euspen's 18th International Conference & Exhibition, Venice, IT, 2018

www.euspen.eu

Electro discharge machining of PCD using rotating cemented carbide electrode mounted on ultrasonic spindle

Shinichi NINOMIYA[1)], Yoji YAMADA[1)], Fumio KOGA[1)], Manabu IWAI [2)], Kiyoshi SUZUKI [3)]

[1] *Nippon Institute of Technology*, [2] *Toyama Prefectural University*, [3] *K.Suzuki New R & D Office*

ninomiya@nit.ac.jp, yoji@yamada-mt.co.jp, fumio_koga@eg-koga.co.jp, iwai@pu-toyama.ac.jp, s-kiyoshi@ipr.ne.jp,

Abstract

Polycrystalline diamond (PCD) is made by sintering fine diamond particles with cobalt as a sintering aid. When a blind-hole is machined into a standard PCD (S-PCD) workpiece using die-sinking EDM it is not possible to remove the nonconductive diamond part. Consequently, machining efficiency is poor and the electrode wear is large on S-PCD. On the other hand, boron-doped diamond particles showed good discharge ability. This second type of PCD material is named electrically conductive polycrystalline diamond (EC-PCD). Authors decided to focus on EC-PCD through the creation of ultrasonic vibration assisted electro discharged machining (EDM). Consequently, the machining efficiency of EC-PCD was enhanced and the electrode wear was reduced. In this study, an ultrasonic vibration assisted EDM using a rotating cemented carbide electrode is proposed for machining the two types of PCDs. Characteristics of blind-hole machining to each PCD were investigated.

PCD (Polycrystalline diamond), ultrasonic assisted EDM, ultrasonic spindle, rotating cemented carbide electrode, electrode polarity

1. Introduction

Polycrystalline diamond (PCD) is made by sintering fine diamond particles. Thus it is very hard to machine PCD due to its high hardness. In the case of a blind-hole machining to a standard PCD (S-PCD), it is difficult to obtain a good surface finish because nonconductive diamond areas cannot be removed by electrical discharges. As a consequence, the electrode wear rate becomes extremely high and the machining efficiency is very low. Whatever, the authors have demonstrated that the electrically conductive polycrystalline diamond (EC-PCD) has excellent machinability using electrical discharge method (EDM) [1]. They showed that machining efficiency of the EC-PCD was improved and the electrode wear was reduced. The method requires providing the tool electrode with an along-axis motion at ultrasonic (US) frequency [2].

In this work, US assisted EDM using a rotating electrode is proposed for machining a blind hole into PCD. Experiments were conducted using both electrode polarities "+" and "-".

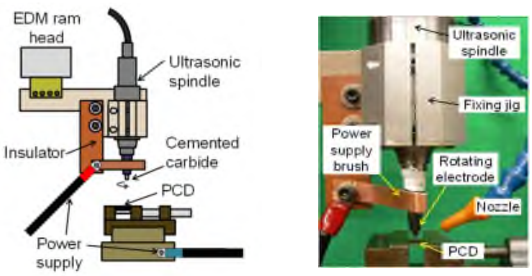
2. Experimental conditions for machining blind holes into PCD

For providing both rotation and ultrasonic (US) vibrations to the electrode, the apparatus shown in Fig1 was mounted onto the spindle of the electric discharge machine. A cemented carbide electrode of 6mm in diameter was shrink-fitted to this US device. The vibration frequency was 40 kHz and the amplitude was 2µm.

A blind hole was machined to the PCD by EDM and effects of the electrode rotation and US vibrations were examined (Table 1). Workpiece materials used are S-PCD and EC-PCD. The influence of polarity of the electrodes was also investigated.

