Development of Electrically Conductive PCD and its EDM Property

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Abstract

Electrically conductive polycrystalline composite diamond (EC-PCD), which consists of electrically conductive diamond grits, has recently been developed for the purpose of providing the material with both excellent tool property and good machinability. This paper deals with an investigation of machinability of EC-PCD by EDM with a copper (Cu) electrode. As a result, it was found that the EDM speed (Material removal rate) for EC-PCD was higher than that of the standard PCD. Although surface roughness of the standard PCD was 13µm Rzjis at set current ip=3A, the same of the EC-PCD was 5µm Rzjis at the same current condition.

1. Introduction

Polycrystalline composite diamond (PCD) is manufactured by sintering fine diamond particles under high pressure and high temperature conditions together with catalyst such as cobalt. It has a feature that it is excel in chipping resistance despite its high hardness [1]. Though PCD is used mainly as cutting tools and wear parts, its application as a wheel for fine machining [2] or as a long lasting electrode for EDM (electro discharge machining) has been recently reported [3].

For processing these PCD components, EDM or grinding technique is generally adopted, but it is significantly hard to process PCD by grinding as the diamond wheel in use easily gets grazed because of the diamond contained in PCD at a rate of higher than 90%. Though PCD can be processed by EDM since it contains electrically conductive cobalt as a catalyst, it has been said that stability and efficiency in EDM is not satisfactory and thus high quality surface cannot be obtained. This is because the diamond itself is non-conductive. In order to cope with these problems attached to PCD processing, it is essential to introduce a new PCD possessing excellent tool property and good machinability at the same time.

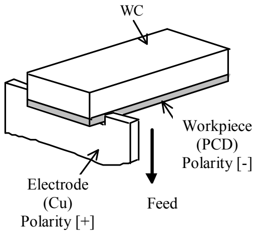


Fig 1 Schematic diagram of die sinking EDM on PCD

Table 1 Experimental conditions for die sinking EDM

Machine used	Linear motor driven EDM machine (Sodick)
Electrode	・Copper (Cu) : 19×19×t0.5mm, Polarity "＋" ・Rotating electrode (for sharp edge profiling) : φ30×t0.5mm
Workpiece	・EC-PCD (Diamond grain size 10 & 25μm) : $5 \times 8 \times t_{PCD}0.7$mm, Polarity "－" ・S-PCD (Diamond grain size φ10 & 25μm) : $5 \times 8 \times t_{PCD}0.4$mm, Polarity "－"
Working fluid	Oil (With jet flow) (Sodick)
EDM conditions	u_i=90V, SV=60V, Ip=1.9～9A, te/to= 20/20μs, No jump, A=5×0.5mm^2, set depth h_0=200μm

Authors have succeeded in experimental manufacture of a new PCD using boron-doped electrically consuctive diamond in place of non-conductive diamond normally used for existing PCD. In order to investigate basic EDM property of EC-PCD, in this study, die sinking EDM experiments were condusted and results were compared with standard PCD (S-PCD).

2. Machinability of EC-PCD in die sinking EDM

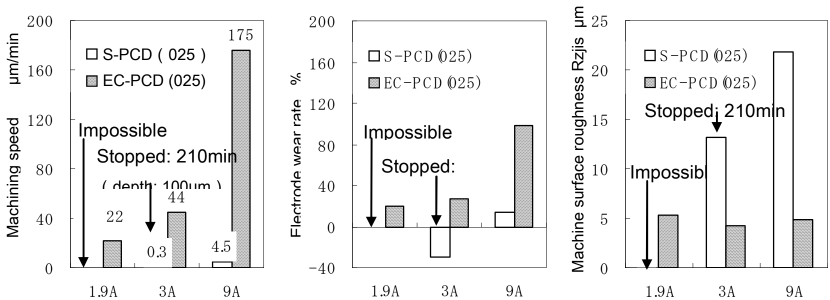
2.1 EC-PCD made up of electrically conductive diamond

In PCD, diamond particles are inter-grown with each other on a carbide substrate by sintering under high pressure and high temperature condition. In EC-PCD, boron-doped diamond with electrical conductivity is used as a starting material.

