TITLE OF INVENTION

Dressing and Manufacture of Outer Blade Cutting Wheel

TECHNICAL FIELD

This invention relates to a method for dressing an outer-diameter blade cutting wheel comprising a base in the form of an annular thin disc of cemented carbide and a blade section formed on the outer periphery of the base, the blade section being an abrasive layer comprising abrasive grains and a metal or alloy bond for bonding the grains to each other and to the base.

BACKGROUND ART

For cutting of rare earth permanent magnets (sintered magnets), the sawing method using outer-diameter blade cutting wheels is well known. By virtue of many advantages including an inexpensive cutting wheel, an acceptable cutting allowance on use of hard-metal blades, a high dimensional accuracy of workpieces, a relatively high machining speed, and a mass scale of manufacture, the outer blade cutting-off technique is widely employed in cutting of rare earth sintered magnets.

Patent Documents 1 to 3 disclose outer blade cutting wheels for use in cutting of rare earth permanent magnets. The known cutting wheel comprises a cemented carbide base and a blade section having diamond or CBN abrasive grains bonded to the outer periphery of the base by metal or alloy plating, typically nickel plating.

The outer blade cutting wheel is typically manufactured by providing a base in the form of an annular thin disc of cemented carbide, distributing diamond or CBN abrasive grains on the outer periphery of the base, and electroplating or electroless plating a metal or alloy to deposit a metal or alloy bond for bonding abrasive grains together or to the base to form an abrasive layer composed of abrasive grains and the metal or alloy bond. The abrasive layer constitutes a blade section. After the blade section is formed, the abrasive layer constituting the blade section is shaped and dressed to expose abrasive grains outside. As the cutting edge wears on use after the preparation, a dressing treatment like that at the end of preparation is taken at an appropriate time interval in order to restore the cutting edge.

The dressing treatment may be generally carried out by wire electrical discharge machining (EDM), or by using a dresser in the form of a grinding wheel of diamond, CBN, SiC or alumina grains, and grinding the surface of the abrasive layer to remove clogging chips or scrape the bonding material for thereby exposing new abrasive grains.

Whether or not the dressing treatment is satisfactory largely affects the cutting performance after preparation or after restoration, for example, leaving cutting marks on the cut surface or causing a difference in cutting accuracy. It is desired to have a method for dressing an outer blade cutting wheel which is capable of sufficient dressing to ensure that chips received in chip pockets in the blade section are shed and part of the bonding material is removed to expose new abrasive grains, for thereby improving the performance of the outer blade cutting wheel.

<u>Citation List</u>

Patent Document 1: JP-A H09-174441
Patent Document 2: JP-A H10-175171
Patent Document 3: JP-A H10-175172
Patent Document 4: JP-A S63-216627
Patent Document 5: JP-A H05-005605

DISCLOSURE OF INVENTION

Embodiments of the invention seek to provide an outer blade cutting wheel comprising a base in the form of an annular thin disc of cemented carbide and a blade section formed on an outer periphery of the base, the blade section being an abrasive layer comprising abrasive grains and a metal or alloy bond for bonding the grains to each other and to the base. Embodiments of the invention also seek to provide a method for dressing the outer blade cutting wheel in a satisfactory and efficient manner so that the cutting wheel as dressed is ready for effective cutoff operation. Embodiments of the invention further seek to provide a method for manufacturing such an outer blade cutting wheel using the dressing method.

In conjunction with an outer blade cutting wheel comprising a base in the form of an annular thin disc of cemented carbide and a blade section formed on an outer periphery of the base, the blade section being an abrasive layer comprising abrasive grains and a metal or alloy bond for bonding the grains to each other and to the base, the inventors have found that in dressing of the blade section of the outer blade cutting wheel, if part of the bond and chips received in chip pockets are dissolved away by electropolishing, then abrasive grains are effectively exposed and chip pockets are formed, achieving satisfactory truing.

Continuing further investigations on the efficient dressing of the blade section by electropolishing, the inventors have found that very efficient and consistent electropolishing can be ensured by clamping the outer blade cutting wheel between a pair of circular jigs to hold the cutting wheel such that the opposed surfaces of the cutting wheel are covered over a predetermined range with the jigs and the blade section projects beyond the outer edge of the circular jigs, immersing the cutting wheel clamped between the jigs in an electropolishing liquid in an electropolishing tank, providing an electrode which is spaced apart from and encloses the outer circumference of the blade section and a pair of electrodes which are opposed to and spaced apart from the side surfaces

of the blade section, as counter electrodes, and conducting electricity to the cutting wheel via the circular jigs and the counter electrodes. That is, efficient and satisfactory dressing operation is possible. It has also been found that in case electroplating or electroless plating is effected on the base having abrasive grains retained on its outer periphery in a plating bath, to deposit a metal or alloy bond for forming the blade section, the plating bath in the electroplating or electroless plating step may be used as the electropolishing liquid after the blade section is shaped or tailored by wire electrical discharge machining (EDM) and/or a grinding wheel.

