(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 680 065 A1

(12) # EUROPEAN PATENT APPLICATION

(43) Date of publication:
15.07.2020 Bulletin 2020/29

(21) Application number: **20160891.6**

(22) Date of filing: **04.06.2018**

(51) Int Cl.:
B24D 5/12 *(2006.01)* ***B24D 18/00*** *(2006.01)*
B24D 3/06 *(2006.01)* ***B24D 3/28*** *(2006.01)*

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(30) Priority: **09.06.2017 JP 2017114180**

(62) Document number(s) of the earlier application(s) in accordance with Art. 76 EPC:
18175786.5 / 3 412 409

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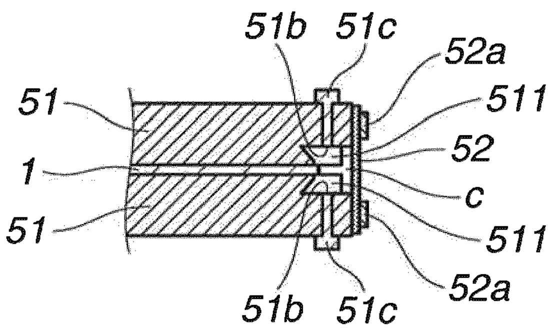
Remarks:
This application was filed on 04-03-2020 as a divisional application to the application mentioned under INID code 62.

(54) **METHOD FOR MAKING OUTER BLADE CUTTING WHEELS**

(57) An outer blade cutting wheel includes an annular thin disc base (1) and a blade section (2) of bonded abrasive grains formed on the periphery of the base. The blade section includes widthwise side portions each of which is provided with channels (21) extending from an inner perimeter to an outer perimeter of the blade section. The cutting wheel is made by an electroplating method in which jig segments (51) applied to the base disc have flanges (51a) which define a cavity (c) for the abrasive grains and bond metal and also have protrusions (511) for forming the channels.

FIG.3B



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Description

TECHNICAL FIELD

[0001] This invention relates to an outer-diameter blade cutting wheel suited for cutting rare earth sintered magnets, and to a method for preparing the same.

BACKGROUND

[0002] A method for cutoff machining a rare earth sintered magnet block using an outer-diameter (OD) blade cutting wheel is well known. The method is implemented by mounting an outer blade cutting wheel on a common sawing machine, and has many advantages including a good dimensional accuracy, a high machining speed and improved mass productivity. Owing to these advantages, the OD blade cutting method is widely used in the cutting of rare earth sintered magnet blocks.

[0003] OD blade cutting wheels for cutting rare earth permanent magnets are typically constructed by furnishing a cemented carbide base, processing its periphery, and bonding diamond or CBN abrasive grains thereto by metal or resin bonding. Since diamond or CBN abrasive grains are bonded to the cemented carbide base, the base is improved in mechanical strength over prior art alloy tool steel or high-speed steel, and an improvement in machining accuracy is achieved. The cemented carbide base allows the blade to be thinned, leading to improvements in manufacturing yield and machining speed.

[0004] Cemented carbides obtained by sintering WC along with Ni or Co are extremely high rigidity materials having a Young's modulus of 450 to 700 GPa, as compared with iron alloy materials of the order of 200 GPa. A high Young's modulus implies a reduced deformation of the blade under the cutting force (or resistance) thereto. For the identical cutting resistance, the blade is less deflected. For the identical deflection of the blade, cutting at the identical accuracy is possible even when the thickness of the blade is reduced. On use of a blade using a cemented carbide base, although the cutting resistance per unit area of the blade remains substantially unchanged, the cutting resistance on the overall blade becomes less by a thickness reduction of the blade. This is advantageous in the case of a multiple blade assembly having a plurality of blades wherein one or more magnet blocks are cutoff machined into a plurality of pieces at a time because the total cutting resistance on the overall blade assembly is reduced. For a motor of the identical power, the number of blades in the multiple blade assembly can be increased. For the identical number of blades, the cutting resistance is reduced, the dimensional accuracy of cutting is improved, and the motor power is saved. When the motor power has a margin relative to the cutting resistance, the feed of the cutting wheel can be accelerated to reduce the cutting time.

[0005] As discussed above, the use of high rigidity cemented carbide base contributes to a significant improvement in productivity of OD blade cutoff machining. Yet the market imposes an ever strengthening demand for rare earth sintered magnet. Since productivity is improved as the machining speed is accelerated, it would be desirable to have an outer blade cutting wheel capable of cutoff machining at a higher speed and higher accuracy than the currently available cutting wheels of cemented carbide bases.

Citation List

[0006]

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 2009-172751

Patent Document 5: JP-A 2013-013966 (EP2543478)

Patent Document 6: JP-B S52-15834

Patent Document 7: WO 00/30810 (EP1050375)

THE INVENTION

[0007] When a rare earth sintered magnet is cut by an outer blade cutting wheel, a grinding fluid or coolant is generally supplied during the cutting step. For the outer blade cutting wheel, a high dimensional accuracy with respect to cut pieces is required. For the purpose of improving the dimensional accuracy of cutting by the outer blade cutting wheel, it is effective to efficiently supply the grinding fluid to the grinding or cutting site to cool the site, to discharge sludge from the grinding site, and to prevent the wheel from chipping.

[0008] An aim herein is to provide new and useful outer blade cutting wheels capable of cutoff machining at high speed and high accuracy, thereby enabling good or improved yields and reduced costs of machining. Methods for preparing and using the same are further aspects.

[0009] With respect to an outer blade cutting wheel comprising an annular thin disc base and a blade section of bonded abrasive grains formed on the periphery of the base, the inventor has found that desired aims can be attained when the blade section includes a widthwise side portion (side face) provided with channels extending in the direction from an inner perimeter to an outer perimeter of the blade section. The resulting outer blade cutting wheel is found capable of cutoff machining at a high speed and high accuracy for thereby achieving improved yields and reduced costs of machining.

[0010] It has also been found that such an outer blade cutting wheel can be advantageously prepared by clamping the base at its planar surfaces between a pair of jig segments so as to cover a portion, exclusive of the periphery, of the base where the blade section is not to be formed, and attaching a mesh member to the jig segments to define a cavity extending along and surrounding the base periphery, the mesh member having openings sufficient to allow passage of gas and liquid, but insufficient to allow passage of abrasive grains, filling the cavity with abrasive grains and closing the cavity, immersing the base, jig segments and mesh member in a plating solution, and electroplating with the base made cathode and allowing the plating metal to precipitate for thereby bonding the abrasive grains along with the plating metal onto the base periphery. The jig used herein consists of jig segments each including a flange which is spaced apart from the base periphery and defines the cavity in part and which is provided with protrusions for forming the channels.

