Dressing-free Grinding of Electrically Conductive PCD by Complex Grinding Assisted with Electrical Discharge Machining

K. Suzuki[1], G. Sugino[1], S. Ninomiya[1], M. Iwai[2]
[1] *Nippon Institute of Technology, Japan*
[2] *Toyama Prefectural University, Japan*

kiyoshi@nit.ac.jp, iwai@pu-toyama.ac.jp, ninomiya@nit.ac.jp

Abstract

Electrically conductive polycrystalline diamond (EC-PCD) material, 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 an effective grinding method for the new EC-PCD. The effect of complex grinding assisted with electrical discharge machining is compared experimentally with conventional grinding using a metal bonded diamond wheel. The result shows that, in the complex grinding, lower and more stable grinding force is realized thanks to the material removal action in EDM and that lower wheel wear and better surface finish are attained by selecting proper conditions for grinding and EDM.

1 Introduction

Being composed of fine diamond particles (≥90vol%) sintered together with cobalt as a solvent under high pressure and high temperature condition, Polycrystalline Composite Diamond (PCD) is excel in chipping resistance despite its very high hardness. That's why PCD is in heavy use as a cutting tool for hard to machine materials and as wear parts. Most commonly, PCD parts are first wire EDMed into required shape and then finished by grinding according to need. However, it is not easy to EDM or grind PCD because diamond particles composing PCD are not electrically conductive and they are strongly inter-grown with each other. To realize high efficiency and high quality processing of PCD simply and at low cost, it is thought to be indispensable to develop a processing technology based on a new idea, or to develop a new PCD possessing superior tool characteristics as well as good machinability at the same time.

In this study, investigation is made on effective grinding method to realize high efficiency, low grinding force and low wheel wear utilizing material characteristics of an electrically conductive PCD (EC-PCD) made up of EC diamond particles, manufactured for the purpose of realizing the PCD with superior tool characteristics and good machinability. To be more precise, complex grinding assisted with electrical discharge machining (C-EDG), where electrical discharge machining and grinding are used in combination for material removal, was applied to EC-PCD and grinding characteristics were investigated.

2 Characteristics of EC-PCD

New PCD (EC-PCD) was manufactured on a trial basis using highly boron doped diamond particles possessing superior heat resistance and electrical conductivity. From results of a heat test, it can be inferred that EC-PCD is superior to standard PCD (S-PCD) in heat resistance.

3 Features of C-EDG on PCD

C-EDG (Fig.1) is a grinding method in which synergistic effect of mechanical removal by abrasives and electrical removal by electrical discharge is expected by impressing pulse voltage between conductive bond matrix and a workpiece during grinding. When workpiece is specified to S-PCD, electro-discharge is generated only on the cobalt binder, thus material removal of diamond particles cannot be expected by electrical discharge [1]. On the other hand, in the case of EC-PCD, it was also thought that C-EDG could achieve material removal of diamond itself as well as cobalt [2]. On the surface layer of the conductive diamond after discharge removal, microscopic irregularity is formed together with carbonized layer. This will reduce the grinding load given to the abrasives embedded in the wheel. This, as a result, is thought to contribute to roughness improvement of the PCD surface. In addition, it is expected that lowering and stabilization of grinding force can be achieved, because bond material on the wheel surface is also removed by electrical discharge.

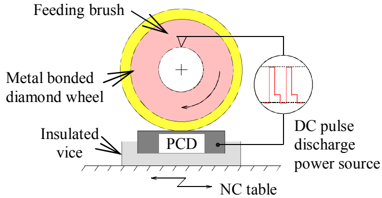

Fig.1: Schematic of C-EDG

4 Experimental apparatus and conditions

As a workpiece, S-PCD (010) and EC-PCD (010) with a particle size of 10μm were used. PCD workpiece was cut into a piece of 5mm×8mm by wire EDM. Grinding experiment was conducted on the NC surface grinder, using a metal bonded diamond wheel (SD600, D150mm×W10mm). A given pulse current was impressed to the wheel flange from multi-purpose discharge power source through feeding brush (Fig.2).