Accordingly, in one aspect, the invention provides a method for dressing an outer blade cutting wheel comprising a base in the form of an annular thin disc of cemented carbide having an outer periphery and a blade section formed on the outer periphery of the base, the blade section being an abrasive layer comprising abrasive grains and a metal or alloy for bonding the grains to each other and to the base, the method comprising the steps of:

clamping the outer blade cutting wheel between a pair of circular jigs to hold the cutting wheel such that the opposed surfaces of the cutting wheel are covered over a predetermined range with the jigs and the blade section projects beyond the outer edge of the circular jigs,

immersing the cutting wheel clamped between the jigs in an electropolishing liquid in an electropolishing tank,

providing an electrode which is spaced apart from and encloses the outer circumference of the blade section and a pair of electrodes which are opposed to and spaced apart from the side surfaces of the blade section, as counter electrodes, and

conducting electricity between the cutting wheel and the counter electrodes for electrolytically dissolving away part of the metal or alloy between abrasive grains and chips received in chip pockets in the blade section surface until abrasive grains are partially raised from the blade section surface.

In a preferred embodiment, the counter electrodes include a cage electrode which is spaced apart from and encloses the outer circumference of the blade section and a pair of annular electrodes which are opposed to and spaced apart from the side surfaces of the blade section.

In a preferred embodiment, the abrasive grains in the blade section are diamond and/or CBN grains, and the metal or alloy for bonding the grains to each other and to the base is formed by electroplating or electroless plating. In a preferred embodiment, the bonding metal is selected from Ni and Cu, and the bonding alloy is selected from Ni-Fe, Ni-Mn, Ni-P, Ni-Co and Ni-Sn alloys.

In a preferred embodiment, the blade section further comprises a metal or alloy infiltrated into voids between abrasive grains or between abrasive grains and the base. More preferably, the infiltrating metal is Sn and/or Pb, and the infiltrating alloy is selected from Sn-Ag-Cu, Sn-Ag, Sn-Cu, Sn-Zn and Sn-Pb alloys and mixtures thereof.

In another aspect, the invention provides a method for manufacturing an outer blade cutting wheel comprising a base in the form of an annular thin disc of cemented carbide having an outer periphery and a blade section formed on the outer periphery of the base, the method comprising the steps of:

effecting electroplating or electroless plating on the base having abrasive grains retained on its outer periphery in a plating bath, to deposit a metal or alloy for bonding the abrasive grains to each other and to the base, for thereby forming an abrasive layer composed of the abrasive grains and the metal or alloy, the abrasive layer constituting the blade section,

tailoring the protrusion, thickness and outer diameter of the abrasive layer by wire electrical discharge machining and/or a grinding wheel, and

dressing the cutting wheel by the dressing method defined above, using the plating bath in the electroplating or electroless plating step as an electropolishing liquid, for thereby electrolytically dissolving away part of the

metal or alloy between abrasive grains and chips received in chip pockets in the blade section surface until abrasive grains are partially raised from the blade section surface.

In a preferred embodiment, the abrasive grains are diamond and/or CBN grains.

In a preferred embodiment, the bonding metal is selected from Ni and Cu, and the bonding alloy is selected from Ni-Fe, Ni-Mn, Ni-P, Ni-Co and Ni-Sn alloys.

The manufacturing method may comprise, after the step of electroplating or electroless plating to form an abrasive layer composed of abrasive grains and the metal or alloy, the step of effecting further electroplating or electroless plating to form a plating cover for enhancing the bond strength between abrasive grains and between abrasive grains and the base; or the step of infiltrating a molten metal and/or alloy into voids between abrasive grains or between abrasive grains and the base and solidifying the metal and/or alloy therein. Preferably the infiltrating metal is Sn and/or Pb, and the infiltrating alloy is selected from Sn-Ag-Cu, Sn-Ag, Sn-Cu, Sn-Zn and Sn-Pb alloys and mixtures thereof.

ADVANTAGEOUS EFFECTS OF INVENTION

The disclosed method for dressing an outer blade cutting wheel comprising a cemented carbide base and a blade section composed of abrasive grains and a metal or alloy bond on the outer periphery of the base may ensure efficient and satisfactory dressing of the blade section. A high-performance outer blade cutting wheel can be manufactured in an efficient and consistent manner.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 schematically illustrates exemplary circular jigs used in the dressing method of the invention.

FIG. 2 schematically illustrates an outer blade cutting wheel held between the jigs, FIG. 2A showing an overall assembly, FIG. 2B showing an outer periphery portion

in one situation, and FIG. 2C showing an outer periphery portion in another situation.

FIG. 3 is a schematic perspective view of an electropolishing or plating tank used in the dressing or manufacturing method.

FIG. 4 is a schematic perspective view of one exemplary cage electrode used as the counter electrode (during electropolishing) or anode (during plating) in the dressing or manufacturing method.

FIG. 5 is a schematic perspective view of a pair of annular electrodes used as the counter electrode in the dressing method.

FIG. 6 is a schematic enlarged view showing the blade section of the cutting wheel relative to the counter electrodes in the dressing method.

