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(54) Title: ROTARY CUTTING TOOL - IN PARTICULAR, A DRILL MILLING CUTTER

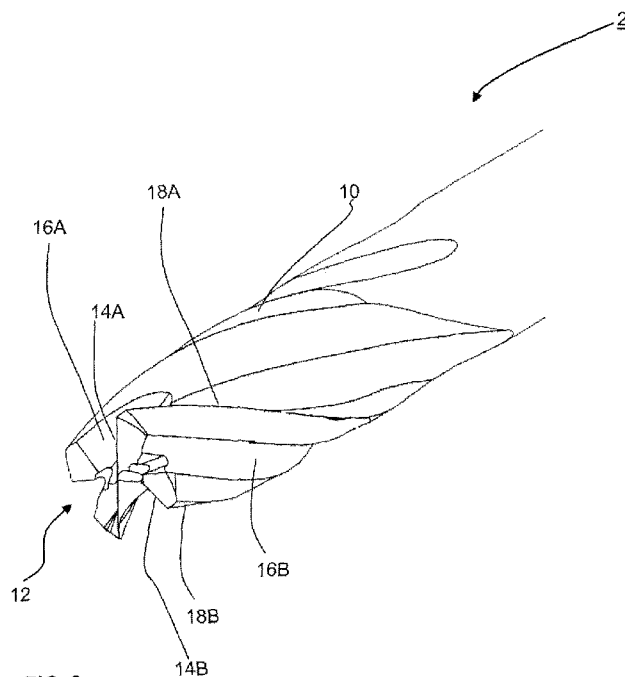


FIG. 2

(57) Abstract: The cutting tool (2) is designed specifically as a drill milling cutter and has a nominal drilled-hole diameter (D), as well as a flat tool face (12). Primary and secondary face cutting edges (14A, 14B) are provided at the tool face (12), wherein the primary face cutting edges (14A) form a drill bit extending over the nominal drill diameter (D), and the secondary face cutting edges (14B) are set back by an axial offset (a) with respect to the primary face cutting edges (14A). In each case, primary and secondary flutes (16A, 16B) are associated with the face cutting edges (14A, 14B), along which peripheral cutting edges (18A, 18B) are arranged which are used during milling. The primary flutes (16A) have a greater cross-sectional area (26A) than the secondary flutes (16B). During the drilling operation, the chips are removed via the primary flutes (16A).



Rotary cutting tool - in particular, a drill milling cutter**RELATED APPLICATION DATA**

Pursuant to PCT Article 8 and PCT Rule 4.10, the present application claims priority to German Patent Application No. 102016222594.4 filed November 16, 2016.

FIELD

The invention relates to a rotary cutting tool - in particular, a drill milling cutter.

BACKGROUND

The rotary cutting tool is generally designed for carrying out a drilling operation with an axial feed, as well as for carrying out a milling operation with radial feed.

When machining workpieces with a curved surface, there is regularly the problem when spot-drilling the surfaces that, in the case of a conventional drill bit, the bit experiences a radial deflection. To ameliorate this problem, so-called spade bits, for example, are used. A spade bit of this kind is, for example, disclosed in EP 1 748 859 B1. This has two face cutting edges, which are arranged in a plane perpendicular to a rotational axis. A flute is assigned to each of these face cutting edges. In particular, with a spade bit of this kind, even, blind holes with a flat drill hole bottom can be created.

Numerous design variants are known for milling cutters in which the tool is advanced perpendicularly to the axis of rotation. Accordingly, US 8 366 354 B2 discloses a milling cutter with peripheral cutting edges which are distributed uniformly around the circumference. A flute is assigned to each of these peripheral cutting edges. A plurality of chip breaking flutes is arranged along the peripheral cutting edges. Other milling cutters are to be found in, for example, US 2014/0356081 A1, or even in US 9,211,593 B2.

SUMMARY

The aim of the invention is to provide a rotary cutting tool with which holes can be drilled reliably and positionally-accurately into workpieces with a curved surface.

The aim is achieved according to the invention by a rotary cutting tool having the features of Claim 1. This cutting tool is designed specifically as a drill milling cutter and has a nominal drill diameter for producing a drilled hole of a defined diameter. The cutting tool further comprises a flat tool face and an adjacent cutting area. The tool has primary as well

as secondary face cutting edges, wherein the primary face cutting edges form a bit spanning the nominal drill diameter. A drilling operation for producing the desired drilled hole can therefore be carried out with the primary face cutting edges. Furthermore, the secondary face cutting edges are set back longitudinally with respect to the primary face cutting edges by an axial offset. Furthermore, primary and secondary flutes which extend longitudinally are assigned to both the primary and the secondary face cutting edges. In addition, primary and secondary peripheral cutting edges run along these flutes. By means of these peripheral cutting edges, a milling operation can be performed. Furthermore, the primary flutes have a greater cross-sectional area than the secondary flutes.