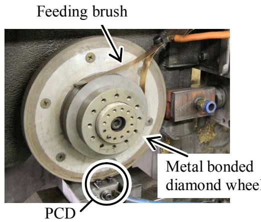

Fig.2: Set-up for C-EDG

Grinding conditions were wheel peripheral speed V_S=40m/s, feed rate V_W=0.1m/min, depth of cut a=1μm, grinding width b=2mm and grinding length l=5mm. Discharge conditions were no load voltage u_i=60V and peak current i_P=6A. Pulse duration was varied from t_e=4~100μs while pulse interval time was fixed at t_o=50μs. Polarity was wheel [+]. Though there are many options such as deionized water or straight oil to be used as a grinding, here, water soluble synthetic working fluid in common use (2% dilution, ρ=12Ω·m) was used.

5 Results of C-EDG experiments

(1) Grinding force (Fig.3). After 50 passes of normal grinding, C-EDG was carried out in steps of 100 passes. In normal grinding, the grinding force for both PCD rapidly increased. This is due to rapid wear of the diamond abrasives contained in the wheel, and a countermeasure is as told to carry out frequent dressing.

When condition of longer pulse duration t_e=100μs was applied, grinding force for both PCD was drastically reduced and stabilized. On these occasions, grinding force for EC-PCD was lowered to 1/3 of that for S-PCD. In the next experiment where grinding was continued using the condition of medial pulse duration t_e=20μs, increase of grinding force for EC-PCD was slight, while gradual increase of grinding force was observed for S-PCD. Condition of t_e=4μs was also tried expecting roughness improvement accompanied by

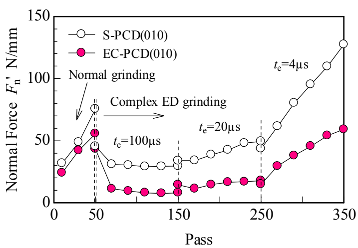

Fig.3: Effect of C-EDG on grinding force
(V_S=40m/min, V_W=0.1m/min, a=1μm, u_i=60V, i_P=6A, t_o=50μs)

miniaturization of discharge energy, but grinding force rapidly increased for both types of PCD. This happened due to higher rate of material removal by grinding compared with that by electric discharge.

(2) Wheel wear. When pulse duration was longer such as t_e=100 and 20μs, wheel wear in grinding S-PCD was smaller by 30~40% compared to the same in grinding EC-PCD, but at short pulse duration t_e=4μs there was no difference in wheel wear observed between the two. Reason for the large wheel wear in grinding EC-PCD at longer pulse duration is thought to be that large discharge energy is apt to flow between wheel and EC-PCD workpiece.

(3) Removal depth of the workpiece. The removal depth got larger with increase of the pulse duration. This demonstrates the fact that the longer the pulse duration the higher the contribution rate of the removal by discharge is.

(4) Workpiece surface condition. The surface condition of S-PCD was formed mostly with craters generated by electrical discharge. On the other hand, in the case of EC-PCD, surface irregularity caused by craters was small in the range of t_e=4~100μs. In particular, at the condition of t_e=20μs where reduction and stabilization of grinding force was observed, surface of the EC-PCD became flat and smooth (Fig.4).

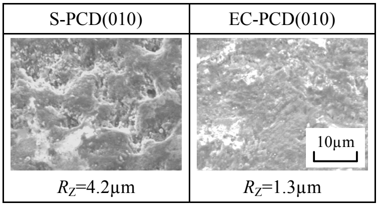

Fig.4: Surface property after C-EDG

5 Conclusion

New PCD (EC-PCD) having superior electrical characteristics was developed without deteriorating intrinsic material properties of PCD, and complex grinding assisted with electric discharge machining (C-EDG) was applied. As a result, it was found that lowering and stabilization of the grinding force, suppression of wheel wears and improvement of surface condition were all achieved.

References:

[1] K.Suzuki, S.Ninomiya, M.Iwai, T.Uematsu, et al.: Attempt of electrodischarge grinding with an electrically conductive diamond-cutting-edge wheel, Proc. of Spring Conf. of JSPE (2005) 1347. (in Japanese)

[2] H.Ohashi, M.Iwai, S.Ninomiya, T.Uematsu, K.Suzuki, et al.: Cutting-edge-forming of a boron doped diamond grit wheel by electrodischarge truing, Proc. of ABTEC (2008) 49. (in Japanese)