grinding process was proposed (Park et al., 1999). They showed that the grinding force affected the dressing time and there existed a threshold of the grinding force to improve a surface roughness of a workpiece. Seo et al. (1999) investigated characteristics of an internal plunge grinding. Through the experimental approach, they indicated that the maximum normal force was nearly equal to the static grinding force and decreased exponentially as the continued machining.

The dressing time is very important in connection with the machining efficiency and the wheel life. Lee and Jung (2000) determined the wheel life by monitoring a behavior of the grinding power for the WA and GC wheel. As the result, an attritious wear of abrasive edges, a wheel loading and a breakage of grains could be verified the grinding power pattern and by the surface integrity. Moreover, the relationship between the average sectional area of a chip and the wheel life was obtained to guide the decision of the dressing time.

In order to evaluate the wheel life, we examined the grinding force, surface roughness and grinding ratio in the cases of varying the depth of cut and the feed rate with WA wheel. The relation between a variation of the grinding force and wheel life was obtained.

2. Grinding Ratio

How to evaluate the performance of grinding wheels is practically important. The most widely used parameter is the grinding ratio (G). The grinding ratio in surface grinding can be simply written as:

$$G = Q_w / Q_s \quad (1)$$

$$Q_w = b\ L\ t \quad (2)$$

$$Q_s = 2\ \pi\ b\ \Delta r \quad (3)$$

where Q_w is the volumetric workpiece removal and Q_s the volumetric wheel wear. L is a total length of a workpiece, and Δr is the radius reduction of the grinding wheel t and b are the depth of cut and the width of the grinding wheel, respectively. Under any grinding condition, it can be seen that the grinding ratio reduces rapidly according to more radius reduction of the grinding wheel.

While higher grinding ratio is generally desirable, the more wear resistant wheel may gives high forces and energies so that it increases a likelihood of thermal damages to a workpiece (S. Malkin, 1989). A more meaningful test for evaluating the wheel performance, which is used by some wheel manufacturers, is to measure both the grinding ratio and the force under fixed grinding conditions. The general approach is to test a series of wheels covering a range of grades rather than a single wheel, as this makes it possible to distinguish between inherent wheel quality and wheel hardness effects.

3. Experimental Condition and Setup

Table 1 lists the experimental condition to obtain the grinding force and the grinding ratio. Grinding wheels of WA80LmV and WA100LmV were used. Specimens were a STD11, SUS304 and STB2. The grinding wheel speed was constant as 1,800 rpm and the feed rates were 2 m/min and 4 m/min. A depth of cut varied 5~20 μm. The chemical composition of specimens is listed in Table 2.

Table 1 Experimental condition

Grinder	Horizontal spindle surface grinder
Workpiece	STD11, SUS304, STB2
Wheel	WA100, WA80
Grinding condition	Wheel speed : 1,800 rpm
	Feedrate : 2, 4 m/min
	Depth of cut : 5~20 μm
	Up & plunge & wet
Fluid	Shell lubricant (soluble type, 10 : 1)
Dressing	Dresser : Single pointed diamond
	Depth of cut : 10~50 μm

Table 2 Chemical composition of specimens (%)

	C	Cr	Mn	Ni	Si	P	S
SUS304	0. 08	19.0	2.0	9.25	1.0	0.045	0.03
STB2	1.1	0.25	0.5	0.25	0.25	0.025	0.025
STD11	1.5	12	0.6	0.5	0.4	0.03	0.03