FIG. 7 is a micrograph under optical stereomicroscope, showing the side surface of a blade section of an outer blade cutting wheel in Example 1.

FIG. 8 is a micrograph under optical stereomicroscope, showing the side surface of a blade section of an outer blade cutting wheel in Comparative Example 1.

FIG. 9 is a micrograph showing the surface of a rare earth permanent magnet piece cut by the outer blade cutting wheel, FIG. 9A and 9B corresponding to Examples 1 and 2, respectively.

FIG. 10 is a micrograph showing the surface of a rare earth permanent magnet piece cut by the outer blade cutting wheel, FIG. 10A and 10B corresponding to Comparative Examples 1 and 2, respectively.

FIG. 11 is a graph comparing the dimensional accuracy of rare earth permanent magnet pieces cut by the outer blade cutting wheels of Examples 1, 2 and Comparative Examples 1, 2.

DESCRIPTION OF PREFERRED EMBODIMENTS

It is noted that since the disc has a center and an outer circumference, the terms "radial" and "axial" are used relative to the center of the disc. And so, the thickness is

an axial dimension, and the height is a radial dimension. Likewise the term "outer" or the like is used relative to the center of the disc.

As used herein, the term "electropolishing" refers to electrolytic polishing.

The invention pertains to an outer blade cutting wheel comprising a base in the form of an annular thin disc of cemented carbide and a blade section formed on the outer periphery of the base, the blade section being an abrasive layer comprising abrasive grains and a metal or alloy for bonding the grains to each other and to the base. One embodiment of the invention is a method for dressing the blade section of the outer blade cutting wheel by electropolishing. The outer blade cutting wheel is held by clamping it between a pair of circular jigs and immersed in an electropolishing liquid in an electropolishing tank, where electropolishing is carried out.

The outer blade cutting wheel is held by clamping the cutting wheel between a pair of circular jigs such that the opposed surfaces of the cutting wheel are covered over a predetermined range with the jigs and the blade section projects beyond the outer edge of the circular jigs. FIG. 1 shows a pair of circular jigs 2, 2 for clamping an outer blade cutting wheel 1 therebetween.

In FIG. 1, circular jigs 2, 2 are shown as discs having a screw insertion bore (not shown) at the center. The circular jigs 2 are made of a dielectric material including engineering plastics or ceramics such as alumina and have an outer diameter smaller than the outer diameter of the cutting wheel 1 to be dressed. Retainer/electrode plates 21, 21 are mounted in central recesses of the circular jigs 2, 2. The electrode plates 21, 21 are in electrical contact with a conductive support or rod 22 via power feed pieces 23, 23 so that electricity may be conducted from the support 22 to the electrode plates 21, 21. It is noted that the portions of these electricity conducting members which come in contact with the electropolishing liquid in the electropolishing tank

are coated with a dielectric material such as silicone. A washer 24 is interposed between the upper jig 2 and the support 22, and another washer 24 is interposed between the lower jig 2 and an end block 25.

The cutting wheel 1 is placed between the circular jigs 2 and 2 as shown in FIG. 1. A screw portion projecting from the support 22 and a screw portion projecting from the end block 25 are threadably engaged into internally threaded bores (not shown) in power feed pieces 23, 23 for fastening the circular jigs 2, 2 via the washers 24, 24 as shown in FIG. 2A. Then the circular jigs 2, 2 hold the cutting wheel 1 as clamped therebetween.

Since the retainer/electrode plates 21, 21 are in contact with the base of the cutting wheel 1 under an appropriate pressure, electricity may be conducted from the support 22 to the electrode plates 21, 21 via the power feed pieces 23, 23 whereby electric current may flow to the cutting wheel 1. Also, since the circular jigs 2, 2 have a smaller outer diameter than the cutting wheel 1, the opposed surfaces of the cutting wheel are covered over a predetermined range with the jigs and the blade section 11 on the outer periphery of the cutting wheel 1 projects beyond the outer edge of the circular jigs 2, 2 as best shown in FIG. 2B. The (radial) projection "p" of the blade section 11 beyond the jigs 2, 2 should preferably be set equal to or greater than the thickness (or axial distance) of the blade section 11 to ensure that the blade section 11 projects beyond the outer edge of circular jigs 2, 2.

The cutting wheel 1 clamped between the circular jigs 2, 2 is immersed in an electropolishing liquid in an electropolishing tank. An electrode which is spaced apart from and encloses the outer circumference of the blade section 11 and a pair of electrodes which are opposed to and spaced apart from the side surfaces of the blade section are provided as counter electrodes. With this setting, electropolishing is carried out.

The electropolishing tank used herein may be similar to the electroplating bath used in forming the blade section by electroplating. One exemplary electropolishing tank is a box-shaped tank 3 equipped with an electric heater 31 for heating the bath and piping 32 for circulating the bath as shown in FIG. 3. Alternatively, the electropolishing tank may be an electroless plating bath used in forming the blade section by electroless plating, in which the counter electrodes are disposed.

