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자성 페라이트의 초고속 연삭

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SUPER HIGH SPEED GRINDING FOR MAGNETIC FERRITE

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1. INTRODUCTION

Ferrite have been widely used as a magnetic material by many electronic industries. During its sintering process, however, a shrinkage of the material cannot be avoided. Therefore, some machining processes are needed after the sintering to attain the accuracy required for a component. Since this material is brittle and hard, grinding with diamond wheel is generally performed as a final process.

In the manufacture of ferrite parts, it is known that the finishing costs can comprise up to 70% of the entire manufacturing cost. This mean that the strategy to reduce the grinding cost is to reduce the grinding cost is to elevate grinding rate because the fraction of wheel cost is considerably low in the total cost. The way to get high grinding rates while maintaining a small grain depth of cut is through the use of high wheel speeds and fine abrasive wheel. Since small grain depth of cut requires high specific grinding energy, considerably high grinding temperature rise occurs being enhanced by the effect of high wheel speed. The elevated grinding zone temperatures tend to inhibit fracture and promote the plastic flow type grinding. High temperatures can have a beneficial effect on the resulting surface integrity, which is contrary to the case of grinding metals.

On the other hand, the surface damage induces during grinding, which might cause the fatal degradation of strength of the ground part, is very severe problem.[1] Besides, when ferrite material is ground, the surface is found to have a shallow magnetically inactive layer due to residual stress.[2, 3] This "dead" layer affects the resolution and storage capacity of the magnetic system.[4]

2. EXPERIMENTAL PROCEDURE

Table 1 shows the grinding and dressing

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conditions. The test wheel is the vitrified diamond wheel which is comprised in the CFRP(Carbon Fiber Reinforced Plastics) core. The test has been conducted to grind workpiece at different rotating wheel speed up to 160 m/s. The workpiece is the Ba ferrite and its characteristics is shown in Table 2.

Table 1 Test Conditions

GRINDING MACHINE	Super high spees surface grinder
GRINDING WHEEL	SD170R100VD2(15″ ×0.63″ ×3.15″)
WORKPIECE	Ba ferrite
GRINDING METHOD	Plunge surface grinding
WHEEL SPEED	30, 80, 120, 160 m/s
WORKPIECE SPEED	0.3, 0.8, 1.2, 1.6 m/s
REMOVAL RATE	3.5 - 30.0 $mm^3/mm \cdot s$
COOL ANT	Soluble oil (50 : 1), High pressure
DRESSING & TRUING	Norton brake truing device

Table 2 Workpiece Characteristics

TYPE OF SINTERING	Normal pressure
FRACTURE TOUGHNESS	5.5 $MPa \cdot m^{1/2}$
VICKERS HARDNESS	11 Gpa

The forces generated at the grinding wheel/workpiece interface were measured using a octagonal ring dynamometer. The force normal (z-axis), and force tangential directions(y-axis), were measured. Force measurements were taken from freshly dressed/trued wheels and for successive cuts. Test bars were cut from the plates both parallel to the direction of extrusion. The bars were machined to normal finished dimensions of 5X3X55 mm. In the grinding of the eventual tensile face of the flexural bars the diamond wheel was dressed and trued using a Norton brake truing device when 0.5 mm of material was bending strength tests were carried out at ambient temperature using a 4 point bend test fixture, the inner span being 15mm and the outer span 45mm. The load and support rollers were located in roller bearings to minimize the influence of friction between specimen and rollers. The fixture was self-aligning as both load and rollers could tilt.

Wheel wear was measured the change of wheel surface after grinding workpiece which have narrower width than that the wheel, by plunge surface grinding.

The surface roughness average (R_a) of typical specimens for each grinding combination was measured using a Talysurf 4 profile meter traversing in a direction parallel to the grinding direction. The residual stresses is estimated by the curvature method. [5]

3.EXPERIMENTAL RESULTS AND DISCUSSION

3.1 GRINDING PERFORMANCE

The grinding force is an important measureme -nt in evaluating the optimum grinding condition and the grindability of the material. Figure 1 shows the relation between removal rate and grinding force at various wheel speed such as 80, 120 and 160m/s. In any wheel speed, grinding force does not change in simply range, even removal rate is increased. There is the inflection range where grinding force does not increase and level off, even removal rate increases. From consideration of the grinding force, not only its magnitude but also its slope with removal rate, it is conclude that super high speed grinding is adequate for the grinding of ferrite. The higher rate of increase in the grinding force in particular involves serious problems in retaining useful properties of ferrite after grinding.

