Fabrication of Grinding Wheel with Dispersed Hard Powder by Electrical Discharge Machining

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1. Introduction
Because industrial products have been becoming higher in performance and finer in size, machining with higher accuracy is required. Grinding process is one of the highly accurate machining methods and very effective for machining hard materials such as cemented carbide and hardening steel.

The abrasive layer of the grinding wheel generally composes 3 elements such as grains, a bond and pores. The abrasive grains on the working surface of a grinding wheel are easily shed and the thickness of an abrasive layer decreases during grinding the hard materials. The pores are loaded by debris during grinding soft materials. Consequently, the grinding wheel should be frequently dressed so that the life of the grinding wheel becomes shorter. Moreover, when the life of the grinding wheel is ended, the grinding wheel is disposed of even if its core is still usable. This is very wasted and makes the cost of the grinding process higher. Some fabrication methods of grinding wheels have been proposed to reduce the fabrication cost, or improve the gripping strength of grain and grinding performance [1][2].

In this paper, a fabrication method of an abrasive layer by electrical discharge machining (EDM) is proposed. The characteristics of the deposited layer are evaluated through a grinding process. This method is applicable to recycle a grinding wheel.

2. Fabrication method
A depositing method of a hard layer by electrical discharge machining (EDM) with a green compact electrode has been studied [3]. Fig. 1 shows an example of the WC-Co accretion with a thickness of 1 mm. The accretion is porous according to the electrical conditions. The green compact has composed only conductive materials. On the contrary, an abrasive, generally insulating material, is added into a mixture of WC and Co powders in the proposed method. In this case, the abrasive grain will be dispersed into the WC-Co accretion working as a bond as shown in Fig. 2. Consequently, the hard layer including the 3 elements can be fabricated by EDM.

A green compact electrode was made by compressing a mixture of WC: 63 wt%, Co: 27 wt% and an abrasive: 10 wt%, which was Al_2O_3, SiC or diamond. Then the abrasive layer was deposited under the conditions shown in Table 1. Fig. 3 shows some examples of the accretion including the abrasive grain observed by a scanning electron microscope (SEM) and energy dispersive X-ray spectroscopy (EDX). The layer in which each of the powders with a size of 20-100 µm dispersed could be deposited on a plate. Some other insulating grains used as the abrasive were also investigated. Fig. 4 shows the range of the grain size and thermal conductivity where the abrasive could be deposited. The grain size and the thermal conductivity mainly affect the deposit properties. Because the heat by discharge is not absorbed into the grains with low
thermal conductivity such as \( \text{Al}_2\text{O}_3 \) and \( \text{ZrO}_2 \) but the WC-Co layer, the grain remains and the reaction of the WC-Co layer with the grain is promoted. On the other hand, the grains with high thermal conductivity such as diamond and CBN were easily disappeared because the whole grain immediately accumulates the heat so that they sublime.

Fig. 5 shows a setup to fabricate a mounted wheel. After a JIS-SKD11 (ASTM-D2) core with a diameter of 18 mm was rotated and translated like a rack-and-pinion during EDM, the mounted wheel shown in Fig. 6 could be fabricated. Its surface roughness was 22 \( \mu \text{m} \).

The grain volume percentage was evaluated with a partial section analyzed by EDX. The volume percentage for #150 or #400 SiC grain was 6% and 10%, respectively, when the volume ratios of the SiC grains in each electrode were 41% and 31%. These ratios are much smaller than that of conventional grinding wheels, 34-62% in nominal. The hardness of the WC-Co layer...
without abrasive was 21 H≤B, harder than a vitrified bond wheel. And the hardness of the layer including SiC grain was -15 H≤B, corresponding to H grade.

3. Grinding performance

JIS-S50C (AISI-1049) carbon steel, aluminum and copper disks were ground with the #400 SiC abrasive layer fabricated on a JIS-SKD11 plate instead of fabricating a big grinding wheel. Table 2 shows grinding conditions. Both the pressure-based in-process measurement method [4] and the contact method were applied to measurement of a radius of the disks with a diameter of 205 mm. The peripheral speed and the depth of grinding a pass were set to 23.6 m/s and 3 μm, respectively. Fig. 7 shows the comparison of two methods. The dotted line shows the coincidence of the in-process measurement with the contact method. All the data exist on the dotted line. The difference between them are less than 0.6 μm. The grinding ratios against aluminum, copper and steel were 19.7, 11.3 and 6.9, respectively. With an increase of the volume percentage of the grains, the grinding ratio is increased. The volume percentage of the wheel used in the experiment was much smaller than conventional wheels. The percentage should be improved.

4. Recycling of wheel

The concept of the machining method by the feedback of shape data [5] was applied to recycle a used grinding wheel. Fig. 8 shows a recycling process. Deposit and removal machining are repeated in this method until the form error remains. The shape was measured with an electric comparator without dismounting the wheel from the quill.

The accretion without abrasive was fabricated to evaluate the strength of the bond. The maximum difference for a thickness of 350 μm was 14 μm by the shape feedback method.

Table 3 shows the grinding conditions. The roughness of the mounted wheels was 20-30 μmRy after truing by EDM. Fig. 9 shows appearance of a ground area. The grinding ratios for wheels primarily deposited and recycled were 15.9 and 13.7, respectively. Though the new layer was deposited without any cleaning in the recycle process, the recycled wheel performed as well as the new wheel.

5. Conclusions

In this paper, the fabrication method of a grinding wheel is proposed. The conclusions can be drawn as
follows.
(1) Many abrasives including super abrasives could be included in the WC-Co layer. The appropriate range of grain size and thermal conductivity exists.
(2) Though the volume ratio of the wheel fabricated by EDM was smaller than that of conventional wheel, the grade was the same. Steel could be ground with the wheel fabricated by EDM.
(3) The grinding wheel was recycled without a great decrease of the grinding ratio.

This method is an effective solution to solve the problems in grinding.

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