[0011] In one aspect, the invention provides an outer blade cutting wheel comprising an annular thin disc base having a pair of planar surfaces and a periphery, and a blade section composed of abrasive grains and a bond and formed on the periphery of the base. The blade section includes widthwise side portions each of which is provided with channels extending from an inner perimeter to an outer perimeter of the blade section.

[0012] In some embodiments the channels penetrate through the blade section at the outer perimeter, especially both the inner perimeter and the outer perimeter. In other embodiments the channels are closed at the outer perimeter although they may penetrate at the inner perimeter.

[0013] In preferred embodiments the channels extend in a radial direction of the base or at an angle of up to 60° relative to the radial direction.

[0014] The channels may reach through to the base, or to an underlay on the base if any.

[0015] Typically, the bond is of an electroplating metal.

[0016] In another aspect, the invention provides a method for preparing an outer blade cutting wheel having a blade section of the form as defined above and in preferred embodiments elsewhere herein. In a preferred aspect the method comprises the steps of:

clamping the base at its planar surfaces between a pair of jig segments so as to cover a portion, exclusive of the periphery, of the base where the blade section is not to be formed, and attaching a mesh member to the jig segments to define a cavity extending along and surrounding the base periphery, the mesh member having openings sufficient to allow passage of gas and liquid, but insufficient to allow passage of abrasive grains,
filling the cavity with abrasive grains and closing the cavity,
immersing the base, jig segments and mesh member in a plating solution, and
effecting electroplating with the base made cathode and allowing a plating metal to precipitate for thereby bonding the abrasive grains along with the plating metal onto the base periphery,
wherein each jig segment includes a flange which is spaced apart from the base periphery and defines the cavity in part and which is provided with protrusions for forming the channels.

[0017] Use of the blades in the cutting of rare earth sintered magnet blocks is a further aspect of our proposals.

ADVANTAGEOUS EFFECTS

[0018] We find that the outer blade cutting wheels disclosed herein are capable of cutoff machining at a high feed speed while maintaining a high accuracy and a low cutting load. Thus improved yields and reduced costs of machining are achievable.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019]

FIGS. 1A and 1B schematically illustrate an outer blade cutting wheel in one embodiment of the invention, FIG. 1A being a side view, FIG. 1B being a cross-sectional view taken along a plane passing the rotational axis of the wheel.
FIGS. 2A, 2B and 2C are side views of the outer blade cutting wheel in different embodiments of the invention.
FIGS. 3A and 3B schematically illustrate a jig and a mesh member used in the preparation of the outer blade cutting wheel, FIG. 3A being an exploded side view, FIG. 3B being a cross-sectional view.
FIG. 4A is a photo showing the blade section of the outer blade cutting wheel in Example 1, FIG. 4B is a photo showing the blade section of the outer blade cutting wheel in Comparative Example 1.
FIG. 5 is a diagram showing the average load current across the spindle motor versus the feed speed of the cutting wheel when a rare earth sintered magnet is cut by the outer blade cutting wheels of Example 1 and Comparative Example 1.
FIG. 6 is a diagram showing the average thickness of magnet pieces versus the feed speed of the cutting wheel when a rare earth sintered magnet is cut into pieces by the outer blade cutting wheels of Example 1 and Comparative Example 1.
FIGS. 7A and 7B schematically illustrate a jig and a mesh member used in Comparative Example 1, FIG. 7A being an exploded side view, FIG. 7B being a cross-sectional view.

[0020] In the following description, like reference characters designate like or corresponding parts throughout the several views shown in the figures.

FURTHER EXPLANATIONS, OPTIONS AND PREFERENCES

[0021] The invention provides an outer blade cutting wheel comprising an annular disc base and a blade section disposed on the periphery of the base. FIG. 1 illustrates one exemplary outer blade cutting wheel, FIG. 1A being a side view, FIG. 1B being a cross-sectional view taken along a plane passing the rotational axis of the wheel. The outer blade cutting wheel 10 is illustrated as comprising a base 1 in the form of an annular thin disc having a pair of planar surfaces, a center bore 1a, and an (outer) periphery, and a blade section 2 composed of abrasive grains and a bond and formed on the periphery of the base 1, the blade section 2 having inner and outer perimeters. The wheel is adapted to rotate about an axis a (FIG. 1B).

[0022] The base is preferably made of cemented carbide. Examples of the cemented carbide include those in which powder carbides of metals in Groups IVB, VB, and VIB of the Periodic Table such as WC, TiC, MoC, NbC, TaC and Cr_3C_2 are cemented in a binder matrix of Fe, Co, Ni, Mo, Cu, Pb, Sn or a metal alloy thereof, by sintering. Among these, typical WC-Co, WC-Ti, C-Co, and WC-TiC-TaC-Co systems are preferred. Also, those cemented carbides which have an electric conductivity susceptible to plating or which can be given electric conductivity with palladium catalysts or the like are preferred. The base is in the form of an annular thin disc typically having an outer diameter of at least 80 mm, preferably at least 100 mm, and up to 200 mm, preferably up to 180 mm, defining the periphery, an inner diameter of at least 30 mm, preferably at least 40 mm, and up to 80 mm, preferably up to 70 mm, defining the center bore 1a, and a thickness of at least 0.1 mm, preferably at least 0.2 mm, and up to 1.0 mm, preferably up to 0.8 mm, between a pair of planar surfaces.

[0023] It is noted that the disc has an axis (or center bore) and a periphery as shown in FIGS. 1A and 1B. The terms "radial" and "axial" are used relative to the center and axis of the disc. Often, the width (or thickness) is an axial dimension, and the length (or height) is a radial dimension.

[0024] The blade section is formed by bonding abrasive grains with a bond to the periphery of the base. The abrasive grains used herein are preferably selected from diamond grains (naturally occurring diamond, industrial diamond), CBN (cubic boron nitride) grains, and a mixture of diamond grains and CBN grains. Preferably abrasive grains have an average grain size of 10 to 500 μm although the grain size depends on the thickness of the base. If the average grain size is less than 10 μm, there may be left smaller voids between abrasive grains, allowing problems like glazing and loading to occur during the cutting operation and losing the cutting ability. If the average grain size is more than 500 μm, faults may arise, for example, magnet pieces cut thereby may have rough surfaces.