Fig. 2 shows the relation of Fig. 1 complied by grain depth of cut which is specified by

$$g/a = 2\frac{v}{V}\sqrt{\left(\frac{1}{D}+\frac{1}{d}\right)t}$$

Hear in,

g :actual grain depth of cut

a : successive cutting edge spacing

v : workpiece speed

V : wheel speed
t : wheel depth
D : wheel diameter
d : workpiece diameter (=in the case of surface grinding)

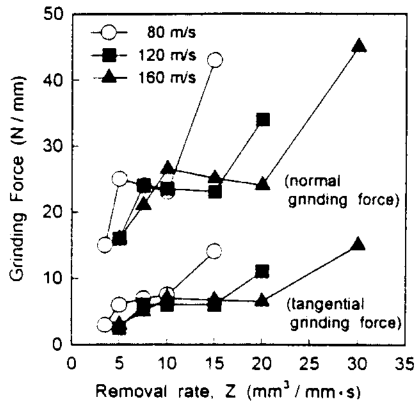

Fig.1 Relation between grinding force and removal rate at different wheel speed

In ferrite grinding, there is the most effective grinding condition to increase removal rate. That is the condition at $g/a=2.5\times10^{-4}$ of grain depth of cut in any wheel speed.

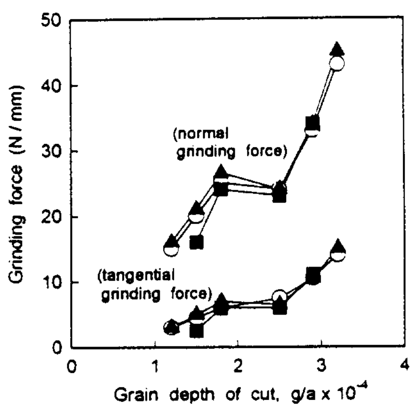

Fig.2 Relation between grinding force and grain depth of cut at different wheel speed

This is considered that fracture of cutting edges of grains under the condition of $g/a=2.5\times10^{-4}$ makes cutting ability of the wheel optimum and cutting edges are abraded at smaller g/a than above and cutting edges are largely g/a. It is considered that this phenomenon is appeared, even if this $g/a=2.5\times10^{-4}$ is changed depending upon different type of grinding machines and wheels and other conditions.

Figure 3 shows the comparative wheel wear at same 2.5×10^{-4} of grain depth of cut in different wheel speed, 30 m/s of conventional speed, 80 m/s of high speed. It is confirmed that dressing interval can be extended to 7 times by increasing wheel speed to 160 m/s. And deterioration of surface roughness can be largely reduced also.

Observing the cutting edges of diamond grain by SEM after grinding the workpiece at various wheel speed, it is found that when the wheel is rotated at higher speed, the cutting edge of diamond grain lasts longer by its less attrition wear, even removal amount.

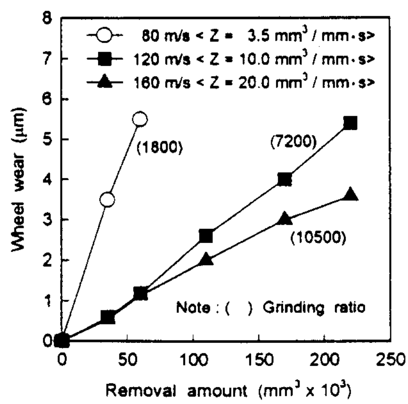

Fig.3 Relation between wheel wear and removal amount at different wheel speed

3.2 Strength and residual stress of ground materials

Figure 4 shows the values of bending strength of ground material vs. removal rate at 30, 80 and 160 m/s of wheel speed. In any wheel speed, strength material tends to be weakened when removal rate increases. At higher wheel speed, reducing ratio of material strength according to increasing removal rate, tends to be lowered. In Fig. 4, the strength of materials ground with Z=3.5mm^3/mm·s at 30 m/s is nearly equivalent as those with Z=10mm^3/mm·s at 80 m/s and Z= 20mm^3 /mm·s at 160 m/s.