A rotary cutting tool of this kind is designed for both a drilling operation and a milling operation. The primary face cutting edges are, in particular, available for the drilling operation, and the peripheral cutting edges specifically for the milling operation. A crucial consideration with regard to the cutting tool is to be seen in the fact that the primary flutes have a greater cross-sectional area than the secondary flutes. Since the primary flutes are assigned to the primary face cutting edges, which are being employed during the drilling operation, an effective removal of chips is ensured during the drilling operation. In addition, the axial offset between the primary and secondary face cutting edges ensures that at least the main cutting load is borne by the primary face cutting edges, so that a main volume of chips is produced by the primary face cutting edges and is carried away by the primary flutes.

The cutting tool is preferably a (full) carbide cutting tool - in particular, one made of tungsten carbide. In this, both the face cutting edges and the peripheral cutting edges are made directly of a carbide base material. Alternatively, it is also possible for all or some of the cutting edges to take the form of, for example, replaceable cutting inserts. Carbide need not necessarily be used for the base body; a tool steel can be used. It is also possible for the cutting tool to take the form of a modular tool, in which a tool head is attached to a carrier tool - in particular, in a replaceable manner.

In general, the tool face is a flat tool face. By this is meant that the primary face cutting edges do not run forwards in the direction of the axis of rotation. Specifically, this is understood to mean that the primary face cutting edges in each case lie within a transverse plane which is oriented perpendicularly to the rotational axis.

With regard to the desired drilling operation using the primary face cutting edges, these form - where applicable, in combination with a chisel edge in the area of the rotational axis - a continuous drill bit which thus extends, uninterrupted, over the entire nominal drill diameter.

With regard to the desired effective chip removal during the drilling operation, the primary flutes have a cross-sectional area which corresponds to at least 1.5 times - and, preferably, at least twice - the cross-sectional area of the secondary flutes. They are thus significantly larger than the secondary flutes. The primary flutes have a cross-sectional area in the range of, at most, three to four times the cross-sectional area of the secondary flutes.

These enlarged primary flutes can be provided, optionally or in combination, by, in particular, two different measures:

On the one hand, the primary flutes have a greater depth than the secondary flutes. The primary flutes therefore preferably extend radially up to a primary core diameter, and the secondary flutes up to a secondary core diameter, wherein the primary core diameter is less than the secondary core diameter.

The secondary core diameter lies, for example, in the range between 1.5 and 3 times that of the primary core diameter.

Furthermore, the primary core diameter preferably generally lies in the range of 0.25 to 0.5 times the nominal drill diameter. The primary core diameter is therefore, by and large, comparatively small. At the same time, the secondary core diameter is significantly larger, so that, considered in the circumferential direction, a variable core diameter is formed which alternates between the primary and the secondary core diameters. The secondary core diameter preferably lies in the range between 0.50 and 0.75 times the nominal drill diameter.

As an alternative to the different flute depths, and, preferably, supplementing them, the primary flutes, on the other hand, cover a wider angular range than the secondary flutes. Here, the angular range is essentially determined by the angular distance between two successive face cutting edges or peripheral cutting edges. Preferably, it is generally intended that the primary and secondary face cutting edges and peripheral

cutting edges alternate with each other. The angular separation between a primary face cutting edge or peripheral cutting edge and a trailing secondary face cutting edge or peripheral cutting edge - considered in the direction opposite to the direction of rotation - is here preferably below 90° , specifically, below 85° , and, in particular, below 75° . The angular distance is still preferably $>30^\circ$ and, in particular, $>40^\circ$. In particular, it lies in the range between 50° and 75° and, in particular, at about 60° .

These angle values for the angular distance are especially valid for a design variant in which exactly two primary face cutting edges and peripheral cutting edges and, supplementarily, two secondary face cutting edges and peripheral cutting edges are provided. In general, the angular distance between the leading primary face cutting edge or peripheral cutting edge and the trailing secondary face cutting edge or peripheral cutting edge is less than $1/n \cdot 360^\circ$, wherein n is the number of cutting edges (total number of primary and secondary face cutting edges or peripheral cutting edges). Specifically, the angular distance is here about $<0.75 \cdot 1/n \cdot 360^\circ$.

In addition, it is generally intended that the primary face cutting edges and, preferably also supplementing this, the secondary face cutting edges, be, in each case, separated from each other by an angular distance of 180° . Here, an angular distance of 180° - or even a slight deviation from this of $\pm 5^\circ$ or $\pm 10^\circ$ - can be set precisely, thereby producing a certain unequal distribution of the primary face cutting edges amongst each other (as well as, supplementarily, an unequal distribution of the secondary face cutting edges as well), in order to prevent, for example, a tendency of the cutting tool to chatter.

The cutting tool is in general designed for an axial feed in the longitudinal direction during the drilling operation, wherein the axial offset between the primary and the secondary face cutting edges is still greater than or equal to the forward feed, so that the secondary face cutting edges are inactive during drilling. This measure therefore ensures that only the primary face cutting edges generate chips during the drilling operation, said chips being entirely removed via the primary flutes. Specifically, the axial offset here lies preferably in the range between 0.05 mm and 0.2 mm, and, preferably, approximately in the vicinity of 0.1 mm.