[0025] The bond may be either a metal (inclusive of alloy) bond or a resin bond. The preferred bond is a metal bond, especially a plating metal resulting from electroplating or electroless plating because the blade section of the desired shape is readily formed on the base periphery. The metal bond used herein may be at least one metal selected from Ni, Fe, Co, Sn and Cu, an alloy of two or more of the foregoing metals, or an alloy of at least one metal selected from the foregoing metals with at least one non-metal element selected from B, P and C.

[0026] Preferably the blade section contains abrasive grains in a fraction of at least 10% by volume, more preferably at least 15% by volume and up to 80% by volume, more preferably up to 75% by volume. Less than 10 vol% means a less fraction of abrasive grains contributing to cutting whereas more than 80 vol% of abrasive grains may increase unwanted loading during the cutting operation. Either situation increases resistance during the cutting operation and so the cutting speed must be reduced. Although the blade section typically consists of abrasive grains and bond, a suitable ingredient other than the abrasive grains and bond may be mixed in a fraction of up to 10% by volume, especially up to 5% by volume for the purposes of adjusting the hardness, stress and modulus of the blade section.

[0027] The abrasive blade section of the outer blade cutting wheel includes widthwise side portions (side faces) each of which is provided with channels extending from the inner perimeter to the outer perimeter of the blade section. FIGS. 2A, 2B and 2C are side views of the outer blade cutting wheel in different embodiments. Suitable channels formed in the blade section encompass channels 21 penetrating through the blade section 2 at both the inner and outer perimeters as shown in FIG. 2A, and channels 21 penetrating through the blade section 2 at the inner perimeter (open at the inner perimeter, or open radially inwardly) and closed (or discontinuing) at the outer perimeter as shown in FIG. 2B. In the embodiments of FIGS. 2A and 2B, the channels 21 extend radially. In another embodiment of FIG. 2C, the channels 21 extend at an angle relative to a radial direction. The angle or inclination of channels is preferably up to 60°, especially up to 45° relative to a radial direction. Further the channels may or may not reach the base or an underlay formed on the surface of the base if any.

[0028] The prior art outer blade cutting wheel includes a blade section having widthwise side portions which are configured planar and parallel to the planar surfaces of the base. We note that such planar side faces are not effective to retain grinding fluid. In contrast, the inventive cutting wheel is characterized in that the blade section includes a widthwise side portion (side face) provided with channels extending from the inner perimeter to the outer perimeter of the blade section. The channels are recesses with generally radial extent. The grinding fluid is retained within the channels. Also, the contact area between the blade section and a work to be cut is accordingly reduced, and the cutting resistance therebetween is reduced. This enables cutoff machining at a high speed and improves the accuracy of high speed cutoff machining over the prior art. The channels may be of any desired shape and need not be of a specific shape. For example, linear, arcuate or elliptic curve channels of rectangular, semicircular or semi-elliptic shape in cross section having a width (transverse distance) of 1 to 10 mm are preferred. Direction can be with reference to radially-extending side edges of the channels. Also the channels need not be regularly arranged although they are typically arranged at equal intervals or evenly distributed around the circumference. The channels are multiple; the number is not particularly limited, usually 10 or more or 20 or more. A proportion/extent of the channels in the blade section is preferably such that the total area of channels is 10 to 50% of the total area of the blade section in a side view (FIGS. 2A-2C) when the blade section is viewed in an axial or widthwise (onto the side face) direction.

[0029] As shown in FIG. 1B, the blade section 2 consists of a pair of clamp legs which straddle the distal or peripheral portion of the base 1 and a body which extends radially outward beyond the distal portion of the base 1 so that the thickness of the blade section 2 is greater than the thickness of the base 1. Each of the clamp legs sandwiching the distal portion of the base 1 preferably has a length of at least 0.5 mm, more preferably at least 1 mm and up to 4 mm, more preferably up to 3 mm and a thickness of at least 0.05 mm, more preferably at least 0.1 mm and up to 0.5 mm, more preferably up to 0.25 mm. The body of the blade section 2 preferably has a length of at least 0.05 mm, more preferably at least 0.1 mm and up to 5 mm, more preferably up to 2.5 mm, depending on the size of abrasive grains.

[0030] The outer blade cutting wheel is generally prepared by forming the specified blade section on the periphery of the base. Suitable methods include a resin bond method of using a resin bond, mixing abrasive grains with the resin, and molding the blade section of resin-bonded abrasive grains on the periphery of the base and a metal bond method of using a metal bond and molding the blade section of metal-bonded abrasive grains, with the metal bond method being preferred. The metal bond method may be either a brazing method of mixing abrasive grains with a metal and molding the blade section or a plating method. The plating method is preferred in that the blade section is effectively formed to the desired shape. The plating method may be either electroplating (or electrodeposition) or electroless plating, with the electroplating method being preferred. The plating solution inclusive of electroplating solution and electroless plating solution may be any of well-known plating solutions capable of forming the metal bond while standard plating conditions for a particular solution may be applied. The anode may be either soluble or insoluble, with the insoluble anode being preferred. The insoluble anode may be any of prior art well-known anodes used in electroplating such as Pt and Ti electrodes.

[0031] When the blade section is formed on the base periphery by the metal bond method, an underlay may be pre-formed on the base periphery. The underlay may be made of a material as exemplified above as the metal bond and formed by either brazing or plating. Also in order to enhance the bond strength established when abrasive grains are bound to the base periphery by the metal bond method, the abrasive grains may be coated by sputtering, electroless plating or the like, prior to use.

[0032] Preferably the blade section of the outer blade cutting wheel is prepared by using electroplating metal as the bond and the following method because the blade section can be easily formed to the desired shape. The method is defined as comprising the steps of:

(1) clamping the base at its planar surfaces between a pair of jig segments so as to cover a portion, exclusive of the periphery, of the base where the blade section is not to be formed, and attaching a mesh member to the jig segments to define a cavity extending along and surrounding the base periphery, the mesh member having openings sufficient to allow passage of gas and liquid, but insufficient to allow passage of abrasive grains,
(2) filling the cavity with abrasive grains and closing the cavity,
(3) immersing the base, jig segments and mesh member in a plating solution, and
(4) electroplating with the base made cathode and allowing the plating metal to precipitate for thereby bonding the abrasive grains along with the plating metal onto the base periphery. Herein, each jig segment includes a flange which is spaced apart from the base periphery and defines the cavity in part and which is provided with protrusions for forming the channels.