The grinding process of ferrite material is mainly to remove the chips by brittle fractures fundamentally, than the growth of surface flaws cannot be avoided. Therefore, the grinding conditions in which the sizes of these flaws are smaller than that of the latent defects must be selected. Otherwise, it is known that the machined surface of ferrite material is formed partially by plastic flow together with by brittle fracture. The both types of surface forming progress at the same time, and it is considered that the proportion of the two depends on the grinding condition.

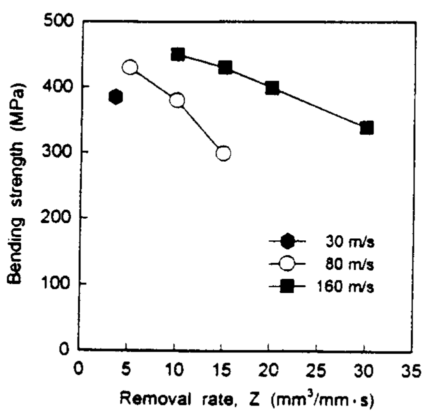

Fig.4 Relation between bending strength and removal rate at different wheel speed

Fig. 5 shows the micro structure of the ground surface of Ba ferrite. The ground surfaces exhibit that the amount of the lpastic flow increases with the increase of the wheel speed. This means that the fracture process during grinding becomes more brittle at lower wheel speed.

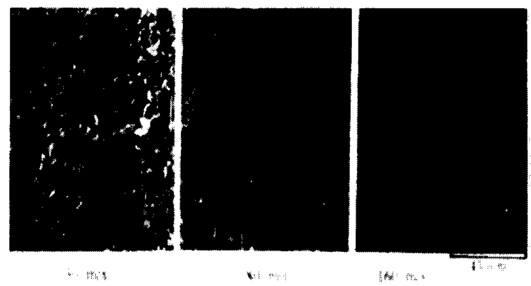

Fig.5 Effect of wheel speed on ground surface of ferrite (Removal rate = 10 mm^3/mm·s)

Grinding process of magnetic ferrites is usually accompanied with chipping and surface flaws. It is considered that the flaws have a significant meaning for the reliabilities of the ground parts. Ordinarily, the fracture of ferrites arises from one of the latent defects which exist in the ferrite material, and the fracture stress determines the basic strength properties of the material. Therefore, the ferrite parts are designed according to these data, and are machined to satisfy the requirement of the size accuracy and the roughness.

When the size of one of the surface flaws which are formed by the grinding process is larger than that of the above mentioned latent defect, the fracture starts from that surface flaws. In this case, the strength property of the ground ferrite part is different from that of the part without grinding, and the reliability on the relations between the finished roughness and the strength have been often pointed out, and it is well known that sometimes the lowering of roughness brings the remarkable decrease in strength. These facts suggest that the subject of grinding process of high performance ferrites is to secure the reliability on finished parts in addition to the improvement in the efficiency and accuracy. Fig. 6 shows relationship between ground surface roughness and removal rate at different wheel speed. As shown in this figure, the surface roughness average (Ra) decrease with increasing wheel speed, and increase with increasing removal rate. However, the effect of removal rate on surface roughness increase more slightly with increasing removal rate at higher wheel speed.

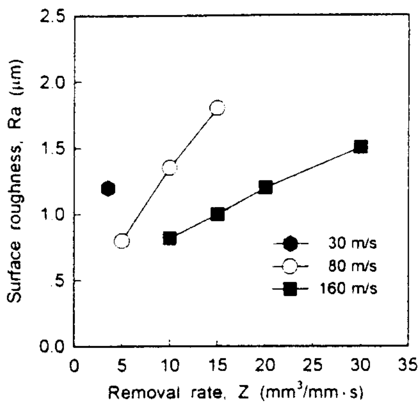

Fig.6 Relation between surface roughness and removal rate at different wheel speed

Fig. 7 shows the relation between bending strength and grinding direction in grinding with various diamond grain size at different wheel speed. As shown in this figure, the difference in bending strength due to grinding direction is smaller at higher wheel speed. Then the strength of the specimens ground in parallel with the length is higher than that of the specimen ground in perpendicular, and the difference in the strength due to the grinding direction becomes larger in grinding with coarser grain size. In the case of grinding by the same grain size wheel, the roughness and the crack size of the finished surface must be the same value. However, those specimens show apparently the different strength by the direction of the tensile stress component which apply to them. This fact shows that the existence of the surface flaw does not always bring on the decrease in strength of ground part. Namely, the surface flaws formed by grinding have remarkable directional qualities, and the factor which affects the flaw size and the direction. Therefore, the failure probability of a machined part is closely related to the machining process and the stress state or the distribution.

