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A review of cBN wheel dressing methods

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Abstract
Grinding is a final manufacturing process aplied in many fields such as: precision mechanical engineering, aerospace, bio-medicine….Grinding wheels with diamond and cBN (cube Boron Nitride) are called "superabrasive wheels' to distinguish from conventinal wheels such as aluminum oxide and silicon carbide. cBN abrasive has very high hardness and high thermal conductivity, helping to inhabit temperature rise of workpiece, increase the tool life, improve machining accuracy. So that, cBN wheel is used widely. In grinding process, dressing is very important to effectively use cBN wheels so that they fully demonstrate their excellent performance. No matter how precisely the wheel is attached to the machine, runout occurs at initial stage after installtion. Also, the abrasive grain layer deteriorates in accuracy and sharpness decreases due to wear in the grinding process. To maintain good sharpness, dressing with a method and condition suitable for the grinding wheel is required. This paper reviews dressing methods of cBN wheel.
Keywords: *–cBN wheel, dressing*

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I. INTRODUCTION

Grinding is a manufacturing process that performs very fine cutting by rotating a grinding wheel at high speed using many hard abrasive cutting edges. In the cutting process, the abrasives scratch continuously onto the workpice surface, so very small chip are removed and the surface roughness is low. So that, grinding is a final processing method aplied in many fields such as: precision mechanical engineering, aerospace, bio-medicine….[1]

Grinding wheels with diamond and cBN are called "superabrasive wheels' to distinguish from conventinal wheels such as aluminum oxide and silicon carbide. cBN abrasive has very high hardness and high thermal conductivity, helping to inhabit temperature rise of workpiece, increasing the tool life, improving machining accuracy. Specially, cBN abrasive has not the electron affinity of carbon. So that, cBN wheel is selected for ferrous materials such as: high speed tool steel, alloy tool steel, nikel-chrome-molybdenum steel…Abrasive cBN grains are three types: single crystalline cBN, polycrystalline cBN and metal-coated cBN. The single crystalline cBN is used for grinding ferrous meterials. The shape is blocky and the crushing strength is high. The polycrystalline cBN is used for grinding ferrous meterials. The shape is irregular and the crushing strength is low. The metal-coated cBN above synthetic abrasive grains coated by metal such as nikel and copper purposes of improving the abrasive grain holding power.[2]

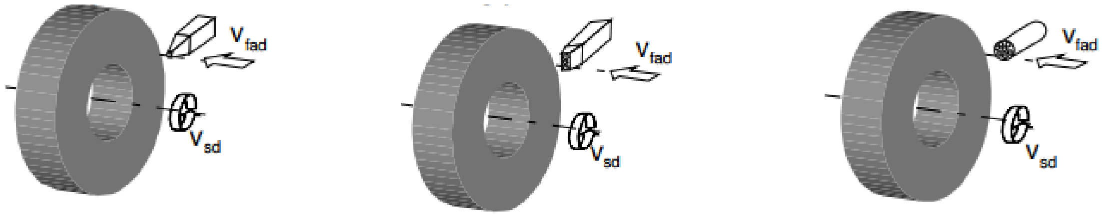
Based on bond material, cBN wheel have four types: resin bond wheel, metallic bond wheel, ceramic bond wheel, electroplated wheel. In rough grinding process, using metallic bond wheel and electroplated wheel because the harder degree of bonding, the longer the lifetime. In finish grinding process, using ceramic bond wheel and resin bond wheel, because the lower the degree of bonding, the higher the roughness.[2]

In grinding process, dressing is very important to effectively use cBN wheels so that they fully demonstrate their excellent performance. No matter how precisely the wheel is attached to the machine, runout occurs at initial stage after installtion. Also, the abrasive grain layer deteriorates in accuracy and sharpness decreases due to wear in the grinding process. To maintain good sharpness, dressing with a method and condition suitable for the grinding wheel is required. This paper reviews dressing methods of cBN wheel.[2]

II. MECHANICAL DRESSING - MD

Based on method's kinematics, mechanical dressing has two methods: method with stationary tool and method with rotating tool. The material of dresser should be harder than cBN. Thus, dresser with diamonds are primarily used for dressing.[1]