[0033] Referring to FIGS. 3A and 3B, the method is described in detail. FIGS. 3A and 3B schematically illustrate a jig and a mesh member used in the preparation of the outer blade cutting wheel, FIG. 3A being an exploded side view, FIG. 3B being a cross-sectional view. In forming the blade section on the base periphery, there are first furnished a jig consisting of segments 51, 51 and a mesh member 52. The jig segments 51, 51 are sized to cover a portion of the base 1 excluding its periphery. The mesh member cooperates with the jig segments 51, 51 to define a cavity which extends along and surrounds the base periphery. The base 1 is clamped at its planar surfaces between the jig segments 51, 51 and the mesh member 52 is extended around and attached to the circumference of the jig segments 51, 51 to define a cavity c. The mesh member 52 used herein may be a metal mesh (e.g. stainless steel mesh) or resin mesh; its specific mesh or perforated character is not critical subject to retaining the abrasive grains.

[0034] Each jig segment 51 includes a flange 51a which is spaced apart from the base periphery and defines the cavity c in part. The flange 51a is provided with protrusions 511 for forming the channels in the blade section. The flange 51a is also provided with an inlet port 51b for feeding abrasive grains into the cavity c. Also shown in FIG. 3 are a plug 51c which fits in the inlet port 51b to constitute a part of the flange 51a, and a band 52a which is wound around to hold the mesh member 52 to the periphery of the jig segment 51.

[0035] This is followed by the step of filling the cavity c with abrasive grains and closing the cavity. When the jig segments 51, 51 as shown in FIG. 3 are used, abrasive grains may be fed through the inlet port 51b. Once the plug 51c is detached, a necessary amount of abrasive grains are fed into the cavity c, after which the plug 51c is fitted in the inlet port 51b again. Abrasive grains may be fed as such or as a slurry of abrasive grains in a liquid such as plating solution or water. In the latter case, extra liquid may be discharged through the mesh member 52.

[0036] Next, the base 1, together with the jig segments 51, 51 and mesh member 52, is immersed in a plating solution. Then the cavity c is filled with the plating solution that penetrates through the mesh member 52.

[0037] Next, electroplating is carried out with the base 1 made cathode. It is noted that a conductive layer or underlay is previously formed on the surface of the base 1 if the base 1 is made of non-conductive material. The plating metal is precipitated for thereby bonding the abrasive grains along with the plating metal onto the periphery of the base (cathode) 1. With the progress of electroplating, the plating solution is successively fed into the cavity c through the mesh member 52. In this way, the cavity c is gradually filled with abrasive grains and plating metal. Typically, the electroplating step is terminated when the cavity c is completely filled with the abrasive grains and the plating metal.

[0038] During electroplating, the base 1 is preferably placed with its planar surfaces kept horizontal. The horizontal setting ensures that abrasive grains, which are kept in contact with or in proximity to one surface of the base 1 under gravity, are bound by the plating metal. The base is turned upside down on the way of the electroplating step, which ensures that abrasive grains, which are kept in contact with or in proximity to the other surface of the base 1 under gravity, are bound by the plating metal. The step of turning the base upside down is not limited to once, and may be repeated several times. Once the plating metal is precipitated to such an extent that abrasive grains are bound to the base, the cavity c may then be opened. In this case, for example, the mesh member is detached, and the jig segments are replaced by non-flanged jig segments, after which electroplating step is restarted as the post-treatment.

[0039] On use of the outer blade cutting wheel of the invention, various works may be cut thereby. Typical works are rare earth sintered magnets or permanent magnets including R-Co rare earth sintered magnets and R-Fe-B rare earth sintered magnets wherein R is at least one of rare earth elements inclusive of Y. R-Co rare earth sintered magnets include RCo_5 and R_2Co_{17} systems. Of these, the R_2Co_{17} magnets have a composition (in % by weight) comprising 20-28% R, 5-30% Fe, 3-10% Cu, 1-5% Zr, and the balance of Co. R-Fe-B rare earth sintered magnets have a composition (in % by weight) comprising 5-40% R, 0.2-8% B, up to 8% of an additive element(s) selected from C, Al, Si, Ti, V, Cr, Mn, Ni, Cu, Zn, Ga, Zr, Nb, Mo, Ag, Sn, Hf, Ta, and W for improving magnetic properties and corrosion resistance, and the balance of Fe or Fe and Co (Co is up to 30 wt% of Fe+Co).

EXAMPLES

[0040] Examples of the invention are given below by way of illustration and not by way of limitation.

Example 1

[0041] An annular thin disc of cemented carbide K10 having an outer diameter of 131 mm, an inner diameter of 60 mm, and a thickness of 0.4 mm was used as a base. By previous nickel electroplating in a nickel plating solution containing 70 g/L of $NiCl_2 \cdot 6H_2O$, 370 g/L of $NiSO_4 \cdot 6H_2O$, 45 g/L of boric acid and 2 g/L of lubricant #82 (JCU Corp.) at a temperature of 55°C, a nickel coating was formed on the periphery of the base as an underlay.

[0042] Jig segments and a mesh member as shown in FIG. 3 were combined with the base having the underlay to define a cavity extending along and surrounding the base periphery. With the plug removed, a slurry of diamond abrasive grains (ASTM #230/270) dispersed in a plating solution (described below) was fed into the cavity through the inlet port, after which the plug was fitted to close the cavity. The flanges were spaced apart a distance of 0.6 mm so that the blade section might have a width of 0.6 mm, and each of clamp legs straddling the base periphery might have a thickness of 0.1 mm and a length of 3 mm. The distance from the base periphery to the mesh member was 2 mm so that the body might have a length of 2 mm. The flange was provided with protrusions such that 36 channels each having a width of 2 mm, a length of 2 mm, and a depth of 0.1 mm will be formed arranged at equal intervals around each side surface of the blade section, and the channels reaching through to the underlay on the base.