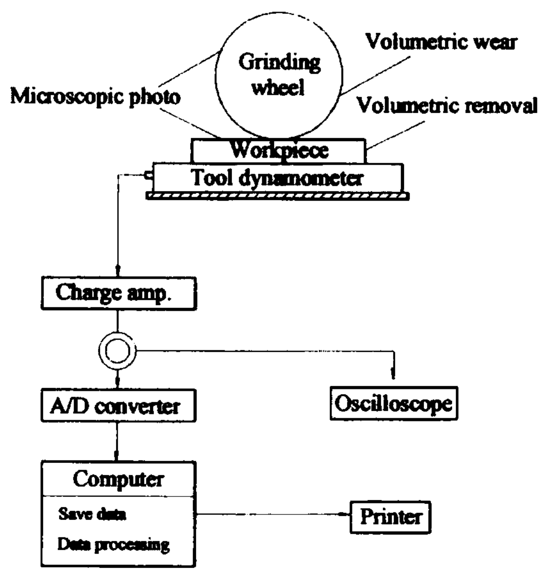


Fig. 1 Schematic diagram of experimental setup

Figure 1 shows the schematic diagram of the experimental setup. To acquire the grinding force, the tool dynamometer was fastened to the bed of the grinding machine. Force signals obtained from the tool dynamometer were transmitted to the charge amplifier and amplified to avoid an attenuation of analog signals. Amplified analog signals were digitalized by the A/D converter with 12 bit resolution and the digitalized data were saved at a personal computer. The grinding ratio was calculated through measurement of the wheel wear amount and the workpiece removal. In addition, the relationship between the static grinding force and wheel life was determined to evaluate the wheel life.

4. Experimental Results and Discussion

4.1 Grinding force and surface roughness

Figures 2 and 3 illustrate the grinding force variations according to depth of cuts and feed rates used to WA100 and WA80, wheel respectively. In all cases, the grinding force increased gradually with increasing the depth of cuts and feed rates. It was also evident that the grain size had not concerned with the force variation.

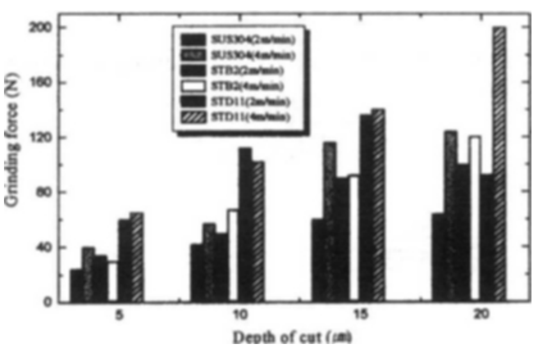


Fig. 2 Variation according to depth of cut (WA100 wheel)

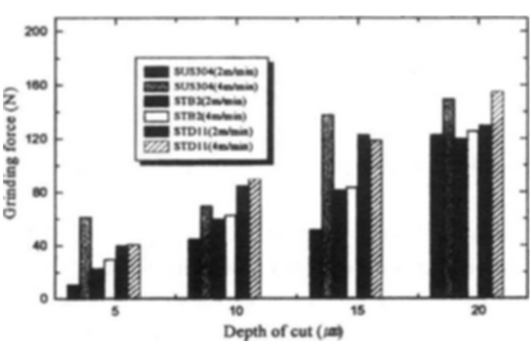


Fig. 3 Variation according to depth of cut (WA80 wheel)

One of most important items in fine grinding is the roughness of a produced surface. The surface roughness is usually measured in the peak-to-valley (R_{max}) and the centerline average (R_a). A tracer instrument having the small radius of curvature at the diamond tip of a stylus is normally used to make such measurements. To distinguish between waviness (long wavelength) and roughness (short wavelength), the output is filtered to remove effect of long wavelength when roughness is desired. The wavelength separating these two regimes is the 'cut-off' length, which is usually 0.8 mm (Kwak et al., 2000).

Figure 4 presented the surface roughness according to the number of ground pieces. The surface roughness in the STD11 specimen before 50^{th} piece was slowly increased with increasing the number of ground pieces, but gradually deteriorated after grinding 50^{th} piece. Similar cases occurred at 20^{th} and 70^{th} ground piece in the SUS304 and STB2 specimen, respectively. It may be due to an irregular self-dressing. When abrasives of a grinding wheel are dull, the grinding force increases because of larger contact area between the wheel and workpiece. Abrasives that are unable to bear the increased force fall from a wheel. A circumference of the wheel is, therefore, made irregular and a surface roughness may be deteriorated. We can infer carefully the wheel life from the rapid deterioration of the surface roughness.

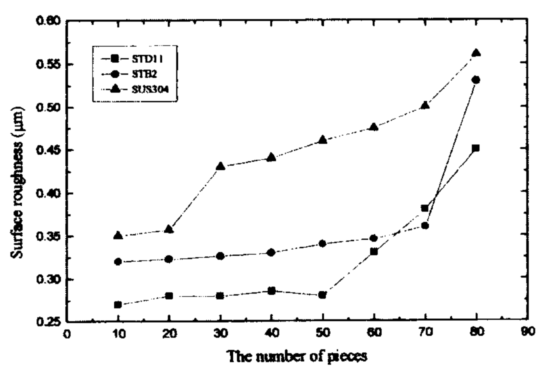


Fig. 4 Surface roughness according to the number of pieces

4.2 Decision of wheel life

The wheel life has been determined as the time that the grinding wheel should be redressed due to wear. In general, periodic dressing has been used for the sake of convenience in grinding process. However, it has many malfunctions such as excessive consumption of the grinding wheel and increased non-machining time. It is thus required to determine the wheel life more reasonable and adequate.