Stationary dressing tools do not exhibit any movement in the peripheral direction of the grinding wheel. The grinding wheel profile originates by means of axial movement along the wheel contour, comparably to a turning process. Rotaring grinding wheel makes dressing speed Vsd. Between the dressing tool and the rotaring grinding wheel, there is a radial dressing feed rate of Vfad. The dresser is set between two dressign stokes radially by depth of dressing cut aed. For profil dressing, dresser with making contact in the form of a point or a line in the peripheral direction are usually the most suitable. The path of the dresser is controlled by CNC programs.[2]

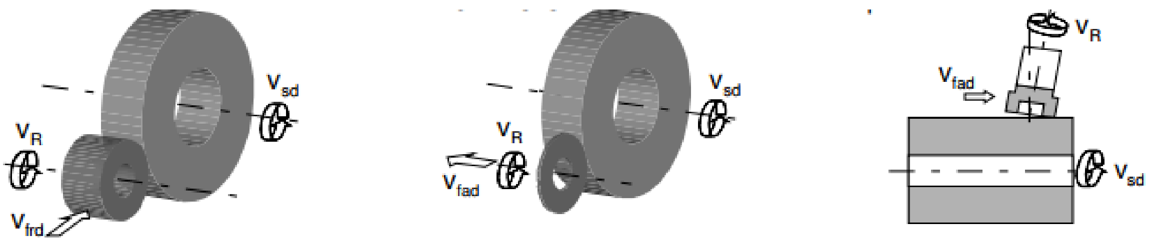


a.Single-grit dresser *b.Plate dresser* *c.Multi dresser*

Fig 1. Stationary dresser[2]

The advantages of this method are simply and be low cost. The disadvantage is that due to the use of few abrasives, the dresser wears quickly, causing errors in profil of grinding wheel.

Rotaring dressers execute an additional rotational movement. If the dresser has the negative profile of the grinding wheel, only radial feed motion is necessary. Dresser rollers that do not engage across the entire wheel width require however a lateral feed.[2]



a. Profile roller *b. Form roller* *c. Cup wheel*

Fig 2. Rotating dresser[2]

III. ELECTRICAL DISCHARGE DRESSING - EDD

In 1987, Suzuki et al. fisrt applied Electrical Discharge Machining (EDM) to dress metal-bond wheel and proposed Electrical Discharge Dressing (EDD) [5]. The superior effects of the proposed methods have been confirmed in the case of grinding of ceramic material with cast iron fiber bond diamond wheels. In 2011, Xu et al. by covering the surface of the resin-bond grinding wheel with graphite powder, realized the EDD of the non-conductive grinding wheel and achived good result [6]. Since then, new special dressing methods: Wire electrical discharge dressing (WEDD); Electro-contact Discharge Dressing (ECDD)… [4]

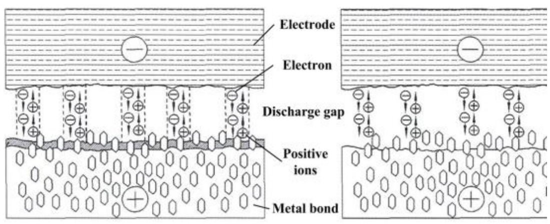
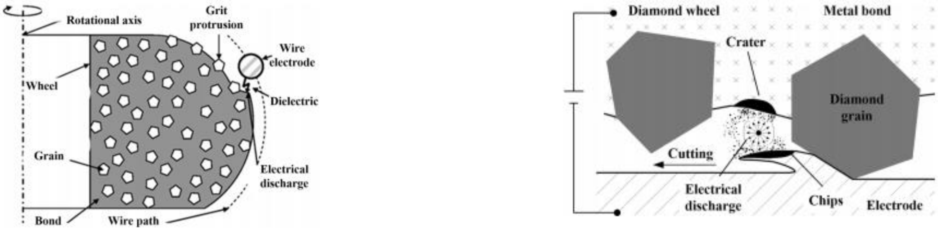


Fig3. . Electrical discharge dressing [4]

Fig. 3 is a schematic diagram of EDD, when a pulse voltage is applied between the electrode (catode) and griding wheel (anode), an electrical field formed between them, causes the discharge medium to ionize, thereby forming a discharge chanel. The pulse power source drives the electrons in the chanel to impact the metal bond at a high speed. The metal bond is etched away by instantaneous high temperature, thereby achieving the purpose of dressing.