With regard to the best possible drilling results, the primary cutting edges preferably extend in each case up to the central axis. In addition, they will preferably lie on a

straight line, so that they form a common, continuous drill cutting edge which extends in a straight line over the entire nominal drill diameter. Alternatively, they have a (slightly) concave or a (slightly) convex curvature.

In the usual way, end-face flanks adjoin the primary face cutting edges opposite to the direction of rotation, and fall away to a corresponding, trailing secondary flute.

In contrast to the face cutting edges, where only the primary face cutting edges are active, in the case of the peripheral cutting edges, not only the primary, but also the secondary peripheral cutting edges are expediently designed as active cutting edges, with a corresponding, suitable cutting geometry. The cutting geometry is preferably identical in both the primary and also the secondary peripheral cutting edges. The peripheral cutting edges, expediently, are identically formed. Specifically, they are of the same (cutting) diameter.

The angular distance between the peripheral cutting edges appropriately remains the same over the entire length of the cutting area; the angular distance preferably does not therefore vary.

The flutes preferably run helically, at a constant angle of twist.

Exactly two primary face cutting edges and two secondary face cutting edges and, corresponding to this, two primary and two secondary peripheral cutting edges are, conveniently, provided.

The nominal drill diameter continues to lie, conveniently, in the range between 3 and 10 mm. Basically, the concept described here can, however, also be applied to larger nominal drill diameters - for example, up to 16 mm.

In a preferred alternative, the cutting tool can take the form of an internally-cooled cutting tool, which therefore has internal cooling ducts. According to one preferred embodiment, the cooling ducts - preferably, precisely two cooling ducts - are here located exclusively in an angular range in which the secondary flutes also lie. This exploits the fact that, in the region of the secondary flutes, there is a larger, secondary core diameter. The cooling ducts are therefore arranged in the thicker core area. Here,

the cooling ducts, or at least outer portions of the cooling ducts, lie within a diameter range which is larger than that of the primary core diameter.

Alternatively and additionally, each cooling duct opens at the tool face in a discharge opening, which is located in such a way that it is connected to both the primary and the secondary flutes. During operation, therefore, the coolant emerging from the discharge opening in question is distributed between both a corresponding primary and also a corresponding secondary flute, thereby achieving efficient cooling.

BRIEF DESCRIPTION OF THE DRAWINGS

An exemplary embodiment of the present invention is explained in greater detail below based on the figures. The figures show:

Figure 1 - a side view of the cutting tool,

Figure 2 - a perspectival view of part of the cutting tool according to Figure 1,

Figure 3 - a plan view of the tool face of the cutting tool,

Figure 4 - a further plan view of the tool face, with the angular ranges marked,

Figure 5 - a sectional view along the sectional line V-V in Figure 1,

Figure 6 - an enlarged side view of part of the tool face area.

DETAILED DESCRIPTION

The cutting tool 2 shown in the figures extends along a rotational axis 4 in the longitudinal direction 6. The cutting tool 2 has a rear shank section 8, as well as a front cutting section 10. The cutting section 10 has a flat tool face 12 at its front end. The cutting tool 2 rotates in use around the rotational axis 4 in a defined rotational direction around the rotational axis 4.

The cutting tool 2 is designed as a combined drill milling cutter and serves for drilling with an axial feed in the longitudinal direction 6, as well as for milling with radial feed in the radial direction perpendicular to the longitudinal direction 6.

The cutting tool 2 generally has a nominal drill diameter D.

Two primary face cutting edges 14A and also two secondary face cutting edges 14B are provided at the tool face 12. The primary face cutting edges 14A form a drill bit extending

along the entire nominal drill diameter D and run along a continuous line. Both the primary face cutting edges 14A and also the secondary face cutting edges 14B are arranged opposite each other with respect to the axis of rotation 4, i.e., as pairs, they form in each case an angle of 180°. Conveniently, the secondary face cutting edges 14B also extend along a straight line. Both the primary and the secondary face cutting edges 14A, 14B generally extend in the radial direction up to the nominal drill diameter D, forming, where applicable, a corner chamfer at the circumference, or even a fillet.

One primary flute 16A or one secondary flute 16B is in each case associated with each face cutting edge 14A, 14B. The associated flutes 16A, 16B are in each case here arranged to be in a leading position with respect to the corresponding face cutting edge 14A, 14B. One primary peripheral cutting edge 18A and one secondary peripheral cutting edge 18B are arranged in each case circumferentially along the corresponding flute 16A, 16B. All four peripheral cutting edges 18A, 18B here lie on the same nominal drill diameter D. Viewed opposite to the longitudinal direction 6, the nominal diameter of the cutting tool 2 can taper somewhat. The peripheral cutting edges 18A, 18B extend over a length L (see Figure 1), and thus define the length of the cutting area 10. Here, the length L lies within a range of two to five times the nominal drill diameter D. The flutes 16A, 16B can even extend beyond this in the direction opposite to the longitudinal direction 6, as can be seen from Figure 1.