Also the electrode which encloses the outer circumference of the blade section 11 at a certain spacing and serves as one counter electrode may be similar to the anode used in electroplating the blade section. One exemplary electrode is a cylindrical cage electrode 4 consisting of two large and small cylindrical frames 41 and 42 which each consists of a pair of rings and several columns connecting the rings and which are concentrically telescoped and linked by ties, as shown in FIG. 4.

The pair of electrodes which are opposed to the side surfaces of the blade section 11 at a certain spacing and which also serve as counter electrodes may be, for example, annular electrodes 5, 6 as shown in FIG. 5. A lower annular electrode 5 is to be disposed below the cutting wheel 1 (near the bottom of the electropolishing tank 3) and consists of an annular frame and an annular metal mesh 51 disposed inside the annular frame. An upper annular electrode 6 is to be disposed above the cutting wheel 1 and consists of an annular frame and an annular metal mesh 61 disposed inside the annular frame. Four upright suspenders 62 each having a hook at the top are attached to the annular frame of the upper electrode 6. The upper annular electrode 6 is positioned above the cutting wheel 1, with the hooks of suspenders 62 engaged with the upper periphery of the cage electrode 4.

These counter electrodes 4, 5, 6 are composed of frames and meshes which are all formed of electroconductive metal material such as titanium, austenite stainless steel or

nickel. Of these, titanium is most preferred for lightweight and corrosion resistance.

The cutting wheel 1 held by the circular jigs 2, 2 is received in the electropolishing tank 3, and the cage electrode 4 and annular electrodes 5, 6 are mounted in place. These members are positioned in such relationship, as shown in FIG. 6, that the cage electrode 4 encloses the circumference of the blade section 11 on the outer periphery of the base 12 (or cutting wheel 1) at a certain spacing, and the pair of annular electrodes 5, 6 are opposed to the side surfaces of the blade section 11 at a certain spacing. Electric current is conducted from support 22 to cutting wheel 1 via power feed pieces 23 and electrode plates 21. Electricity is also conducted to the cage electrode 4 and annular electrodes 5, 6 as the counter electrode. Then the surface of blade section 11 of cutting wheel 1 is electrolytically polished.

The electropolishing liquid used in electropolishing may be selected from well-known electropolishing liquids, depending on the metal or alloy bond in the blade section 11. Typically an electropolishing liquid which readily dissolves away the metal or alloy bond is used. Also electrolytic conditions may be determined as appropriate in accordance with the type of bond and the degree of dressing. In an example where a single metal such as by nickel plating is used as the bond, an electropolishing liquid having the same composition as the nickel plating bath used for that nickel plating may be used. Specifically, a nickel plating bath containing 240 to 380 g/L of nickel sulfate, 40 to 90 g/L of nickel chloride, and 40 to 60 g/L of boric acid or a nickel sulfamate plating bath containing 450 to 650 g/L of nickel sulfamate, 5 to 15 g/L of nickel chloride, and 30 to 40 g/L of boric acid may be used as the electropolishing liquid. In the former example where the nickel plating bath is used as the electropolishing liquid, electropolishing may be effected at a current density of 1 to 10 A/dm^2. In the latter example where the nickel sulfamate plating bath is used,

electropolishing may be effected at a current density of 3 to 10 A/dm^2.

Alternatively, an electroless nickel plating bath used in nickel deposition by electroless plating may be used as the electropolishing liquid. Specifically, an electroless nickel plating bath containing 20 to 25 g/L of nickel sulfate, 20 to 25 g/L of sodium hypophosphite, 5 to 10 g/L of sodium acetate, and 5 to 10 g/L of sodium citrate may be used as the electropolishing liquid. In this example, electropolishing may be effected at a current density of 0.3 to 1.0 A/dm^2.

As alluded to above, the outer blade cutting wheel subject to the dressing method of the invention is one comprising a base in the form of an annular thin disc of cemented carbide and a blade section formed on the outer periphery of the base, the blade section being an abrasive layer comprising abrasive grains and a metal or alloy bond for bonding the grains to each other and to the base.

The abrasive grains and the metal or alloy bond used herein are not particularly limited. Examples of the abrasive grains include diamond grains, cubic boron nitride (CBN) grains, alumina grains, alumina based grains, SiC grains, and SiC based grains. Of these, diamond grains and/or CBN grains are preferred. The bonding metal or alloy is preferably a single metal or alloy to be deposited by electroplating or electroless plating though not limited thereto. More particularly, the metal is preferably selected from Ni and Cu. The alloy is preferably selected from Ni-Fe, Ni-Mn, Ni-P, Ni-Co and Ni-Sn alloys.

It is also acceptable that a metal or alloy infiltrates into microscopic voids between abrasive grains or between abrasive grains and the base. The infiltrating metal may be either one or both of Sn and Pb. The infiltrating alloy may be selected from Sn-Ag-Cu, Sn-Ag, Sn-Cu, Sn-Zn, and Sn-Pb alloys, for example, or a mixture thereof.