a.Wire electrical discharge dressing (WEDD) *b.Electro-contact discharge dressing (ECDD)*

Fig 4. Other Electrical discharge dressing methods [4]

The electrode material is required to have a high melting point, a high expansion coefficient, good electrical and thermal conductivity. The electrode materials are used as graphite, copper, zinc, copper zinc and copper tungsten. Due to their poor wear resistance, graphite electrode is not effective. When using copper-tungsten, the number of effective pulse discharge and the dressing efficiency were the highest.[4]

ECDD is a new dressing method applied to metal - diamond wheel, fisrt introduced by Tamaki in 1992 [7], using pulsed AC or DC power but not dielectric fluid. The grinding wheel and electrode are connected to the poles of the power source. The grinding wheel performs the cutting process. When chips are swept into the gap, causing a short circuit and the bonded-metal is removed by melting and evaporation. WEDD is a new method first introduced by Rhoney in 2002 [10]. The advantage of the method is that the wire moves continously, so it is less affected by electrode wear and suitable for dressing forming wheel.

Sanchez et al. introduced a method to dressing metal-CBN wheel using single electrode discharge. The principle of this method is similar to electrical discharge milling. A single metal electrode rotates and move along the wheel axis according to a path. Electrical corrosion help to dress wheel. The advantages of this method are: single electrode made of Cu-W alloy, small diameter (0.6mm) is simpler to make and much cheaper than forming electrode. Profile of wheel is made easilly by CNC that control the moving trajectory of the electrode.[11]

IV. ELECTROLYTIC IN PROCESS DRESSING - ELID

Electrolytic in process Dressing (ELID) is a dressing method first introduced by Ohmori et al. in 1990. This method is especially effective for fine, metal-bond wheel. ELID includes: conventional, intermittent, electrode-less, nozzle ELID.[13]

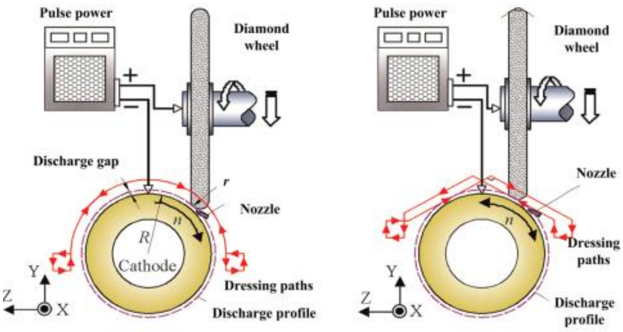


Fig 5. Electrolytic in process Dressing [4]

In the conventional ELID method, the dressing process and the machining process happen at the same time. A complete current loop is formed between electrode, electrolyte, the wheel and the power source, and the electrolytic effect will continously dress the grinding wheel.[4]

ELID interval dressing is aplied to internal grinding. After the grinding wheel is blunt, and then withdrawn into the pipe shape electrode for dressing. The dressing mode is changed from continous dressing to intermittent dressing. The using of the pipe shape electrode greatly improves the dressing efficiency.[15]

ELID electrode-less dressing was proposed by Qian et al. Two electrodes of the power supply are connected to the wheel and workpiece. When pulsed power is used, When the pulse power source is used, since the dressing principle is similar to the EDD, spark discharge phenomenon is likely to occur between the electrodes, which will generate ablation pits on the surface of the workpiece.[16]

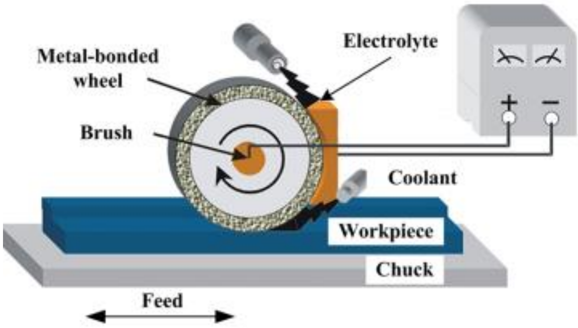


Fig 6. Conventional ELID [4]