In addition, the cutting tool 2 in the exemplary embodiment also has a total of two cooling ducts 20, which terminate in discharge openings 22 in the tool face 12. The discharge openings 22 - as seen from above - are arranged at the end of a flank 24 of a leading primary face cutting edge 14A, and also, at the same time, roughly within the area of a radially internal end of the secondary face cutting edge 14B. The discharge opening 22 therefore lies simultaneously, not only in the flank 24 of a leading primary face cutting edge 14A, but also in the flank 24 of the associated trailing secondary face cutting edge 14B. This measure ensures that, during operation, a coolant emerging from the discharge opening 22 is distributed between both the corresponding primary flute 16A and also the secondary flute 16B.

Of particular importance for the cutting tool is, firstly, that there is an axial offset "a" (see Figure 6) between the primary face cutting edges 14A and the secondary face cutting edges 14B and, secondly, that a primary cross-sectional area 26A of a

corresponding primary flute 16A is significantly larger than a secondary cross-sectional area 26B of a secondary flute 16B.

As Figure 4, in particular, shows, here, the primary flute 16A extends over an angular range α_1 , and the secondary flute 16B extends over a significantly smaller angular range α_2 . The angular range α_1 is here preferably at least 1.5 times - more preferably, at least twice - as large as the angular range α_2 . In the exemplary embodiment, the angular range α_1 is about 90° , and the angular range α_2 is only 30° . In the exemplary embodiment, the angular range α_1 is therefore approximately three times as large as the angular range α_2 .

It is also of particular importance that a special angular distance β_1 be set between a particular leading primary face cutting edge 14A and a trailing secondary face cutting edge 14B. In the exemplary embodiment, the angular distance β_1 is about 60° . Correspondingly, an angular distance β_2 , which is usually significantly greater than the angular distance β_1 , is set between a secondary face cutting edge 14B and the primary face cutting edge 14A trailing behind this. The angular distance β_2 typically corresponds to the angular distance between the primary face cutting edges 14A (e.g., 180°), minus the angular distance β_1 . Due to the opposing paired arrangement of the primary and secondary face cutting edges 14A, 14B, a corresponding angular distance β_2 is located at $180^\circ (+/- 10^\circ)$, minus the angular distance β_1 - in the exemplary embodiment, therefore, at $120^\circ (+/- 10^\circ)$.

The differing cross-sectional areas 26A, 26B are, additionally, also due to the significantly different flute depths of the two flutes 16A, 16B. The different flute depths here result in different core diameters. The smallest distance of the primary flutes 16A or the secondary flutes 16B from the axis of rotation 4 is therefore defined by the relevant core diameter. Correspondingly, a primary core diameter is associated with the primary flutes 16A, and a secondary core diameter d_2 is associated with the secondary flutes 16B. Here, the primary core diameter d_1 is considerably smaller than the secondary core diameter d_2 , as can be seen, in particular, from Figure 5. In the exemplary embodiment, the primary core diameter d_1 corresponds approximately to 0.6 times the secondary core diameter d_2 .

The ratio d_1/D of the primary core diameter d_1 to the nominal drill diameter D preferably lies in the range of 0.25 to 0.5.

Furthermore, the ratio d_2/D of the secondary core diameter d_2 to the nominal drill diameter D preferably lies in the range of 0.5 to 0.75.

The axial offset "a" shown in Figure 6 conveniently lies within the range of 0.05 mm to 0.2 mm.

During operation of the cutting tool 2, an axial feed is set such that it is less than the axial offset "a," so that the secondary face cutting edges 14B will not then come into cutting contact with the workpiece during the drilling operation. This means that the axial feed per angular distance between the primary face cutting edge 14A and a trailing associated secondary face cutting edge 14B will be less than or equal to the axial offset "a."

A cutting tool 2 of this kind is used, in particular, for making drilled holes in curved workpieces. Specifically, this cutting tool 2 is used for cutting pilot holes in curved workpieces - for example, in the case of a crankshaft of a motor vehicle. These often require oil feeder holes or other kinds of holes. Here, an exact positioning of the holes in the curved workpiece surface is essential.

When the cutting tool 2 is used, it is initially advanced in the radial feed direction to the tool, i.e., perpendicular to the axis of rotation 4, so that a quasi-flat face is milled into the curved workpiece surface. The axial depth of penetration in the direction of the longitudinal direction 6 is comparatively shallow and is typically less than or equal to the nominal drill diameter D . Once the desired drilling position is achieved, the drilling operation is carried out after the milling operation, and the cutting tool 2 (alone) is advanced in the longitudinal direction 6 in order to cut the desired drilled hole. Here, the drilling operation is carried out by the primary face cutting edges 14A, so that the chips produced during drilling are preferably removed exclusively via the primary flutes 16A. The removal of chips is not critical during milling, since, due to the radial infeed operation, they are ejected radially out of the flutes 16A, 16B by the centrifugal forces.