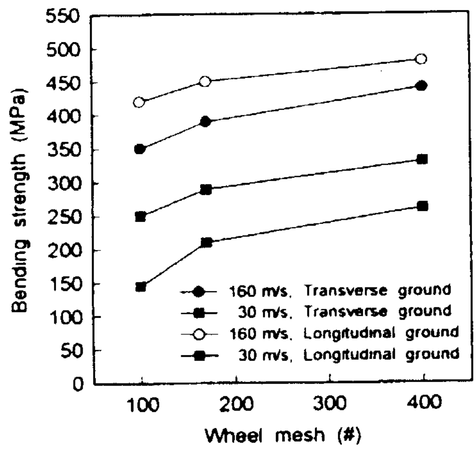

Fig.7 Effect of grinding direction and diamond grain size on bending strength at different wheel speed(Removal rate = 10 $mm^3/mm \cdot s$)

Then the estimation of the strength of a machined part under the combinate stress is very complicated because of the variety of fracture origin, and understanding the relation between reliability of a ground part and grinding condition is necessary and required.

The damage induced during is usually in the form of residual stresses, both compressive and tensile, and surface/subsurface cracks which have a major influence on the mechanical properties and integrity of the material. The residual stresses induced by grinding process alter electromagnetic properties such as permeability and resistivity of the near surface in ferrite, thus causing the deterioration of its performance in electronic devices. The depth and magnitude of the residually stressed layer, including the relative amount of residual compression and tension are important which control the strength and magnetic properties and magnetic properties of the ground ferrite. Fig. 8 shows the relation between wheel speed residual stress of ground ferrites. It is seen from in this figure, that the magnitude of the surface compressive stresses becomes lower with increasing wheel speed. Also, the compressive stress extends to a smaller depth at higher wheel speed. Higher wheel speed results in smaller chip thickness and also smaller forces acting at the individual cutting edges of the wheel, so that compressive residual stresses and the possibility of surface damage are therefore reduced.

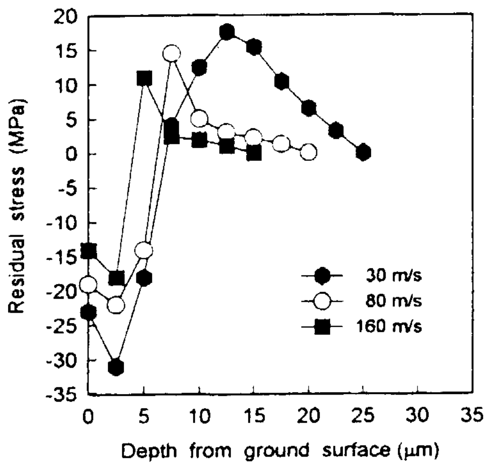

Fig.8 Residual stresses of ferrite ground at different wheel speed (Removal rate = 20 $mm^3/mm \cdot s$)

4. CONCLUSIONS

1) The most effective grinding condition for increasing removal rate in ferrite grinding is $g/a=2.5\times10^{-4}$ of grain depth of cut.
2) Increase of wheel speed from conventional 30 m/s to 160 m/s of super high speed allows to improve grinding performance such as 5.5 times higher removal rate and 7 times longer dressing interval without lowering ferrite strength.
3) The ground surfaces exhibit that the amount of the plastic flow increases with the large increase of the wheel speed, and the surface roughness decrease predominantly at super wheel speed.
4) The difference in bending strength due to grinding direction is smaller at super wheel speed.
5) The magnitude of the surface compressive stresses becomes lower with increasing wheel speed. Also, the compressive stress extends to a smaller depth at super wheel speed.

5. REFERENCES

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