[0043] Next, the base together with the jig, mesh member and abrasive grains was immersed in a nickel plating solution containing 70 g/L of $NiCl_2 \cdot 6H_2O$, 370 g/L of $NiSO_4 \cdot 6H_2O$, 45 g/L of boric acid, 2 g/L of lubricant #82 (JCU Corp.), 20 g/L of #83S (JCU Corp.) and 0.5 g/L of #81S (JCU Corp.) as brightener, with the planar surfaces of the base kept horizontal. Using the conductive underlay on the base as a cathode and a titanium case electrode as an anode, nickel electroplating was carried out at a temperature of 55°C and a constant voltage of up to

0.7 V for a total time of 420 minutes. During electroplating, hydrogen gas evolved from the plating site. During electroplating, the procedure of interrupting electric conduction, turning the base upside down, and restarting electric conduction was repeated 32 times, every electric amount to precipitate 1 to 3 AM/dm^2 of nickel.

[0044] It was confirmed that abrasive grains were bound to the base, after which the jig segments and mesh member were detached. It was confirmed that the cavity had been completely filled with abrasive grains and the plating metal, after which non-flanged jig segments were attached. Nickel electroplating under the same conditions as above was carried out for 120 minutes as post-treatment, yielding an outer blade cutting wheel. FIG. 4A is a photo showing the outer appearance of the blade section of the cutting wheel. As seen, the channels in this example were open radially inwardly but closed to the outer perimeter.

Comparative Example 1

[0045] An annular thin disc of cemented carbide K10 having an outer diameter of 131 mm, an inner diameter of 60 mm, and a thickness of 0.4 mm was used as a base. By previous nickel electroplating in a nickel plating solution containing 70 g/L of $NiCl_2 \cdot 6H_2O$, 370 g/L of $NiSO_4 \cdot 6H_2O$, 45 g/L of boric acid and 2 g/L of lubricant #82 (JCU Corp.) at a temperature of 55°C, a nickel coating was formed on the periphery of the base as an underlay.

[0046] Jig segments and a mesh member as shown in FIG. 7 were combined with the base having the underlay to define a cavity extending along and surrounding the base periphery. With the plug removed, a slurry of diamond abrasive grains (ASTM #230/270) dispersed in a plating solution (described below) was fed into the cavity through the inlet port, after which the plug was fitted to close the cavity. The flanges were spaced apart a distance of 0.6 mm so that the blade section might have a width of 0.6 mm, and each of clamp legs straddling the base periphery might have a thickness of 0.1 mm and a length of 3 mm. The distance from the base periphery to the mesh member was 2 mm so that the body might have a length of 2 mm. Since the parts in FIG. 7 are the same as in FIG. 3 except that the flange of each jig segment is not provided with protrusions for forming channels, their description is omitted.

[0047] Next, the base together with the jig, mesh member and abrasive grains was immersed in a nickel plating solution containing 70 g/L of $NiCl_2 \cdot 6H_2O$, 370 g/L of $NiSO_4 \cdot 6H_2O$, 45 g/L of boric acid, 2 g/L of lubricant #82 (JCU Corp.), 20 g/L of #83S (JCU Corp.) and 0.5 g/L of #81S (JCU Corp.) as brightener, with the planar surfaces of the base kept horizontal. Using the conductive underlay on the base as a cathode and a titanium case electrode as an anode, nickel electroplating was carried out at a temperature of 55°C and a constant voltage of up to 0.7 V for a total time of 480 minutes. During electroplating, hydrogen gas evolved from the plating site. During electroplating, the procedure of interrupting electric conduction, turning the base upside down, and restarting electric conduction was repeated 32 times, every electric amount to precipitate 1 to 3 AM/dm^2 of nickel.

[0048] It was confirmed that abrasive grains were bound to the base, after which the jig segments and mesh member were detached. It was confirmed that the cavity had been completely filled with abrasive grains and the plating metal, after which non-flanged jig segments were attached. Nickel electroplating under the same conditions as above was carried out for 120 minutes as post-treatment, yielding an outer blade cutting wheel. FIG. 4B is a photo showing the outer appearance of the blade section of the cutting wheel. The widthwise side surfaces of the blade section were planar and parallel to the planar surfaces of the base.

Cutting Test

[0049] From a R-Fe-B rare earth sintered magnet block of 40 mm long (cutting length direction of the cutting wheel) and 16 mm high (cutting depth direction of the cutting wheel), six magnet pieces of 2 mm thick were cut by using the outer blade cutting wheel of Example 1 or Comparative Example 1, and operating the cutting wheel at a rotational speed of 7,040 rpm, a cutting depth per pass of 1 mm, and a feed rate (moving rate in length direction) of 100 mm/min to 700 mm/min. During the cutting operation, the average load current across the motor for the rotating spindle of the cutting wheel was measured, with the results shown in FIG. 5. Each of the cut magnet pieces was measured for thickness at five points: 4 corners and the center, an average of which was computed. A cutting accuracy was evaluated in terms of thickness variations of magnet pieces, with the results shown in FIG. 6.

Notes

[0050] In respect of numerical ranges disclosed in the present description it will of course be understood that in the normal way the technical criterion for the upper limit is different from the technical criterion for the lower limit, i.e. the upper and lower limits are intrinsically distinct proposals.

[0051] For the avoidance of doubt it is confirmed that in the general description above, in the usual way the proposal of general preferences and options in respect of different features of the cutting wheel, method and use constitutes the proposal of general combinations of those general preferences and options for the different features, insofar as they are combinable and compatible and are put forward in the same context.

[0052] The entire contents of Japanese Patent Application No. 2017-114180 filed on 9 June 2017, the priority of which is claimed herein, are hereby incorporated by reference as a precaution in case of error in translation or transcription.

[0053] The following numbered clauses, corresponding to the original claims of the parent application, are not claims but part of the description disclosure.