The dressing method of the invention is, of course, advantageously used in the dressing treatment of dressing a (worn) outer blade cutting wheel with a blunt cutting edge to

restore a fresh cutting edge. Since the electroplating bath or electroless plating bath used in forming the blade section can be used as the electropolishing liquid, the dressing method of the invention may also be advantageously used in the dressing step of a process of manufacturing an outer blade cutting wheel by electroplating or electroless plating to deposit a metal or alloy bond around abrasive grains to form a blade section, tailoring the blade section, and dressing the blade section.

Namely, another embodiment of the invention is a method for manufacturing an outer blade cutting wheel comprising a base in the form of an annular thin disc of cemented carbide having an outer periphery and a blade section formed on the outer periphery of the base, the method comprising the steps of effecting electroplating or electroless plating on the base having abrasive grains retained on its outer periphery in a plating bath, to deposit a metal or alloy for bonding the abrasive grains to each other and to the base, for thereby forming an abrasive layer composed of the abrasive grains and the metal or alloy, the abrasive layer constituting the blade section; tailoring the protrusion, thickness and outer diameter of the abrasive layer by wire electrical discharge machining and/or a grinding wheel; and dressing the cutting wheel by the dressing method of one embodiment, using the plating bath in the electroplating or electroless plating step as an electropolishing liquid. As used herein the term "protrusion" of the abrasive layer is a height of the abrasive layer as measured from the base surface in an axial direction of the base.

When electroplating or electroless plating is effected to deposit a metal or alloy on the base to form an abrasive layer serving as the blade section, the same jigs as the circular jigs used in the above dressing method may be used in the electroplating or electroless plating. In this case, however, the outer diameter of circular jigs 2, 2 is larger than the base 12, as shown in FIG. 2C, to define a space

between outer peripheral portions of the jigs 2, 2, which is filled with abrasive grains. With abrasive grains held in the space, plating is carried out whereby the plating metal or alloy bonds abrasive grains together and to the base. The radial distance "d" of the space for receiving abrasive grains may be determined as appropriate, depending on the size of the blade section 11 to be formed there. The metal or alloy to be deposited by electroplating or electroless plating is as exemplified above.

The means for holding abrasive grains in the space between the outer peripheral portions of circular jigs 2, 2 may be magnetic attraction, for example. Magnetic holding may be achieved by previously coating abrasive grains with a magnetic material, and attaching permanent magnets to circular jigs 2, 2, for thereby holding the abrasive grains in the space by the magnetic attractive force.

In carrying out electroplating, a plating bath similar to the bath shown in FIG. 3 may be used. In the case of electroplating, the cage electrode 4 is used as the anode rather than the counter electrode, and a pair of annular electrodes 5, 6 are unnecessary. In the case of dressing by electropolishing, this plating bath may be used as the electropolishing bath without a substantial modification except that a pair of annular electrodes 5, 6 are positioned and used as the counter electrode along with the cage electrode 4.

Once the abrasive layer composed of abrasive grains and the metal or alloy bond is formed by electroplating or electroless plating, additional electroplating or electroless plating may be carried out to form a plating cover for enhancing the bond strength between abrasive grains and between abrasive grains and the base. This cover plating may be carried out in the same manner as the previous electroplating or electroless plating. The only difference is that the outer diameter of the circular jigs 2, 2 is smaller than the cutting wheel so that the blade section 11 in the form of the abrasive layer projects beyond the outer

edge of the jigs 2, 2 as shown in FIG. 2B. Then cover plating is applied to the abrasive layer.

Alternatively, once the abrasive layer composed of abrasive grains and the metal or alloy bond is formed by electroplating or electroless plating, a molten metal and/or alloy may be infiltrated into voids between abrasive grains and between abrasive grains and the base and solidified there. More particularly, in the outer blade cutting wheel having the blade section formed by bonding abrasive grains to the base via electroplating or electroless plating, since the abrasive grains used have a certain particle size, the abrasive grains are bonded such that contacts between grains and between grains and the base are only local. Voids are left between abrasive grains and between abrasive grains and the base. The electroplating or electroless plating is impossible to fully fill these voids with the plating metal or alloy. As a result, the blade section still contains voids in communication with its surface even after the plating. If such voids are filled with a metal or alloy, then the bond strength is improved and eventually a higher machining accuracy is available. The infiltrating metal or alloy preferably has a melting point of up to 350°C while examples of the metal or alloy are the same as mentioned above.

The metal or alloy may be infiltrated into the abrasive layer or blade section, for example, by working the metal or alloy into a wire with a diameter of 0.1 to 2.0 mm, preferably 0.8 to 1.5 mm, particles, or a thin-film ring of the same shape and size as the blade section having a thickness of 0.05 to 1.5 mm, resting the wire, particles or ring on the blade section, heating the blade section on a heater such as a hot plate or in an oven to a temperature above the melting point, holding the temperature for letting the molten metal or alloy infiltrate into the blade section, and thereafter slowly cooling to room temperature. Alternatively, infiltration is carried out by placing the outer blade cutting wheel in a lower mold half with a clearance near the blade section, charging the mold half with a weighed amount of metal or alloy,

mating an upper mold half with the lower mold half, heating the mated mold while applying a certain pressure across the mold, for letting the molten metal or alloy infiltrate into the blade section. Thereafter the mold is cooled, the pressure is then released, and the wheel is taken out of the mold. The cooling step following heating should be slow so as to avoid any residual strains.