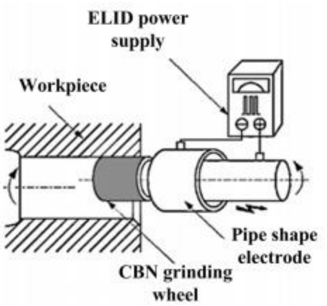


Fig 7. ELID interval dressing [4]

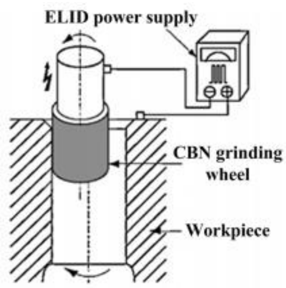


Fig 8. ELID electrode-less dressing [4]

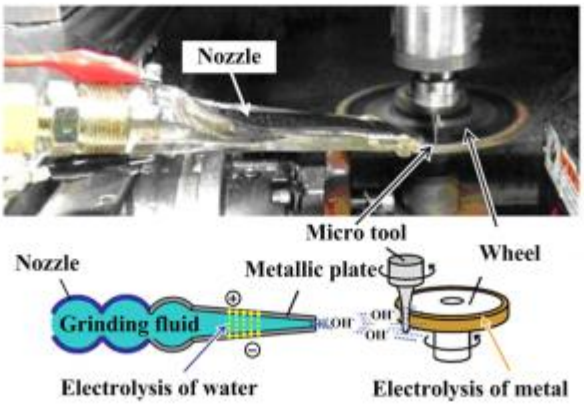


Fig 9. Nozzle ELID dressing [4]

When grinding special parts such as micro lenses and micro lens molds, the diameter of the grinding wheel is so small (several micrometers). So that installing the electrode is very difficult. The nozzle ELID dressing was introduced by Ohmori et al. The electrodes are replaced by fluid nozzle. Ions are created during the electrolysis process as a chemecal that is sprayed directly onto grinding wheel surface. This chemecal disolve the metal bond causing the dressing process.[18]

V. PULSED LASER DRESSING - PLD

Ramesh Babu et al. firstly introduced pulsed lazer dressing method to dress the Al2O3 wheel in the 1908s, making the birth of PLD.[19]

The laser beam has tangential and radial incidence beam. Tangential beam moves along the wheel axis to set feed speed v and dressing depth ap. This beam purpose is removing the abrasive grains and bond agent, to make perfect wheel profile. To improve dressing accuracy, the tangetial beam should be cut layer by layer, meaning that after cutthe lazer beam will move down the same amount as follows. To simultaneously remove both abrasive grains and bond agent, the laser beam energy must be enough to melt the bonding material.[4]

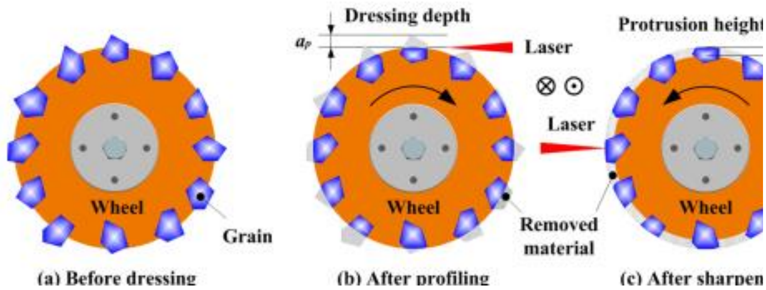


Fig10. Pulsed lazer dressing [4]

Radial beam reciprocates in the direction of the grinding wheel axis to set feed speed. Only the bond agent is removed, so that the abrasive grains obtain a suitable height to achieve the purpose of dressing.[21]

C.Zhang et al. studied the breakdown of the abrasive grains-adhesive bond by laser beam and provided theory to optimize laser beam parameters. By experimental researching with pico second laser pulses to dress V-cBN and B-cBN wheel, they determined the bond breaking energy threshold for plastic, ceramic and abravise grains.[23]

Bing Guo et al. introduced theoretical model of PLD to optimize energy distributrion during the dressing process and analyzed the effect of depth of cut, wheel rotation speed, laser energy and dressing time to quality of dressing process.[24]

VI. COMBINATION DRESSING - CD

Mechanical-laser combination dressing.