Figure 5 shows the relation between the volumetric wheel wear and workpiece removal. At the workpiece removal of 1,500 mm^3 in the STD11 specimen, the wheel wear was slowly increased. In the STB2 and SUS304 specimen, the rapid increasing points of the wheel wear were generated about 2,100 mm^3 and 600 mm^3 respectively.

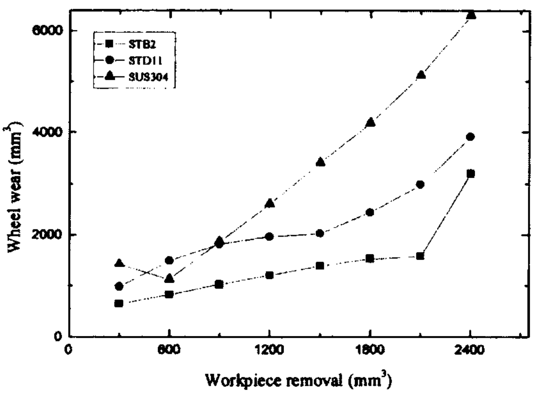


Fig. 5 Relationship between volumetric wear of wheel and workpiece removal

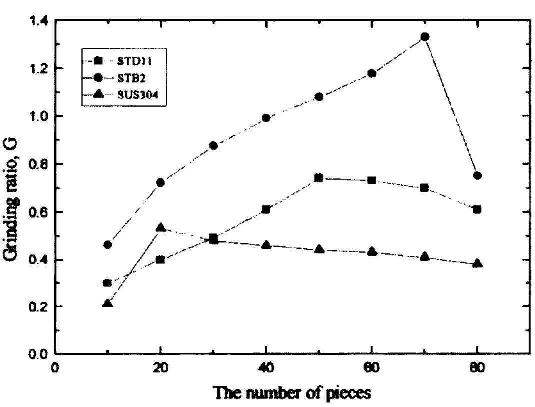


Fig. 6 Grinding ratio according to the number of pieces

From the result shown in Fig. 5, the grinding ratio was calculated and plotted in Fig. 6. The grinding ratio of the STD11 specimen before 50^{th} piece increased with the number of pieces but it decreased after 50^{th} piece. Similar to the surface roughness in Fig. 4, the grinding ratio of the others was reduced after 20^{th} and 70^{th} piece. From the results of Figs. 4 and 6, it was seen that determination of the wheel life was possible to apply monitoring of the grinding ratio.

For the purpose of seeking the wheel life, a grinding force was used. Figure 7 shows a typical grinding force signal, and the grinding force is divided in the static and dynamic grinding force. The level of the static grinding force means the absolute magnitude of the grinding force.

Figure 8 shows a change of static grinding force for the STD11 specimen. The static grinding force was diminished suddenly after 50^{th} piece, which