Here, the cutting tool 2 is preferably a so-called pilot drill. The resulting hole is typically drilled wider and deeper in a subsequent drilling step (counterboring). The cutting tool 2 has, accordingly, a small nominal drill diameter D in the range of only 4 mm to 8 mm.

CLAIMS

1. Rotary cutting tool (2) - in particular, a drill milling cutter
 - with a nominal drill diameter (D),
 - with a flat tool face (12),
 - with a cutting area (10) extending along an axis of rotation (4) in a longitudinal direction (6) towards the flat tool face (12), wherein
 - the tool face (12) has primary and secondary face cutting edges (14A, 14B),
 - the primary face cutting edges (14A) form a drill bit extending over the nominal drill diameter (D),
 - the secondary face cutting edges (14B) are set back in the longitudinal direction (6) by an axial offset (a) with respect to the primary face cutting edges (14A),
 - in each case, primary and secondary flutes (16A, 16B), extending in the longitudinal direction (6) and starting at the tool face (12), are associated with the primary and secondary face cutting edges (14A, 14B),
 - primary and secondary peripheral cutting edges (18A, 18B) run along the primary and secondary flutes (16A, 16B),
 - the primary flutes (16A) have a greater cross-sectional area (26A) than the secondary flutes (16B).
2. Cutting tool (2) in accordance with the previous claim, in which the cross-sectional area (26A) of the primary flutes (16A) corresponds to at least 1.5 times
 - and, preferably, at least twice - the cross-sectional area (26B) of the secondary flutes (16B).
3. Cutting tool (2) in accordance with one of the two previous claims, in which the primary flutes (16A) extend radially up to a primary core diameter (d1), and the secondary flutes (16B) extend up to a secondary core diameter (d2), wherein the primary core diameter (d1) is smaller than the secondary core diameter (d2).
4. Cutting tool (2) in accordance with the previous claim, in which the secondary core diameter (d2) lies in the range between 1.5 and 3 times that of the primary core diameter (d1).

5. Cutting tool (2) in accordance with one of the two previous claims, in which the primary core diameter (d_1) lies in the range of 0.25 to 0.5 times the nominal drill diameter (D).
6. Cutting tool (2) in accordance with one of the previous claims, in which the primary flutes (16A) cover a greater angular range (α_1) than the secondary flutes (16B).
7. Cutting tool (2) in accordance with one of the previous claims, in which a primary face cutting edge (14A) is at an angular distance (β) from a trailing secondary face cutting edge (14B) which is less than 85° and, in particular, less than 75° .
8. Cutting tool (2) in accordance with the previous claim, in which the primary face cutting edges (14A), as well as the corresponding secondary face cutting edges (14B), are separated from each other by an angular distance of ca. 180° .
9. Cutting tool (2) in accordance with one of the previous claims, which is designed for a given forward feed in the longitudinal direction (6) during the drilling operation, wherein the axial offset (a) is greater than or equal to the forward feed, so that the secondary face cutting edges (14B) are inactive during drilling.
10. Cutting tool (2) in accordance with one of the previous claims, in which the axial offset (a) lies in the range between 0.05 mm and 0.2 mm.
11. Cutting tool (2) in accordance with one of the previous claims, in which the primary face cutting edges (14A) extend in each case up to the axis of rotation (4).
12. Cutting tool (2) in accordance with one of the previous claims, in which the primary cutting edges (14A) extend in each case in a straight line.
13. Cutting tool (2) in accordance with one of the previous claims, in which both the primary cutting edges and the secondary peripheral cutting edges (18A, 18B) are shaped for cutting.
14. Cutting tool (2) in accordance with one of the previous claims, in which the primary and the secondary peripheral cutting edges (18A, 18B) are of the same diameter.

15. Cutting tool (2) in accordance with one of the previous claims, in which precisely two primary face cutting edges (14A) and two secondary face cutting edges (14B) are provided.
16. Cutting tool (2) in accordance with one of the previous claims, which has cooling ducts (20) that are formed in an angular range in which the secondary flutes (16B) also lie.
17. Cutting tool (2) in accordance with one of the previous claims, which has cooling ducts (20) that, at the tool face (12), open in a discharge opening (22) which is connected to both the primary and the secondary flutes (16A, 16B).