1. An outer blade cutting wheel comprising an annular disc base having a pair of planar surfaces and a periphery, and a blade section composed of abrasive grains and a bond and formed on the periphery of the base,
wherein the blade section includes side faces provided with channels extending from an inner perimeter to an outer perimeter of the blade section.
2. A cutting wheel of clause 1 wherein the channels penetrate to both the inner perimeter and the outer perimeter of the blade section, or the channels penetrate to the inner perimeter and are closed at the outer perimeter.
3. A cutting wheel of clause 1 or 2 wherein the channels extend in a radial direction of the base or at an angle of not more than 60° relative to the radial direction.
4. A cutting wheel of any one of clauses 1 to 3 wherein the channels reach through to the base, or to an underlay on the base if any.
5. A cutting wheel of any one of clauses 1 to 4 wherein the bond is of metal, preferably plated metal.
6. A cutting wheel of any one of the preceding clauses wherein the channels are evenly distributed around the blade section.
7. A cutting wheel of any one of the preceding clauses wherein the channels account for at least 10% of the area of the blade section as seen from the axial direction.
8. A method for preparing an outer blade cutting wheel of any one of clauses 1 to 7, comprising the steps of:

clamping the base at its planar surfaces between a pair of jig segments so as to cover a portion, exclusive of the periphery, of the base where the blade section is not to be formed, and attaching a mesh member to the jig segments to define a cavity extending along and surrounding the base periphery, the mesh member having openings sufficient to allow passage of gas and liquid, but insufficient to allow passage of abrasive grains,
filling the cavity with abrasive grains and closing the cavity,
immersing the base, jig segments and mesh member in a plating solution, and
effecting electroplating with the base acting as cathode and allowing a plating metal to deposit thereby bonding the abrasive grains along with the plating metal onto the base periphery,
wherein the or each jig segment includes a flange which is spaced apart from the base periphery and defines the cavity in part and which is provided with protrusions for forming the channels in the blade section.

9. Use of an outer blade cutting wheel according to any one of clauses 1 to 7 for cutting rare earth sintered magnet blocks.

Claims

1. A method for preparing an outer blade cutting wheel comprising an annular disc base (1) having a pair of planar surfaces and a periphery, and a blade section (2) formed on the periphery of the base and composed of abrasive grains and a bond, the method comprising the steps of:

clamping the base (1) at its planar surfaces between a pair of jig segments (51) so as to cover a portion of the base other than the periphery where the blade section is not to be formed, and attaching a mesh member (52) to the jig segments to define a cavity extending along and surrounding the base periphery, the mesh member having openings sufficient to allow the passage of gas and liquid, but not the passage of the abrasive grains;
filling the cavity with abrasive grains and closing the cavity;
immersing the base (1), jig segments (51) and mesh member (52) in a plating solution, and
effecting electroplating with the base acting as cathode and allowing plating metal to deposit, thereby bonding the abrasive grains along with the plating metal onto the base periphery,
and wherein the blade section (2) includes side faces provided with channels (21) extending in a direction from an inner perimeter to an outer perimeter of the blade section, and the or each said jig segment (51) includes a flange (51a) which is spaced apart from the base periphery and defines the cavity in part, and the flange has protrusions (511) for forming the channels in the blade section.

2. A method of claim 1 wherein
the channels (21) penetrate both the inner perimeter and the outer perimeter of the blade section (2), or the channels (21) penetrate the inner perimeter and are closed at the outer perimeter.

3. A method of claim 1 or 2 wherein the channels (21) extend in a radial direction of the base, or at an angle of not more than 60° relative to the radial direction.

4. A method of any one of the preceding claims wherein the channels (21) reach through the blade section to the base (1), or to an underlay on the base if any.

5. A method of any one of the preceding claims wherein the channels (21) are evenly circumferentially distributed around the cutting wheel.

6. A method of any one of the preceding claims wherein the channels (21) account for at least 10% of the area of the blade section as seen from the axial direction.

7. A method of any one of the preceding claims wherein the blade section (2) consists of a pair of clamp legs which straddle the distal peripheral portion of the base (1) and a body which extends radially outward beyond the peripheral portion of the base, and the thickness of the blade section is greater than the thickness of the base.

8. A method of any one of the preceding claims wherein the base is made of cemented carbide.

9. A method of any one of the preceding claims wherein the base (1) is in the form of an annular thin disc having an outer diameter defining the periphery of at least 100 mm, and up to 180 mm, an inner diameter defining a center bore (1a) of at least 40 mm, and up to 70 mm, and a thickness between the pair of planar surfaces of at least 0.2 mm and up to 0.8 mm.

10. A method of any one of the preceding claims wherein the plating metal forming the bond is at least one metal selected from Ni, Fe, Co, Sn and Cu, alloys of two or more of the foregoing metals, and alloys of at least one metal selected from the foregoing metals with at least one non-metal element selected from B, P and C.

11. A method of any one of the preceding claims wherein a metal underlay is formed on the base periphery before forming the blade section (2).