The laser beam softens and even melts the bond material directly in front of dresser. Instead of removing abrasive grains and bond agent, the dresser only remove plastic material, thereby effectively slow down wear rate of dresser and improve dressing efficiency and precision.[4]

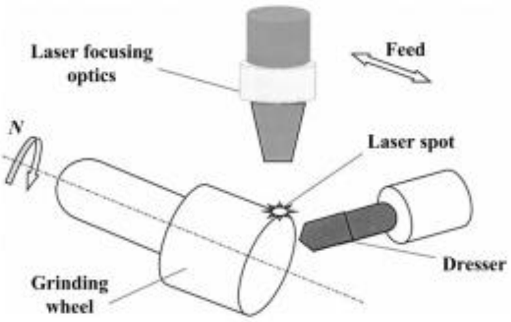


Fig 11. Mechanical-laser combination dressing [4]

Mechanical-ELID combination dressing

Fig. 12 is a schematic diagram of Mechanical-ELID combination dressing. The dresser is a cup wheel. The grinding wheel is profiled by cup wheel. The cup wheel is continously dressed by ELID in the profiling process. So that the uniformity of the abrasive grain is obtain. And the cup wheel is sharpened by ELID to obtain a suitable abrasive protrusion height.[4]

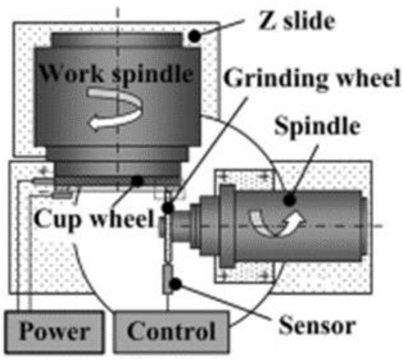


Fig 12. Mechanical-ELID combination dressing [4]

Mechanical-EDD combination dressing.

Wang et al. proposed a dry electrical discharg assisted single point diamond pen dressing method. The principle of Mechanical-EDD combination dressing is similar to the principle of Mechanical-laser combination dressing. Thermal energy generated from the electrical discharge process causes the bonf material in front of the diamond pen to soften and even melt, helping to improve dressing efficiency and precision.

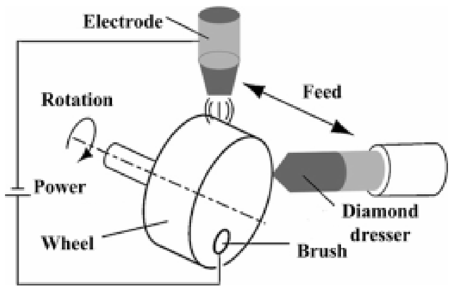


Fig 13. Mechanical-EDD combination dressing [4]

Mechanical-chemical combination dressing.

Fig. 14 is a schematic diagram of Mechanical-chemical combination dressing. When the plate wheel moves axially in the direction of velocity v, the over-protruded grits firstly contact the diamond grits on the plate wheel, being abraded roughly. Then, the over-protruded grits contact the steel. The chemical reactions will occur to generate graphite and iron carbon compounds. Next, the diamond grits on the other side of the plate wheel will contact the over-protruded grits, removing those chemical reaction products. The uniformity of the abrasive protrusion height on the surface of grinding wheel is enhanced after dressing.[4]

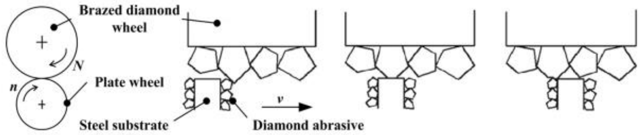


Fig 14. Mechanical-chemical combination dressing [4]

VII. SUMMARY AND PROSPECT

This article focuses on an overview of cBN grinding wheel dressing methods. This article analyzes a list of cBN grinding wheel dressing methods from the latest researches. These methods include using mechanical, electrial discharge, electrolytic, laser and combination processes to regenerate the surface of cBN grinding wheels. The article also addresses the challenges and opportunities in developing methods for dressing cBN grinding wheels. These studies not only help increase the efficiency of the machining process but also contribute to the protection of the environment and resources, through the reuse and recycling of cBN materials. At the same time, these methods also open up opportunities for research and application of cBN grinding wheels in new fields, such as healthcare and energy.

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