euspen's 16th International Conference & Exhibition, Nottingham, UK, May 2016
www.euspen.eu

# Proposal of coarse grain PCD with fine particles of boron-doped diamond mixed in

Manabu Iwai [1], William Chen [2], Peter Chen [2], Bear Lin [2], Kiyoshi Suzuki [3]

[1] *Toyama Prefectural University,* [2] *Fine Abrasives Taiwan Co., Ltd.,* [3] *K.Suzuki New R & D Office*

*Email: iwai@pu-toyama.ac.jp*

**Abstract**
For machining MDF (medium density fibreboard) materials in the woodworking industry, tools tipped with a coarse grade PCD (polycrystalline composite diamond) composed of coarse grain (over 25 µm in diameter) diamond particles are preferably used in general. In the existing coarse grade PCD, fine (a few micron meters or so) diamond particles are mixed in for the purpose of filling the voids between the coarse diamond particles. However, the fine diamond particles immixed in the PCD tend to be deteriorated or burned down easily during synthesis, causing some problems such as strength reduction and roughness worsening. The authors proposed a new PCD immixed with fine particles of boron doped diamond with superior heat resistance. As a result of the heating test, the new PCD showed higher heat resistance in terms of weight reduction and surface condition. Specifically, while a lot of dents formed by burning down of the fine diamond particles were seen on the surface of the existing PCD after the test at 900 °C, only a few dents were observed on the new PCD. In the wire EDM cutting test, machining speed was improved in the new PCD.

Keywords: PCD, coarse PCD, PCD insert, boron doped diamond, sintering, heat resistance, EDM property

## 1. Introduction

For machining MDF (medium density fibreboard) used in the woodworking industry, tools tipped with a so-called coarse PCD (polycrystalline composite diamond) composed of coarse diamond particles (over 25 µm in diameter) is used in general taking into account of wear resistance. In the existing coarse PCD, fine diamond particles (a few micron meters or so) are filled in the voids between the coarse diamond particles for the purpose of increasing a true density ratio (Fig.1(a)). However, it is reported that the fine diamond particles filled in the PCD tend to be deteriorated or burned down easily during synthesis, causing some problems such as strength reduction and so on. The authors developed a new PCD (electrically conductive PCD, EC-PCD) immixed with fine particles of boron doped diamond possessing a superior heat resistance, and have conducted various application researches [1] to date. From a contact heating test of PCD with a cobalt, it has been found that a temperature at which the deterioration by reaction with the cobalt starts is about 150 °C higher in the EC-PCD in comparison with the conventional PCD [2]. To solve the problems associating with the conventional PCD during synthesis, the authors proposed a new PCD immixed with fine particles of boron doped diamond with excellent heat resistance (Fig.1(b)), and examined its thermal stability and machinability in wire EDM.

## 2. Specification of the PCD used

Description of the PCD samples used for the experiments is given in Table 1. Here, the PCD used is a coarse grain type immixed with fine diamond particles at a proper ratio. In this table, coarse and fine particles of conventional (standard) diamond are symbolized as S and s, respectively, and similarly coarse and fine particles of boron doped diamond are expressed as B and b, respectively. Thickness of the PCD layer and the carbide layer is about 0.6 mm and 1 mm, respectively for all types of PCD (Ss, Sb, Bs and Bb).

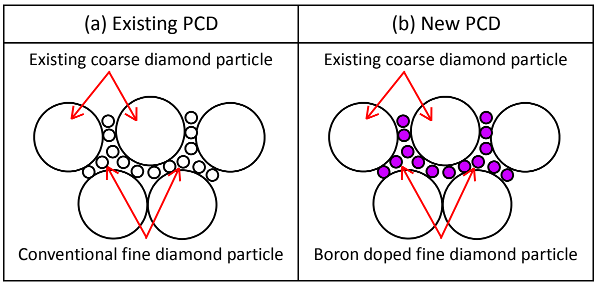



**Figure 1.** Feature of new PCD immixed with fine particles of boron doped diamond.

**Table 1** Specification of PCD used

| **Composition** | **PCD layer** | **Cemented carbide layer** |
|---|---|---|
| Coarse (ϕ25µm) Fine (a few µm) | mm | mm |
| 1) Ss = Existing coarse D. + Conventional fine D. | 0.62 | 0.95 |
| 2) Sb = Existing coarse D. + B doped fine D. | 0.58 | 1.00 |
| 3) Bs = B doped coarse D. + Conventional fine D. | 0.63 | 0.91 |
| 4) Bb = B doped coarse D. + B doped fine D. | 0.65 | 0.94 |

## 3. Thermal stability of PCD

A reduction rate of the weight of each PCD was measured after heated in the air for 15 minutes using a tubular electrical resistance furnace. For this experiment, single layered PCD (without cemented carbide backing) of 4mm in diameter and 0.3mm in thickness weighing 0.35 g was used. Number of tested is just one. Results are shown in Fig.2.

Comparison was made by the temperature at which weight reduction exceeded 1 %. The temperature of conventional PCD (Ss) is 850 °C, whereas that of the PCD (Bb, Bs, composed mainly of coarse boron diamond) is 950 °C. In the case of Sb, a newly proposed coarse PCD with fine particles of boron doped diamond immixed, the temperature is 900°C.

Observations of the PCD surfaces after heated at 900 °C are shown in Fig.3. On the surface of the conventional PCD (Ss), dents formed by burning down of the fine diamond particles can be seen in the boundaries of the coarse diamonds, while no change was observed in both Bs and Bb. On the surface of the newly proposed PCD (Sb), number of dents seems to be limited compared with Ss.

