A Study on Dynamic Friction Polishing Method Utilizing Resistance Heating for Electrically Conductive Diamond

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Abstract

This paper proposes a new dynamic friction polishing (DF polishing) method utilizing resistance heating to solve a problem of too high pressure on a workpiece in the previous DF polishing method proposed by the authors. In the new method, an electrically conductive diamond workpiece (which has proper electric resistance) is heated by an electrical current flowing from a stainless steel disc tool to the diamond workpiece during the DF polishing and as a result polishing efficiency increases remarkably even at a very low pressure on the workpiece. For example, polishing efficiencies of 233 and 800 μm/min are attained at low pressures such as 2 and 5 MPa, respectively, at a disc sliding speed of 2500 m/min.

1 Introduction

The authors developed "Dynamic Friction Polishing (DF polishing) Method". This method enables high efficiency abrasive-free polishing of single crystal and polycrystalline diamonds (PCD) by simply pressing them against a stainless steel (SUS304) disc rotating at a high peripheral speed (V_S>2500m/min). The method utilizes a thermochemical reaction occurring as a result of dynamic friction between a diamond and a rotating disc as shown in Fig.1 [1]. In the authors' previous paper [2,3], top of the diamond test piece (0.6mm×0.6mm, (100) plane) was removed at a rate of 2.6mm/min (0.94mm^3/min) under polishing conditions of sliding speed V_S=4000m/min, pressure P=130MPa and polishing time t=10s. Although the DF polishing method realizes high efficiency polishing of diamonds without diamond

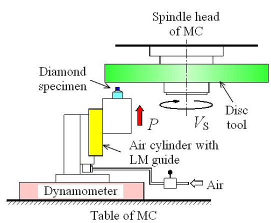

Fig.1: Schematic of conventional DF polishing method

abrasives, a bottleneck for practical use of this method is a high pressure over 100MPa required for pressing a diamond workpiece against a rotating stainless steel disc.

In this paper, a new DF polishing method utilizing resistance heating is proposed to deal with the above-mentioned problem and is applied to machining of an electrically conductive diamond that has recently become commercially available.

2 Proposal of DF polishing method utilizing resistance heating

An electrically conductive diamond (EC diamond) used as a workpiece in this study can be heated by the electrical current passing through, because it has proper electric resistance (proper electrical conductivity). A new DF polishing method is proposed by utilizing this phenomenon of resistance heating. In the proposed method, as shown in Fig.2, an EC diamond workpiece is heated by means of an electrical current flowing from a stainless steel disc tool to the diamond workpiece during polishing. An increase in machining efficiency is expected in the proposed method because temperature of the diamond workpiece is raised and the thermal diffusion of carbon atoms from the diamond can be accelerated.

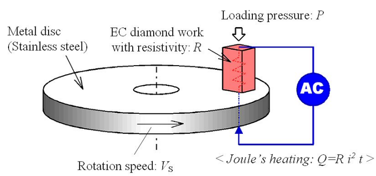

Fig.2: Schematic of resistance heating assisted DF polishing method

3 Experimental devices and conditions

An experimental setup is shown in Fig.3. The diamond workpiece is an EC-CVD diamond (CVDITE-CDE, 3×6×0.5t mm, ρ=0.4~1×10^{-3}Ω·m, Element Six [4]). In the experiments, the diamond workpiece was set on a linear guided air cylinder with a holder so as that the end surface (3×0.5mm) of the diamond is to be a polished surface.

The disc tool with a diameter of 240mm is made of stainless steel SUS304. Surface of the disc tool was finished to a roughness of nearly R_Z=0.9µm by turning with a cutting tool set on the table. Though the data is

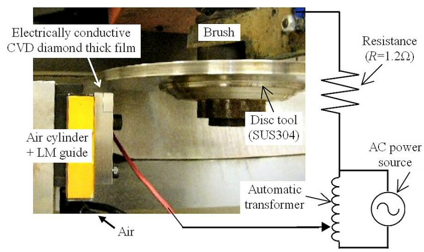

Fig.3: Experimental setup

not shown, the disc tool surface has hardly been worn and the initial smooth surface property has been maintained even after the repeated experiments. An AC power source is used for the resistance heating. When the peak voltage of u_i=25V is charged, the effective value of current is i_e=14A.

4 Experimental results

4.1 Temperature rise of diamond workpiece by resistance heating

A temperature rise of an EC diamond workpiece by resistance heating was measured with an infrared thermography. The disc tool was stopped during the measurement. It was found that the diamond workpiece was heated in a very short time. The maximum temperature reached to about 600°C near the contact surface after 2 seconds. After that, though the resistance heating was continued for 60 seconds, the maximum temperature kept nearly constant at about 600°C.

4.2 Polishing efficiency

The effect of the resistance heating on the polishing efficiency in the new DF polishing was investigated. The polishing conditions were: sliding speed V_S=200~2500m/min, pressure P=1.0~17.7MPa and polishing time t=30 seconds. The oscillation of the workpiece (width=8mm, 12.5 times/min) was given in the radial direction in order to get a smoother polished surface.

(1) State of polishing. In the case of polishing without resistance heating, a small number of red sparks was generated from the machining point during polishing. While, in the case of polishing with resistance heating, the diamond workpiece became red by the resistance heating and sometimes bluish white sparks were from the machining point. Consequently, it is supposed that a temperature of the machining point was considerably high.

(2) Polishing efficiency. Fig.4 shows an effect of the pressure on the polishing efficiency. When the sliding speed was V_S=2500m/min, in the case of the DF polishing utilizing resistance heating, polishing efficiency was about 800μm/min in the pressure range of P=5~17.7MPa. And, even at a lower pressure such as

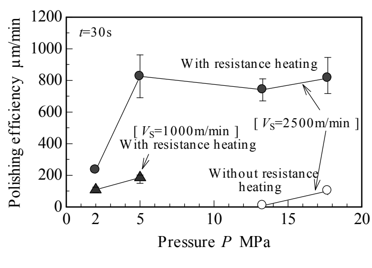

Fig.4: Polishing efficiency in resistance heating assisted DF polishing

P=2MPa, polishing efficiency of 233µm/min was achieved. On the other hand, when the resistance heating was not utilized, polishing efficiency decreased considerably and was 102µm/min and only 9µm/min at P=17.7MPa and P=13.3MPa, respectively. Furthermore, even when a lower sliding speed of V_S=1000m/min and a lower pressure of P=2MPa or 5MPa were adopted, the diamond was successfully removed by polishing with the resistance heating.

Though data is not shown, it was found that polishing efficiency is proportional to a sliding speed and that, even at a low sliding speed V_S=200m/min and a low pressure P=2MPa, the polishing efficiency of 26µm/min was attained.

(4) Surface condition. When sliding speed and pressure were decreased to V_S=1000m/min and P=1MPa, the surface roughness was improved to about 4µmR_Z (Fig.5).

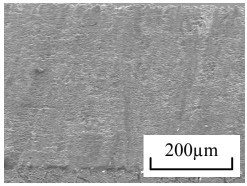

Fig.5: Diamond surface property after DF polishing with resistance heating (V_S=1000m/min, P=1MPa)

5 Conclusion

A new DF polishing method in which an EC diamond workpiece is heated utilizing resistance heating was proposed. It has been found that the diamond workpiece is successfully polished even at a low sliding speed and a low pressure. It seems that this method can be applied to polishing not only the EC diamond thick film but also PCD and that the problem of too high pressure in the previous DF polishing method has been solved.

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