Before the metal or alloy is rested on the abrasive layer or blade section, for example, a commercially available solder flux containing chlorine or fluorine may be applied to the blade section for the purpose of improving the wettability of the blade section or retaining the metal or alloy to the blade section.

After the abrasive layer or blade section is formed on the outer periphery of the base as mentioned above and before the dressing by the inventive method is applied to the blade section, the protrusion, thickness and outer diameter of the blade section are tailored by wire electrical discharge machining (EDM) or by grinding and polishing with a grinding wheel of aluminum oxide, silicon carbide or diamond. At this point, the blade section at the edge may be chamfered (beveled or rounded) to a degree of at least C0.1 or R0.1, though depending on the thickness of the blade section, because such chamfering is effective for reducing cut marks on the cut surface or mitigating chipping of a magnet piece at the edge. Thereafter, the blade section is subjected to dressing by the inventive method.

EXAMPLE

Examples are given below by way of illustration and not by way of limitation.

Example 1

A cemented carbide base in the form of an annular thin disc having an inner diameter of 60 mm and an outer diameter of 133 mm was held by clamping it between a pair of circular jigs as shown in FIGS. 1, 2A and 2B. The circular jigs had an

outer diameter which was 2 mm smaller than the outer diameter of the base so that the outer edge of the base projected 1 mm beyond the outer circumference of the jigs. Electroplating was carried out in a nickel electroplating bath #1, defined below, to deposit an undercoat. The base was then held by clamping it between a pair of circular jigs 2, 2 as shown in FIGS. 1, 2A and 2C. The circular jigs 2, 2 had an outer diameter which was 2 mm larger than the outer diameter of the base. Permanent magnet segments were built in the outer peripheral portions of the jigs. The space defined between the outer peripheral portions of the jigs (FIG. 2C) was filled with 0.8 g of diamond abrasive grains pre-coated with a magnetic material (nickel) and having an average particle size of 130 μm. The diamond grains were held within the space by the magnetic force. The assembly was immersed in a nickel electroplating bath #2, defined below, in an electroplating tank 3 as shown in FIG. 3. Electroplating was carried out to deposit nickel to bond abrasive grains together and to the base, thereby bonding abrasive grains to the outer periphery of the base to form an abrasive layer. At this point, the cage electrode 4 served as an anode.

Next the base was held by clamping it between a pair of circular jigs as shown in FIGS. 1, 2A and 2B. The circular jigs had an outer diameter which was 2 mm smaller than the outer diameter of the abrasive layer-baring base so that the abrasive layer on the outer periphery of the base projected beyond the outer circumference of the jigs. Electroplating was carried out in a nickel sulfamate electroplating bath, defined below, in an electroplating tank 3 shown in FIG. 3 to deposit a plating cover for enhancing the bond strength between abrasive grains and between abrasive grains and the base. The abrasive layer thus obtained was ground using two grinding wheels, WA and GC grinding wheels, thereby tailoring the protrusion and thickness of the abrasive layer so that the abrasive layer had a protrusion of 50 μm. The abrasive layer was further ground to an outer diameter of 135 mm by wire EDM, completing the blade section.

Next, the base having the blade section formed was held by clamping it between a pair of circular jigs as shown in FIGS. 1, 2A and 2B. The circular jigs had an outer diameter which was 2 mm smaller than the outer diameter of the blade section-baring base so that the blade section projected beyond the outer circumference of the jigs. The blade section was dressed by electropolishing using the nickel electroplating bath #2 (used in the previous electroplating) as the electropolishing liquid, completing an outer blade cutting wheel. At this point, the plating tank 3 of FIG. 3 used in the previous electroplating was used as the electropolishing tank, and annular electrodes 5, 6 as shown in FIG. 5 were positioned as shown in FIG. 6. With the annular electrodes 5, 6 and cage electrode 4 set as the counter electrode, and the base as the anode, electropolishing was carried out.

<u>Nickel electroplating bath #1 (undercoat plating)</u>

Composition

$NiCl_2$-$6H_2O$	55	g/L
$NiSO_4$-$6H_2O$	370	g/L
Boric acid	45	g/L

Plating conditions

Bath temperature	50-55	°C
Constant current	0.5	A/dm^2
Conduction time	60	min

<u>Nickel electroplating bath #2</u>

Composition

$NiCl_2$-$6H_2O$	70	g/L
$NiSO_4$-$6H_2O$	370	g/L
Boric acid	45	g/L

Plating conditions

Bath temperature	50-55	°C
Constant current	0.2	A/dm^2
Conduction time	150	min

Nickel sulfamate plating bath

Composition

$Ni(NH_2SO_3)_2$-$4H_2O$	600	g/L
$NiCl_2$-$6H_2O$	10	g/L
Boric acid	35	g/L

Plating conditions

Bath temperature	60-65	°C
Constant current	0.5	A/dm^2
Conduction time	60	min

The side surface of the blade section of the resulting outer blade cutting wheel was observed under an optical stereomicroscope, with the micrograph shown in FIG. 7. It is evident that abrasive grains were fully exposed (or raised) and definite chip pockets were defined between abrasive grains.