FIG.1A

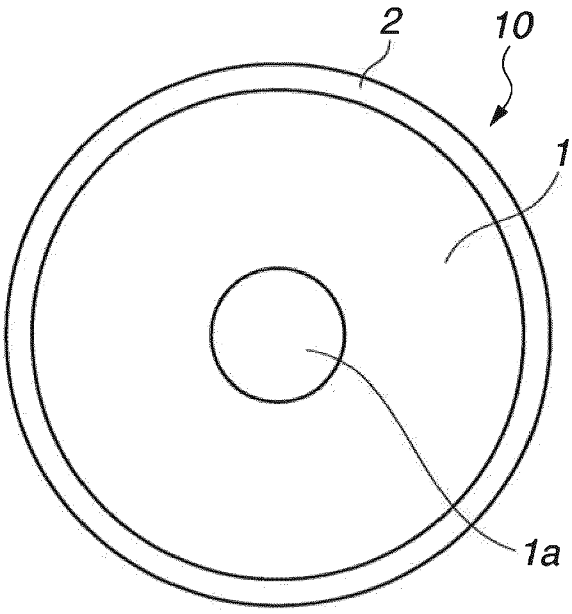


FIG.1B

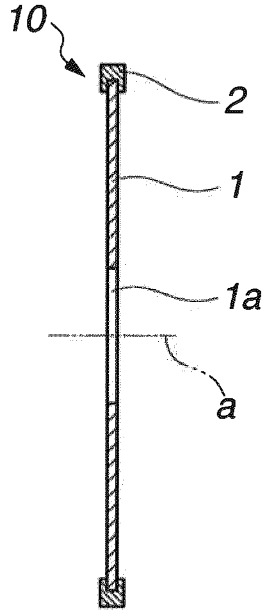


FIG.2A

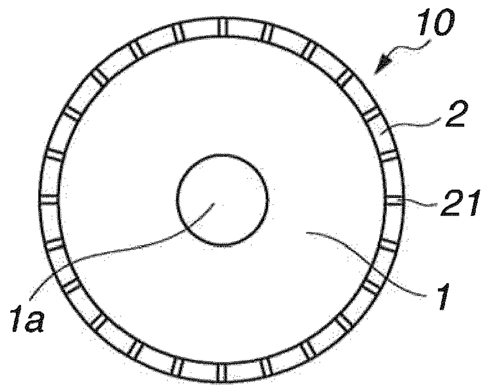


FIG.2B

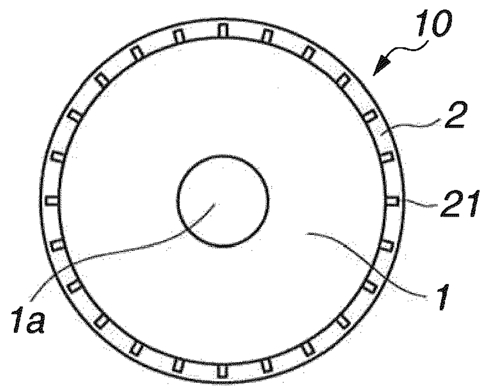


FIG.2C

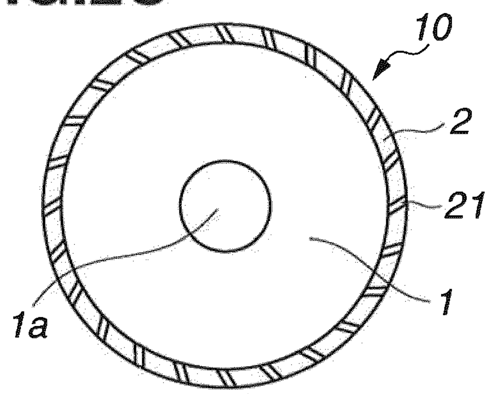


FIG.3A

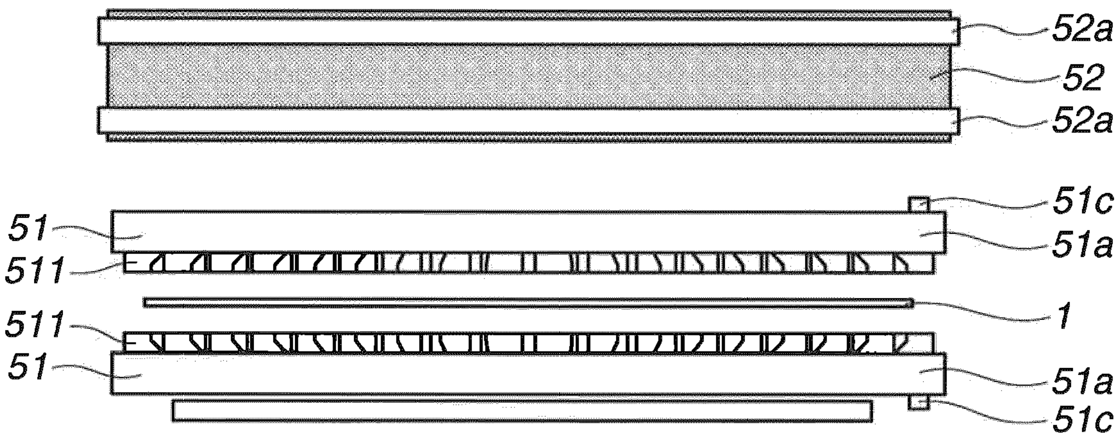
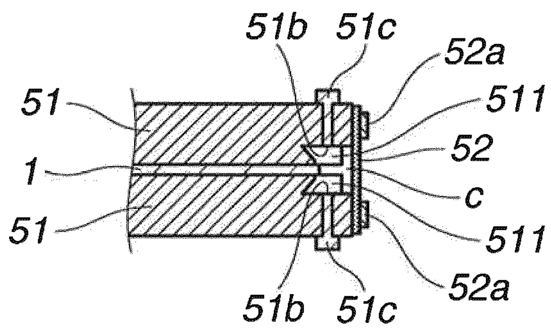

52a
52
52a
51c
51
51a
511
1
511
51
51a
51c

FIG.3B


51b
51c
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51
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c
51
511
52a
51b
51c

FIG.4A

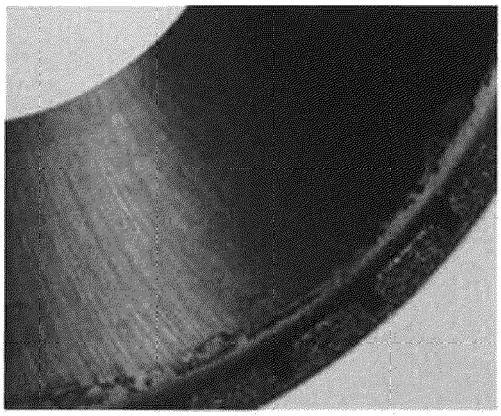


FIG.4B

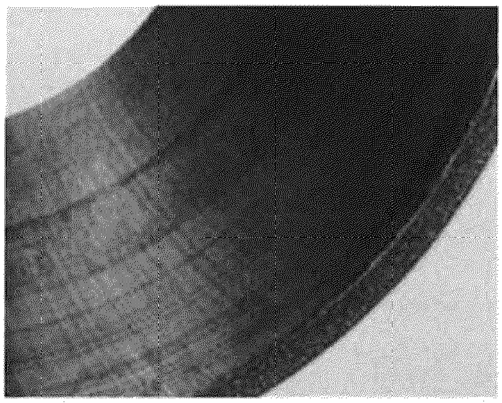
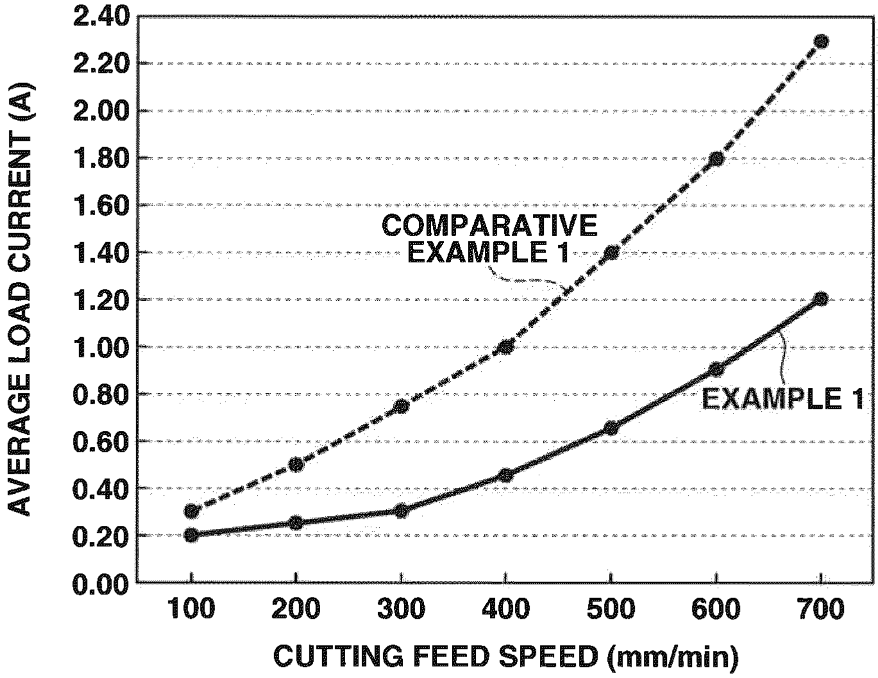