3. Results of experiment for "+" polarity

Fig.2 and Fig.3 show a surface condition and profile of the PCDs after machining for 15 minutes. In every case, a process mark of a hole was formed, but the evidence of the machining was little or

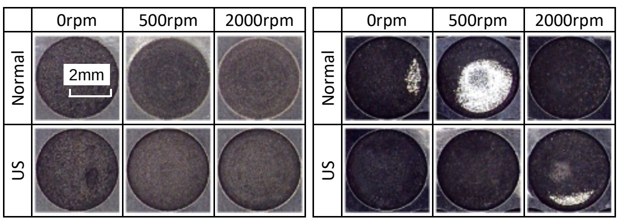


(a) Experimental set up (b) Appearance

Figure 1. Blind hole machining to PCD by ultrasonic spindle

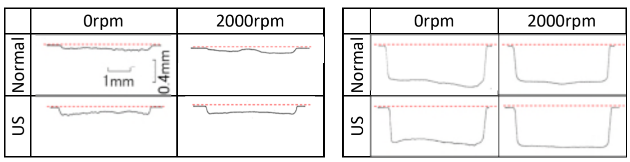
Table 1. Experimental conditions

Equipment	EDM machine: AQ35L(Sodick), US spindle: R2(industria)
Electrode	Cemented carbide: A1, (SUMITOMO) φ4mm×25mm
Workpiece	S-PCD (Element six), EC-PCD (FACT): Grain size=10µm
EDM parameters	Eo=90V, SV=60V, Ip=9.0A, τ_{on}/τ_{off}=50µs /20µs, Machining time: 15minutes, Electrode rotational speed : 0(without rotation), 500rpm, 2000rpm
US parameters	Frequency: f=40KHz, Amplitude ： a=2µm/p-p, Vertical vibration (Axial direction)



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

Figure 2. State of machined PCD surface (Electrode polarity "+")



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

Figure 3. Hole profile of machined PCD (Electrode polarity "+")

nothing in the case of S-PCD when US vibrations were not given. But, when US vibrations were given, depth of the hole machined became deeper. On the other hand, much deeper hole was machined on EC-PCD. Machining efficiency in all cases was higher with US vibrations compared to the cases without US vibrations (Fig.4). Especially for the S-PCD, the increment ratio was significant marking 6.8 times at maximum.

As for the electrode wear (Fig.5), in the case of S-PCD the wear was reduced as the rotational frequency of the electrode increased, marking the maximum suppression rate of 1/4, but effect of the rotational frequency was small in the case of EC-PCD. In the meantime, it was found that providing US vibrations to the electrode suppressed the electrode wear.

When rotation is provided to the electrode, the discharge debris can easily be removed around the periphery of the electrode but it tends to stay around the center of the rotation. Also, US vibrations enhance the ability to discharge the debris and improve the electro discharge frequency. By providing rotation and US vibrations to the electrode, EDM characteristics could be improved.

4. Results of experiment for "-" polarity

The polarity of the carbide electrode was switched to minus. The other parameters were kept identical to those used in the previous experiments. Fig.6 shows the machined surfaces of the processed PCD workpieces. Though some marks of machining are seen, PCD was not removed and some adhered substances were observed. The dimension of adhered substances was assessed to few micron metres (Fig.7). A length of each electrode wear is shown in Fig.8. For all experimental conditions, the electrode wear increased when the rotational velocity of the electrode increased. Also, the electrode wear increased when US vibrations were provided.

As a result of EDS (Energy dispersive X-ray spectrometry) analysis of the substances adhered on the PCD surface, W (Tungsten) and Co (cobalt) were observed (Fig.9). At first, it was thought that these adhered substances were due to the oil decomposed during the experiment. Whatever, the authors suggest that the particles of the cemented carbide removed by electro discharge were actively and robustly adhered onto the PCD surface and a repeating action of build up and removal of the carbide film functions when polarity of the carbide electrode is negative [3]. This film works as a protection of the PCD surface, thus PCD could be a non-consumable electrode under this condition.