Using the outer blade cutting wheel, a rare earth permanent magnet block (Nd-Fe-B magnet) was cutoff machined into magnet pieces under the following conditions.

OD cutting wheel operating conditions

Rotational speed	6000	rpm
Feed speed	400	mm/min
Depth of cut	1	mm/pass

FIG. 9A is a photograph showing the cut surface of a cut magnet piece. It is evident from FIG. 9A that the cut surface was smooth and free of cutting marks. Using the outer blade cutting wheel, four magnet pieces of 2 mm thick were sawed. The maximum difference in thickness between opposite cut surfaces of each piece was measured for evaluating the dimensional accuracy of cutting. The results are plotted in the graph of FIG. 11. As is evident from FIG. 11, the four magnet pieces had a dramatically improved dimensional accuracy as demonstrated by a maximum thickness difference of around 0.025 μm. It is demonstrated that the outer blade cutting wheel is improved in machining accuracy.

Comparative Example 1

An outer blade cutting wheel was manufactured as in Example 1 except that the electropolishing was omitted, and instead, the dressing was achieved by the grinding with grinding wheels and the machining by wire EDM. The protrusion, thickness and outer diameter of the abrasive layer were tailored (protrusion 50 μm) by grinding with grinding wheels, and the outer diameter was tailored by wire EDM.

The side surface of the blade section of the outer blade cutting wheel was observed under an optical stereomicroscope, with the micrograph shown in FIG. 8. Few abrasive grains were exposed on the side surface and no definite chip pockets were seen.

Using the outer blade cutting wheel, a rare earth permanent magnet block (Nd-Fe-B magnet) was cutoff machined into magnet pieces under the same conditions as in Example 1. FIG. 10A is a photograph showing the cut surface of a cut magnet piece. It is evident from FIG. 10A that many cutting marks were seen and the cut surface was unacceptable. Using the outer blade cutting wheel, four magnet pieces were sawed as in Example 1 for evaluating the dimensional accuracy of cutting. The maximum thickness difference is plotted in the graph of FIG. 11. As is evident from FIG. 11, the four magnet pieces were inferior in dimensional accuracy as demonstrated by a maximum thickness difference in far excess of 0.05 μm. Therefore, the outer blade cutting wheel is inferior in machining accuracy to Example 1.

Example 2

An outer blade cutting wheel was manufactured as in Example 1 except that the cover plating was omitted, and instead, a Sn-Pb alloy was infiltrated into the abrasive layer or blade section. Infiltration of Sn-Pb alloy was carried out by resting the blade section-baring base on a hot plate at 230°C, heating the base for 5 minutes, melting a wire of Sn-Pb alloy having a diameter of 8 mm using a

soldering iron at 230°C, applying the molten alloy to the hot blade section on the base, letting the alloy infiltrate, and allowing the blade section to cool down.

Using the outer blade cutting wheel, a rare earth permanent magnet block (Nd-Fe-B magnet) was cutoff machined into magnet pieces under the same conditions as in Example 1. FIG. 9B is a photograph showing the cut surface of a cut magnet piece. It is evident from FIG. 9B that the cut surface was smooth and free of cutting marks. Using the outer blade cutting wheel, four magnet pieces were sawed as in Example 1 for evaluating the dimensional accuracy of cutting. The maximum thickness difference is plotted in the graph of FIG. 11. As is evident from FIG. 11, the four magnet pieces had a dramatically improved dimensional accuracy as demonstrated by a maximum thickness difference of around 0.025 μm. It is demonstrated that the outer blade cutting wheel is improved in machining accuracy.

Comparative Example 2

An outer blade cutting wheel was manufactured as in Example 2 except that the electropolishing was omitted, and instead, the dressing was achieved by the grinding with grinding wheels and the machining by wire EDM. The protrusion, thickness and outer diameter of the abrasive layer were tailored (protrusion 50 μm) by grinding with grinding wheels, and the outer diameter was tailored by wire EDM.

Using the outer blade cutting wheel, a rare earth permanent magnet block (Nd-Fe-B magnet) was cutoff machined into magnet pieces under the same conditions as in Example 1. FIG. 10B is a photograph showing the cut surface of a cut magnet piece. It is evident from FIG. 10B that many cutting marks were seen and the cut surface was unacceptable. Using the outer blade cutting wheel, four magnet pieces were sawed as in Example 1 for evaluating the dimensional accuracy of cutting. The maximum thickness difference is plotted in the graph of FIG. 11. As is evident from FIG. 11, the four

magnet pieces were inferior in dimensional accuracy as demonstrated by a maximum thickness difference in far excess of 0.1 μm, with one piece showing a remarkable thickness variation in excess of 0.2 μm. Therefore, the outer blade cutting wheel is inferior in machining accuracy to Example 2.