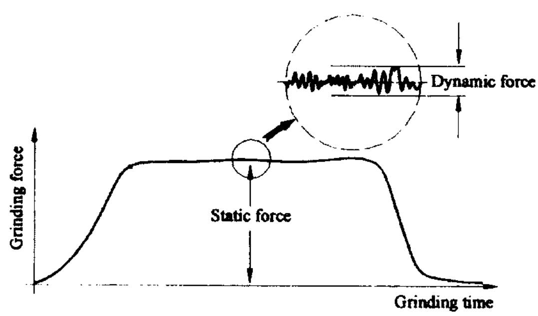


Fig. 7 Definition of static and dynamic grinding force

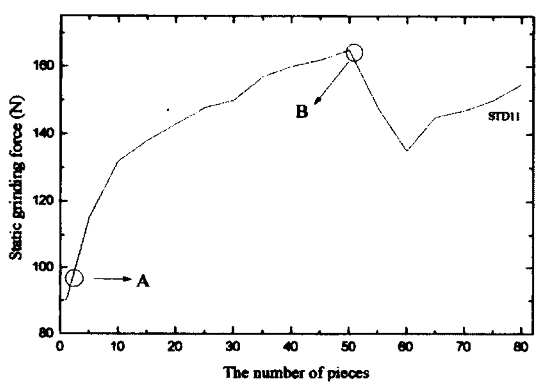
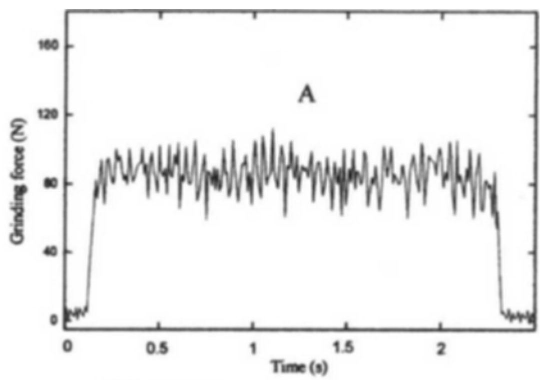


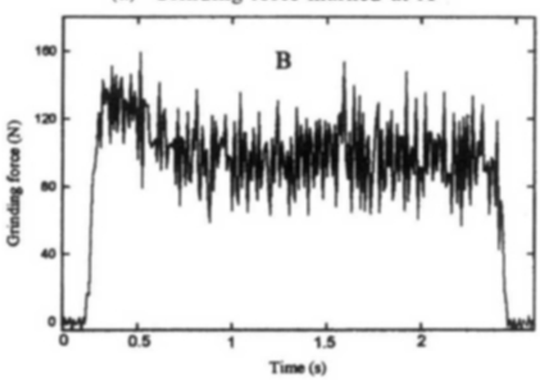
Fig. 8 Static grinding force according to the number of pieces

coincided with the wheel life of the STD11 specimen.

Difference of the grinding force signal between after just dressing, marked as A in Fig. 8, and after wheel life, marked as B, was shown in Fig. 9. After just dressing the static grinding force maintained nearly a constant level about 80N, but after wheel life this level oscillated widely. This offers a cue for predicting the wheel life with the static grinding force.



(a) Grinding force marked at A



(b) Grinding force marked as B

Fig. 9 Grinding force comparison between A and B

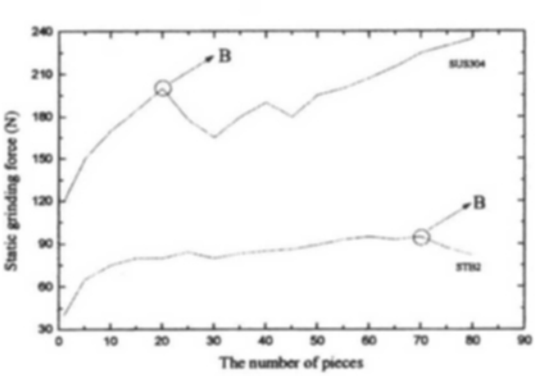


Fig. 10 Static grinding force in STB2 and SUS304 specimen

For other materials such as the STB2 and the SUS304, the same examination was conducted and the results were plotted in Fig. 10. The locations marked as B in Fig. 10, represent the wheel life of the SUS304 and the STB2 specimen. The wheel life of the SUS304 specimen, because of the property of ductility that caused easily the loading of a wheel, was shorter as 20th piece than the STB2 as 70th piece. From Figs. 8 and 10, it could be concluded that the wheel life was 50th, 20th and 70th piece for the STD11, SUS304 and STB2 specimen, respectively.

5. Conclusions

In order to evaluate a wheel life and to verify the relation between the G-ratio and the static grinding force, a series of examinations were conducted in surface grinding. It has been shown that the grinding force increased gradually with increasing the depth of cut and the feed rate. The grain size was not related to the force variation.

After grinding 50th piece of the STD11 specimen, the surface roughness of a workpiece deteriorated rapidly. The similar results were acquired at 20th and 70th piece in the SUS304 and the STB2 specimen. The grinding ratio and static grinding force decreased significantly at that time. The wheel life in the STD11, the SUS304 and the STB2 specimen was determined as 50th, 20th, and 70th piece. It was found that the wheel life could be estimated by the grinding ratio and the static grinding force.

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