2.2 Experimental technique and conditions

A PCD workpiece wire cut to a specified dimension was placed downward underneath the spindle, and a copper electrode (t=0.5mm) was set upward on the table. An area to be EDMed is A=2.5 (5x0.5)mm^2. Figure 1 shows experimental diagram and appearance, and Table 1 shows experimental conditions. As for polarity, the electrode was set to "+" and the workpiece (PCD) was set to "-". Three different kinds of set current Ip , namely 1.9A, 3A, 9A were used, and pulse condition te/to was set to 20/20μs .

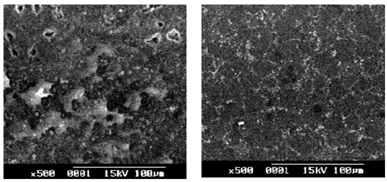
During EDM processing, working oil was jet flowed with a nozle. Set machine depth was 200μm, but when machining time exceeded 60 minutes, the experiment was stopped and evaluation was made. Two grades of PCD composed of different grain size of the diamond, namely 10μm and 25 μm, were used.



(a) Machining speed (b) Electrode wear rate (c) Roughness of the machine surface

Fig.2 Results of die sinking EDM on S-PCD (025) and EC-PCD (025)
(Cu electrode: u_i=90V, SV=60V, te/to=20/20μs, Area EDMed A=5×0.5mm^2, h_0=200μm)

2.3 Results and consideration



(a)S-PCD(025) (b)EC-PCD(025)

Fig.3 Aspect comparison of the machined surface (Ip=3A)

Comparison result of EDM property between S-PCD and EC-PCD (diamond grain size: 25μm) are shown in Fig.2)

1) Machining speed: In EDM of S-PCD, machining time significantly got longer when Ip became lower, and when the current was 1.9A, machining didn't proceed at all, so the experiment was stopped after 30 minutes from judgement that machining was impossible. When the current was 3A as well, machining was stopped at the machining depth of 100μm (approx. 210min). With EC-PCD, machining could be proceeded up to the depth of h_0=200μm with no problem at any level of current. When comparing the machining efficiency, EC-PCD showed a great advantage, where machining speed for EC-PCD was 40 times higher than that for S-PCD.

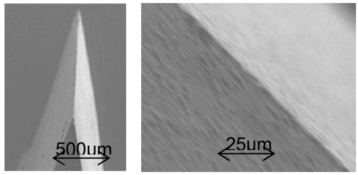
2) Wear rate of the electrode: In machining EC-PCD, wear rate of the electrode increased with increase of the set current. Therefore, it is necessary to select appropriate machining conditions. In machining S-PCD at 3A, minus value was recorded due to the adhesion of graphitic carbon on the electrode surface making the electrode thicker.

3) Roughness of the machined surface: While roughness on S-PCD (025) was Rzjis =13.2-21.8μm, the same on EC-PCD (025) was far better such as Rzjis =4.25-5.33μm (Fig 3).

3. Applications

3.1 An attempt of fine EDM

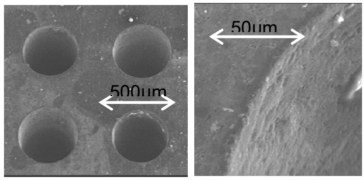
Creation of a sharp edge profile on an end face of EC-PCD (010) was attempted using a rotating Cu electrode. Plain surface area on both sides of the apex angle was made flat, and edge line of the apex angle could be processed to a sharp edge of around 2-3μm (Fig.4). Hole making was attempted against EC-PCD (025) using a thin Cu electrode and obtained a good result with smooth surface without chipping (Fig.5).



(a) Front edge profile (b) Slant face of the edge (Scaled up)

Fig.4 Profiling a sharp edge onto EC-PCD(010) (Apex angle 30°)

(Cu electrode, u_i=90V, rough ⇒finish EDM)



(a) Hole profile (b) Edge part (Scaled up)

Fig 5 Example of fine hole processing on EC-PCD(025)

(Cu electrode (ϕ 0.3mm), hole diameter≒ ϕ 320μm)

3.2 Wire EDM property

It has been already confirmed also in wire EDM that machining efficiency and surface roughness is superior on EC-PCD compared with the results on S-PCD.

4. Conclusion

EC-PCD consisting of electrically conductive diamond particles was newly manufactured, and its EDM machinability was investigated. As a result, it was made clear that EC-PCD could show superior properties in die sinking EDM such as improved machining speed and surface finish, compared with existing S-PCD.

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