CLAIMS:

1. A method for dressing an outer blade cutting wheel comprising a base in the form of an annular thin disc of cemented carbide having an outer periphery and a blade section formed on the outer periphery of the base, the blade section being an abrasive layer comprising abrasive grains and a metal or alloy for bonding the grains to each other and to the base, said method comprising the steps of:

clamping the outer blade cutting wheel between a pair of circular jigs to hold the cutting wheel such that the opposed surfaces of the cutting wheel are covered over a predetermined range with the jigs and the blade section projects beyond the outer edge of the circular jigs,

immersing the cutting wheel clamped between the jigs in an electropolishing liquid in an electropolishing tank,

providing an electrode which is spaced apart from and encloses the outer circumference of the blade section and a pair of electrodes which are opposed to and spaced apart from the side surfaces of the blade section, as counter electrodes, and

conducting electricity between the cutting wheel and the counter electrodes for electrolytically dissolving away part of the metal or alloy between abrasive grains and chips received in chip pockets in the blade section surface until abrasive grains are partially raised from the blade section surface.

2. The dressing method of claim 1 wherein the counter electrodes include a cage electrode which is spaced apart from and encloses the outer circumference of the blade section and a pair of annular electrodes which are opposed to and spaced apart from the side surfaces of the blade section.

3. The dressing method of claim 1 or 2 wherein the abrasive grains in the blade section are diamond and/or CBN grains, and the metal or alloy for bonding the grains to each other and to the base is formed by electroplating or electroless plating.

4. The dressing method of any one of claims 1 to 3 wherein of the metal or alloy for bonding the grains to each other and to the base, the bonding metal is selected from Ni and Cu, and the bonding alloy is selected from the group consisting of Ni-Fe, Ni-Mn, Ni-P, Ni-Co and Ni-Sn alloys.

5. The dressing method of any one of claims 1 to 4 wherein the blade section further comprises a metal or alloy infiltrated into voids between abrasive grains or between abrasive grains and the base.

6. The dressing method of claim 5 wherein the infiltrating metal is Sn and/or Pb, and the infiltrating alloy is selected from the group consisting of Sn-Ag-Cu, Sn-Ag, Sn-Cu, Sn-Zn and Sn-Pb alloys and mixtures thereof.

7. A method for manufacturing an outer blade cutting wheel comprising a base in the form of an annular thin disc of cemented carbide having an outer periphery and a blade section formed on the outer periphery of the base, said method comprising the steps of:

effecting electroplating or electroless plating on the base having abrasive grains retained on its outer periphery in a plating bath, to deposit a metal or alloy for bonding the abrasive grains to each other and to the base, for thereby forming an abrasive layer composed of the abrasive grains and the metal or alloy, the abrasive layer constituting the blade section,

tailoring the protrusion, thickness and outer diameter of the abrasive layer by wire electrical discharge machining and/or a grinding wheel, and

dressing the cutting wheel by the method of claim 1 or 2, using the plating bath in the electroplating or electroless plating step as an electropolishing liquid, for thereby electrolytically dissolving away part of the metal or alloy between abrasive grains and chips received in chip pockets in the blade section surface until abrasive grains are partially raised from the blade section surface.

8. The method of claim 7 wherein the abrasive grains are diamond and/or CBN grains.

9. The method of claim 7 or 8 wherein of the metal or alloy for bonding the grains to each other and to the base, the bonding metal is selected from Ni and Cu, and the bonding alloy is selected from the group consisting of Ni-Fe, Ni-Mn, Ni-P, Ni-Co and Ni-Sn alloys.

10. The method of any one of claims 7 to 9, comprising, after the step of electroplating or electroless plating to form an abrasive layer composed of abrasive grains and the metal or alloy, the step of effecting further electroplating or electroless plating to form a plating cover for enhancing the bond strength between abrasive grains and between abrasive grains and the base.

11. The method of any one of claims 7 to 9, comprising, after the step of electroplating or electroless plating to form an abrasive layer composed of abrasive grains and the metal or alloy, the step of infiltrating a molten metal and/or alloy into voids between abrasive grains or between abrasive grains and the base and solidifying the metal and/or alloy therein.

12. The method of claim 11 wherein the infiltrating metal is Sn and/or Pb, and the infiltrating alloy is selected from the group consisting of Sn-Ag-Cu, Sn-Ag, Sn-Cu, Sn-Zn and Sn-Pb alloys and mixtures thereof.

Dressing and Manufacture of Outer Blade Cutting Wheel

ABSTRACT

An outer blade cutting wheel (1) comprising a base and a blade section (11) of metal or alloy-bonded abrasive grains is dressed by clamping the cutting wheel between a pair of circular jigs (2) such that the blade section (11) projects beyond the jigs, immersing the cutting wheel in an electropolishing liquid, positioning counter electrodes (4, 5, 6) relative to the blade section, and effecting electropolishing for thereby removing part of the metal or alloy bond and chips received in chip pockets until abrasive grains are exposed on the blade section surface.

Fig. 6