5. Conclusion

In this research, US EDM with a rotating carbide electrode was applied for the machining of blind holes onto both S-PCD and EC-PCD substrates. By investigating the effect of the electrode polarity, the following finding were highlighted.

1) For positive polarity of the carbide electrode: the machining efficiency and the flatness of the bottom face of the hole improved by the effect of electrode rotation and US vibrations in both cases of S-PCD and EC-PCD.

2) For negative polarity of the carbide: the machining of the PCD did not progress at all and the electrode was largely worn. When both rotation and US vibrations were applied to the electrode then the wear of the cemented carbide electrode was accelerated.

The authors would like to express their gratitude to Sodick Co., Ltd. Industria Co., Ltd. and "Technical Committee for FT" under JSAT for their kind cooperation.

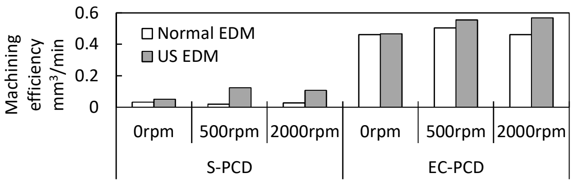


Figure 4. Machining efficiency of PCD (Electrode polarity "+")

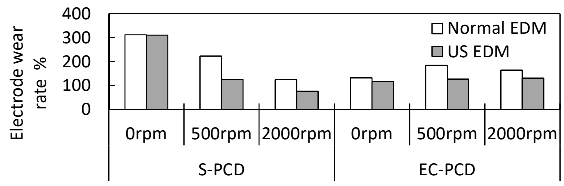
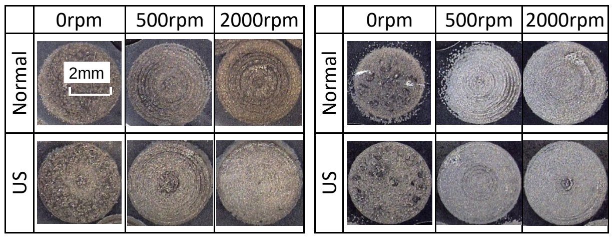


Figure 5. Electrode wear rate (Electrode polarity "+")



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

Figure 6. State of machined PCD surface (Electrode polarity "-")

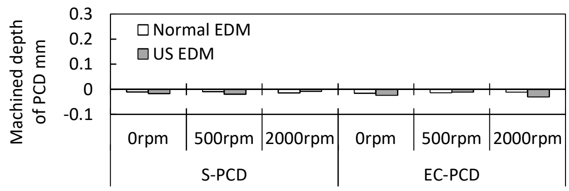


Figure 7. Machined depth of PCD after EDM (Electrode polarity "-")

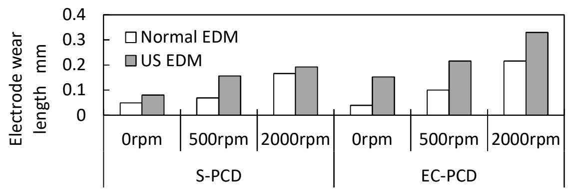


Figure 8. Electrode wear length after EDM (Electrode polarity "-")

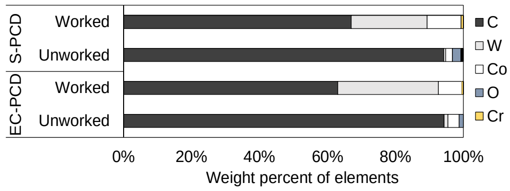


Figure 9. EDS elemental analysis of PCD surface before and after EDM (Electrode polarity "-")

References

[1] Suzuki K, Ninomiya S, Iwai M, et.al, 2009 *Proc. of ABTEC Conf.* 113 (in Japanese)

[2] Ninomiya S, Iwai M, Suzuki k, 2017 *Proc. of euspen's 17th Conf.* 180.

[3] Mouri N, Saito N, et.al, 1993 *J. of JSPE* 59, 4 625