FIG.5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2.20
2.00
1.80
1.60
1.40
1.20
1.00
0.80
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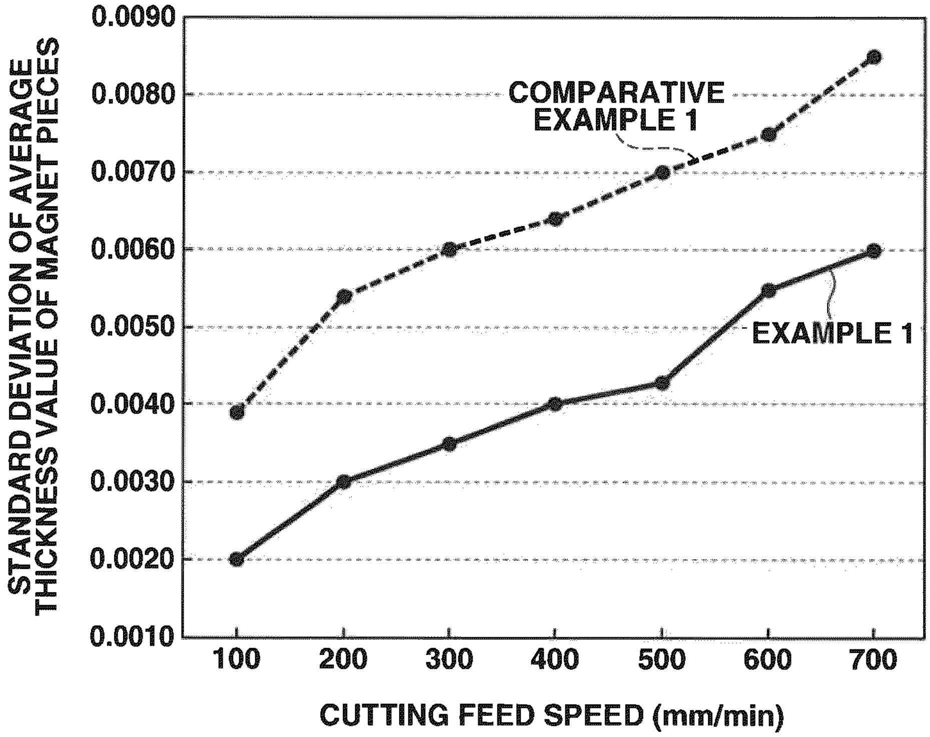
0.40
0.20
0.00
AVERAGE LOAD CURRENT (A)
COMPARATIVE EXAMPLE 1
EXAMPLE 1
100
200
300
400
500
600
700
CUTTING FEED SPEED (mm/min)

FIG.6


STANDARD DEVIATION OF AVERAGE THICKNESS VALUE OF MAGNET PIECES
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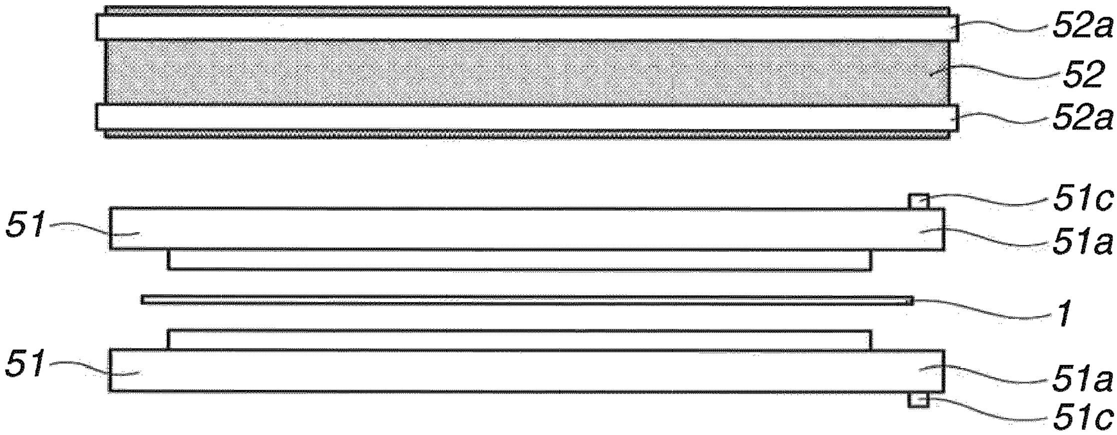
0.0080
0.0070
0.0060
0.0050
0.0040
0.0030
0.0020
0.0010
COMPARATIVE EXAMPLE 1
EXAMPLE 1
100
200
300
400
500
600
700
CUTTING FEED SPEED (mm/min)

FIG.7A


52a
52
52a
51c
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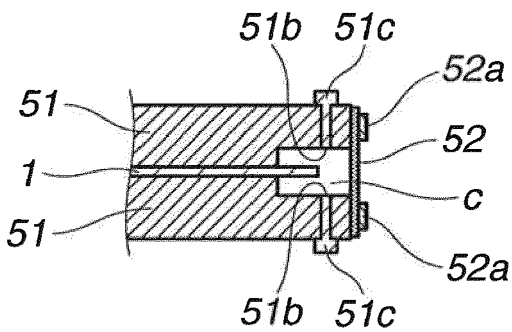
51a
1
51
51a
51c

FIG.7B


51b
51c
52a
51
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1
c
51
52a
51b
51c

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EUROPEAN SEARCH REPORT

Application Number
EP 20 16 0891

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The present search report has been drawn up for all claims

3

Place of search	Date of completion of the search	Examiner
Munich	4 June 2020	Arhire, Irina

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