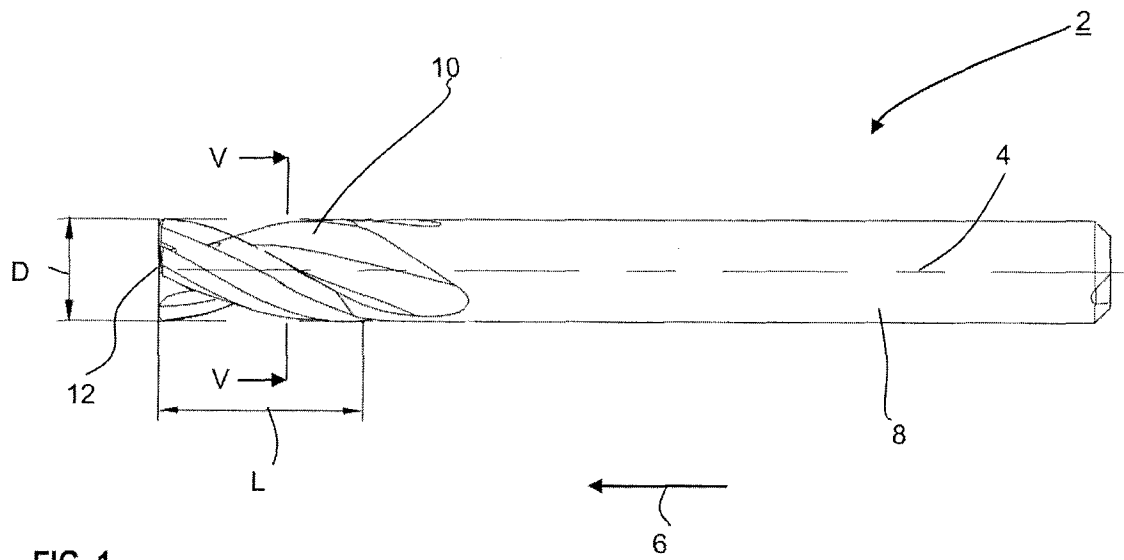


FIG. 1

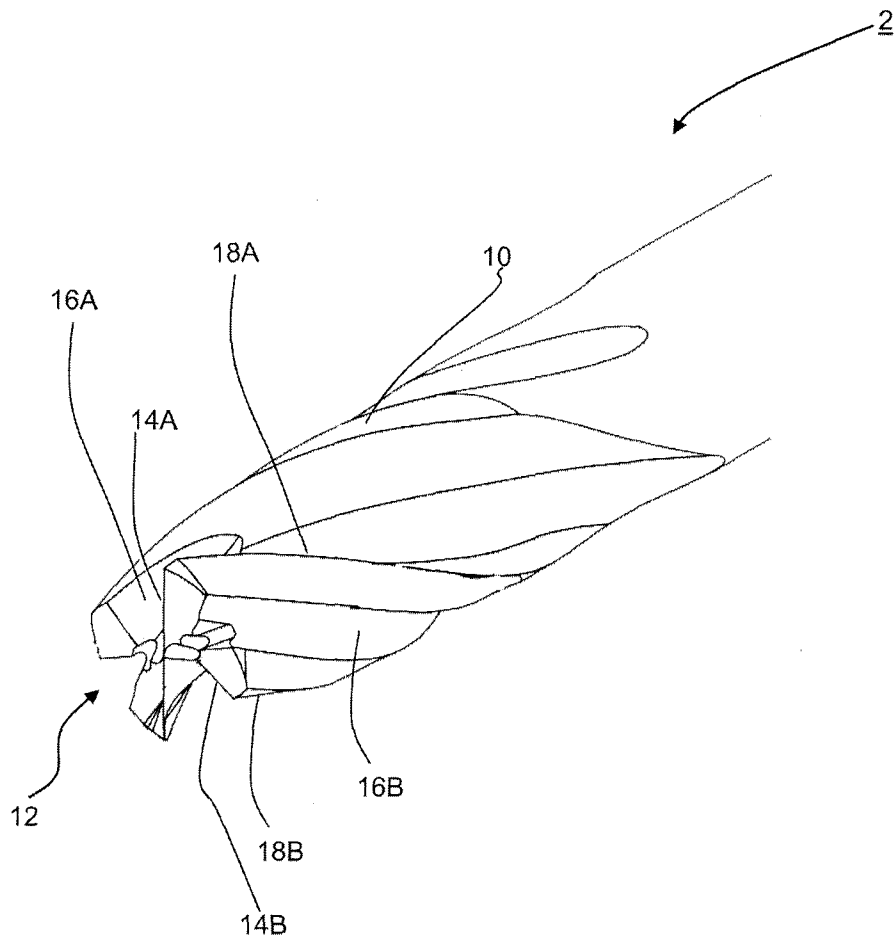


FIG. 2

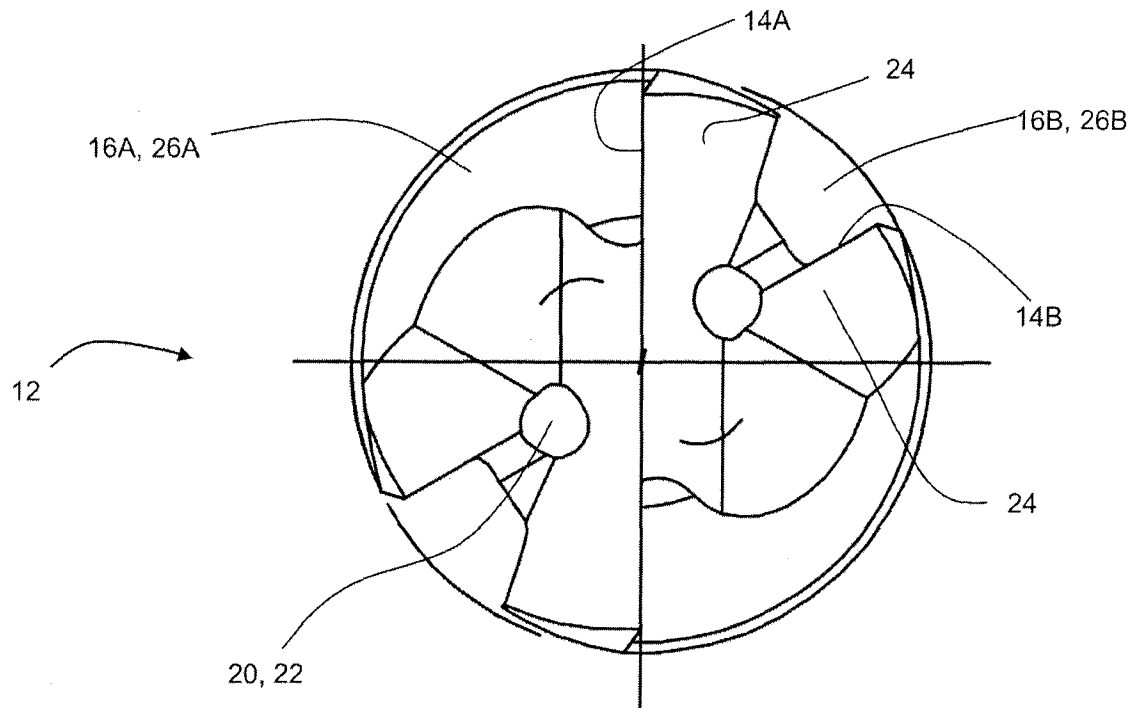


FIG. 3

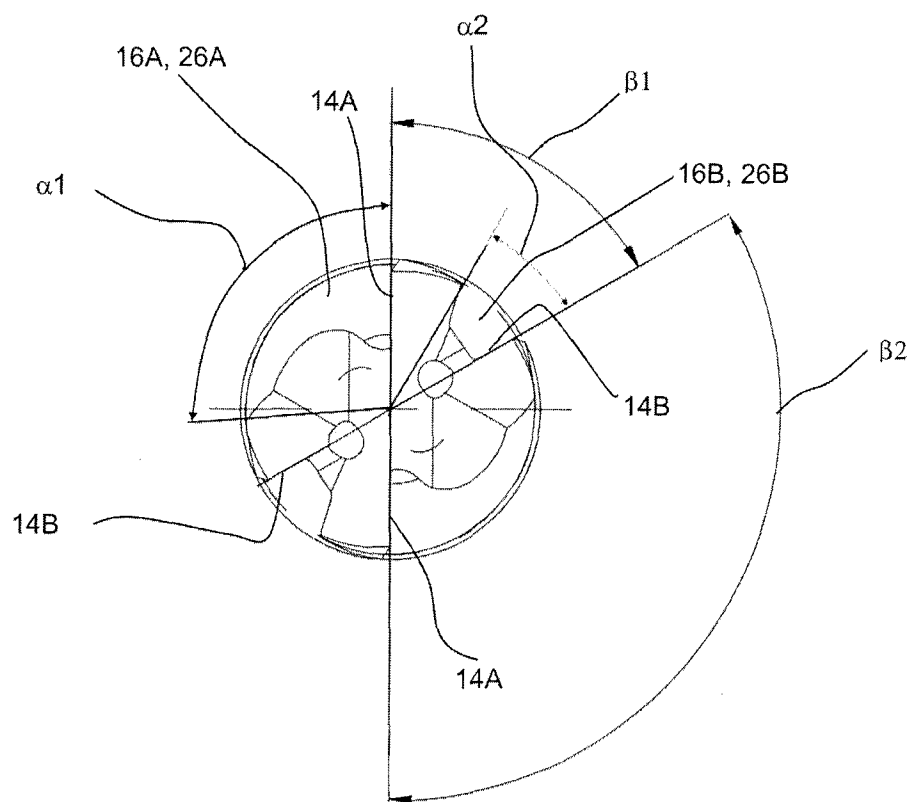


FIG. 4

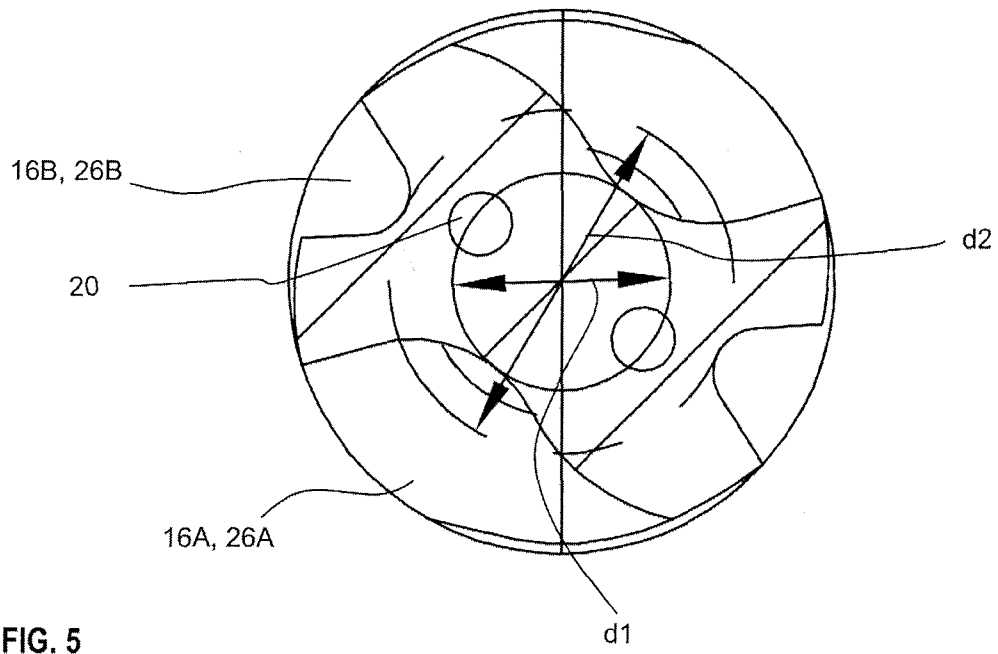


FIG. 5

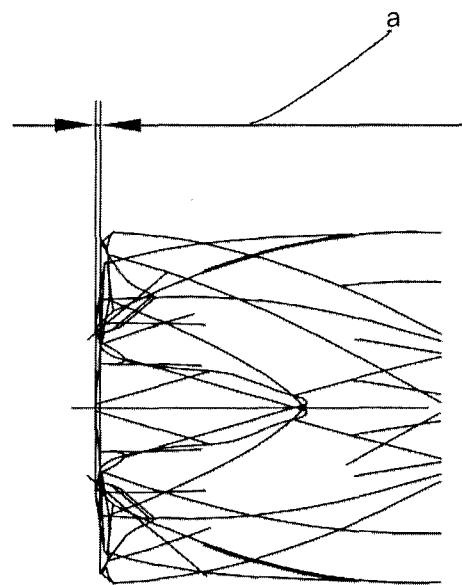


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2017/061896**A. CLASSIFICATION OF SUBJECT MATTER****B23C 5/10(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHEDMinimum documentation searched (classification system followed by classification symbols)
B23C 5/10; B23C 5/02Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility modelsElectronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: rotary cutting tool, drilling, milling, face cutting edge, peripheral cutting edge, flute, cross-sectional area, core diameter**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	KR 10-2009-0017840 A (YU, SEUNG SUN) 19 February 2009 See paragraphs [0012]-[0014] and figures 3, 4.	1-3