## 4. Wire EDM performance

### *4.1. EDM machine and conditions*

Performance was examined in cutting PCD samples (PCD layer + cemented carbide backing) by wire EDM (bronze wire ϕ0.2 mm) in water. The cutting was performed using 1st cut condition for roughing and 7th cut condition for finishing. The evaluation results are shown in Figs. 4, 5 and 6.

### *4.2. Results of wire EDM*

(1) Rough machining (1st cut condition): All the PCDs (Sb, Bs and Bb) which contain boron doped diamond could be cut at slightly higher speed compared with the conventional PCD (Ss). On the surface of the conventional PCD (Ss) after machining, dents formed by burning of the fine diamond particles were seen, resulting in an increased value of the surface roughness such as $R_z$=9.5 µm. In the case of Sb containing fine particles of boron doped diamond, a surface roughness resulted in large value, similar level of Ss. On the other hand, Bs and Bb, both of which are based on the course boron doped diamond, improved the surface roughness. In comparison with the conventional PCD (Ss), the roughness improvement rate of Bs and Bb was 13 % ($R_z$=8.3 µm) and 26 % ($R_z$=7.1 µm), respectively.

(2) Finish machining (7th cut condition): Using finishing conditions the PCD samples were machined up to 7th cut. Roughness of the finished surface was greatly improved on all the samples except the PCD (Sb) where no significant improvement was found.

(3) Edge quality after finish cutting: In evaluation of the edge quality finished by wire EDM, Bs and Bb composed of coarse boron doped diamond particles were found good (Fig.6). Especially, it was found that the sharpness and surface roughness of the edge on both Bs and Bb were excellent when finish cutting (7th cut) was conducted in water.

## 5. Conclusion

In this research, the authors focused attention on the boron doped diamond in order to improve the performance of coarse PCD tools, and have manufactured a new PCD where fine (a few µm in diameter) particles of boron doped diamond were mixed in to fill the voids between coarse (25 µm in diameter) diamond particles. As a result of the heating test, the new PCD (Sb) was found to improve the heat resistance by 30 % in comparison with the conventional coarse PCD (Ss). In the PCD (Bs and Bb) pronounced effect was observed on the removal rate and surface finish, though no significant effect was found in the new PCD (Sb). Having obtained these results, the authors are due to examine further on the effects of immixing fine particles of boron doped diamond by varying a particle size and a mixing ratio.

The authors would like to express their thanks to Dr. S. Sano and Mr. E. Yamada of Sodick Co., Ltd..

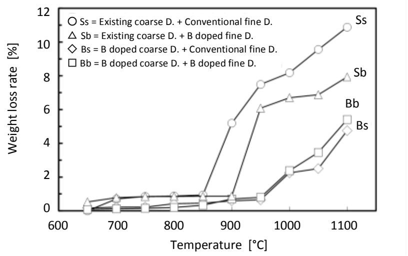



**Figure 2.** Weight reduction rate in heat resistance test.

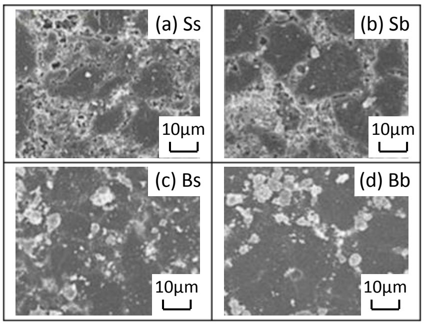
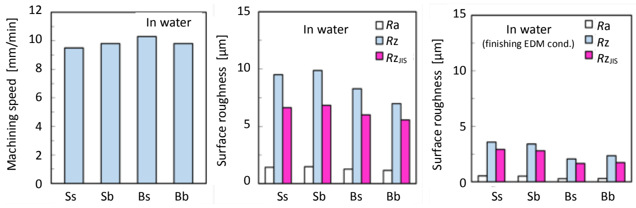



**Figure 3.** PCD surface condition after heated at 900 °C.




[Machining speed] [Surface roughness]
(a) Machining speed and surface roughness in rough machining (1st cut condition)

(b) surface roughness in finish machining (7th cut condition)

**Figure 4.** EDM results of rough and finish machining.

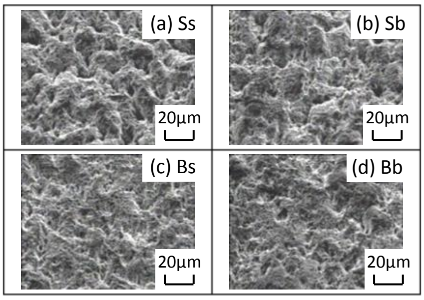



**Figure 5.** PCD surface condition after rough machining (1st cut cond.).

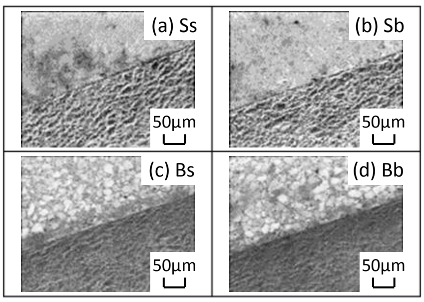



**Figure 6.** Edge condition after finish cutting (7th cut cond.).

**References**

[1] K. Suzuki, M. Iwai, S. Ninomiya, et al.: Development of New PCD Made Up of Boron Doped Diamond Particles and its Machinability by EDM, *Advanced Materials Research* **76-78** (Trans Tech Publications Ltd., 2009) 684.

[2] W.Chen, M.Iwai, S.Ninomiya, K.Suzuki: Material Properties of a New PCD Made of Boron Doped Diamond Particles, *Advanced Materials Research*, **1017** (Trans Tech Publications, 2014) 154.