Y	JP 2007-136627 A (MITSUBISHI MATERIALS KOBE TOOLS CORP.) 07 June 2007 See claim 1 and figure 3.	1-3
A	JP 2014-210324 A (NACHI FUJIKOSHI CORP.) 13 November 2014 See paragraph [0018] and figure 3.	1-3
A	US 2014-0227050 A1 (ISCAR, LTD.) 14 August 2014 See paragraphs [0090]-[0093], [0097]-[0102] and figures 1B, 2B.	1-3
A	CN 202461638 U (KUNSHAN OSK PRECISION TOOLS CO., LTD.) 03 October 2012 See abstract and figures 1, 3.	1-3



Further documents are listed in the continuation of Box C.



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Date of the actual completion of the international search

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Date of mailing of the international search report

15 March 2018 (15.03.2018)

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2017/061896**Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)**

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☒ Claims Nos.: 4-17
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of any additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2017/061896

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
KR 10-2009-0017840 A	19/02/2009	None	
JP 2007-136627 A	07/06/2007	None	
JP 2014-210324 A	13/11/2014	JP 6089917 B2	08/03/2017
US 2014-0227050 A1	14/08/2014	CA 2901470 A1	21/08/2014
		CN 104968458 A	07/10/2015
		EP 2956266 A1	23/12/2015
		EP 2956266 B1	05/04/2017
		JP 2016-506876 A	07/03/2016
		KR 10-2015-0115783 A	14/10/2015
		PL 2956266 T3	29/09/2017
		PT 2956266 T	25/05/2017
		RU 2015138914 A	17/03/2017
		US 9211594 B2	15/12/2015
		WO 2014-125474 A1	21/08/2014
		WO 2014-125474 A8	26/02/2015
CN 202461638 U	03/10/2012	None	