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- (54) **Title:** ROTARY TOOL FOR PRECISION MACHINING OF A DRILLED HOLE IN A WORKPIECE, AND METHOD FOR PRECISION MACHINING OF A DRILLED HOLE

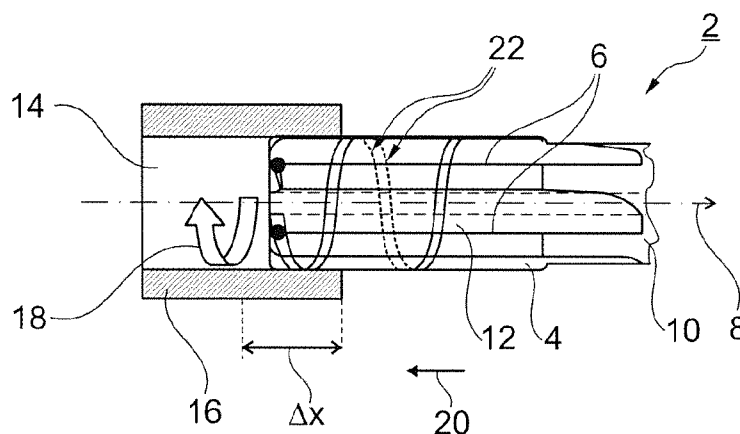


Fig. 1

- (57) **Abstract:** In order to achieve as highly accurate an alignment of the frictional tool (2) as possible and therefore as high a drilled hole quality as possible during the precision machining of a drilled hole (14), the cutting edges (6) of the frictional tool (2) are divided into two cutting groups (A, B), the cutting edges (6A, 6B) of which are spaced apart with respect to one another in each case by an axial spacing (x) from one another. Here, the axial spacing (x) is selected in such a way that, at a predefined first, slower feed speed (v1), merely the cutting edges (6A) of the first cutting edge group (A) are in engagement with the workpiece (16) and, at a higher, predefined second feed speed (v2), all cutting edges (6A, 6B) are in engagement with the workpiece (16).

**Rotary tool for precision machining of a drilled hole in a workpiece, and
method for precision machining of a drilled hole**

Background of the Invention

The invention relates to a rotary tool for precision machining of a drilled hole in a workpiece, in particular a frictional tool, having a tool head which extends in the axial direction and has a plurality of cutting edges on its circumference, which cutting edges are arranged on an identical cutting circle. Furthermore, the invention relates to a method for precision machining of a drilled hole with the aid of a rotary tool of this type.

For highly precise production or precision machining of drilled holes, frictional tools are usually used as precision machining tools or what are known as finishing tools. A frictional tool of this type can be gathered, for example, from US 2003/0156912 A1. Frictional tools of this type usually have a plurality of (reaming) cutting edges which are arranged in each case on a common cutting circle, that is to say are at the same radial spacing from a tool center axis. For precision machining of a drilled hole, the frictional tool is guided up to said drilled hole. Firstly the exact roundness of the drilled hole but also the exact orientation along a desired drilled-hole longitudinal axis are decisive for highly precise drilled-hole machining. In order to ensure this, the center or rotational axis of the frictional tool has to coincide with the desired setpoint longitudinal axis of the drilled hole and also has to be oriented exactly with respect to said longitudinal axis. In the real world application situation, however, there is the problem that these two preconditions are not always met in a satisfactory manner.

Object of the Invention

Proceeding herefrom, the invention is based on the object of specifying a rotary tool and a method for precision machining of a drilled hole, which ensure high-quality precision machining.

Achievement of the Object

According to the invention, the object is achieved by a rotary tool having the feature of claim 1 and by a method having the features of claim 11.

The rotary tool has a tool head which extends in the axial direction and has a plurality of cutting edges on its circumference. Said cutting edges are arranged on an identical cutting circle. Here, the cutting edges are divided into a first cutting edge group and a second cutting edge group, the two cutting edge groups being spaced apart from one another in the axial direction by an axial spacing. Said axial spacing is selected in such a way that, at a predefined first feed speed, only the cutting edges of the first cutting edge group are in engagement with the workpiece, and that, at a predefined second feed speed which is faster than the first feed speed, the cutting edges of both the first and the second cutting edge group are in engagement with the workpiece. Here, the cutting edges of the respective cutting edge group are usually arranged at the same axial height and each individual cutting edge is usually also allocated a dedicated flute for transporting away the drilling chips here.

In the method according to the invention, first of all the slower feed speed is set at the beginning of the precision machining with a rotary tool of this type, with the result that merely the first cutting edge group is in engagement with the workpiece. After a predefined axial feed has been reached, the feed speed is then increased, in particular to the second feed speed, with the result that it is ensured that all cutting edges come into engagement with the workpiece.

Rotary tool is generally understood to mean a tool which rotates about a rotational axis during machining. In particular, it is a frictional tool. In addition, the concept which is described here is preferably also used in spindle tools and counterboring tools.

This embodiment is based on the finding that the quality of the hole machining is influenced decisively at the beginning of the precision machining operation, since an alignment of the precision machining tool relative to the drilled hole takes place at the beginning of the precision machining operation. Even in the case of highly accurate machine tools, in which the precision machining tool is clamped, a certain offset and/or a certain oblique positioning, for example, as a result of elastic yielding cannot be avoided completely, for example.

Tests have now shown that the alignment at the beginning of the precision machining operation is influenced decisively by the number of cutting edges which come into engagement with the workpiece. It has been determined here that a lower number of cutting edges or even only one cutting edge is advantageous, since very satisfactory true running coaxially with respect to the desired drilled hole longitudinal axis is produced as a result and the rotary tool does not follow a pilot hole (drilled hole) which is already present and is possibly not very positionally accurate.

However, a low number of cutting edges leads to only a low process speed, since the cutting capacity per cutting edge and therefore the feed per cutting edge and revolution are restricted.

Highly accurate precision machining with simultaneous retention of a very high process speed is then achieved by way of the rotary tool according to the invention and by way of the method according to the invention. The specially configured rotary tool namely makes it possible to begin the precision machining operation first of all with an only small number of cutting edges and therefore to achieve high accuracy and alignment of the precision machining tool. At the same time, the tool permits a high process speed to be set by switching over to the second feed

speed, since the cutting capacity is then distributed to a greater number of cutting edges.

Furthermore, for the same purpose, the number of cutting edges in both cutting edge groups is selected to be equally large in one preferred embodiment. Here, the overall number of cutting edges also depends, in particular, on the selected nominal diameter of the tool. In the case of a rotary tool having a diameter of up to 8 mm, four cutting edges are typically used, in the case of a rotary tool having a diameter of between 8 and 25 mm, six cutting edges are typically used and, in the case of a rotary tool having a nominal diameter of greater than 25 mm, eight cutting edges are typically used. As an alternative to the symmetrical division of the number of cutting edges to the first and second cutting edge group, there is also the possibility of an asymmetrical division, for example 1/2, 1/3, 2/4, 2/6, 3/5, etc., the first number in each case specifying the number of cutting edges of the first cutting edge group and the second number specifying the number of cutting edges of the second cutting edge group.

It is provided in one expedient development, furthermore, that the cutting edges of a respective cutting edge group are arranged substantially identically distributed around the circumference. Here, substantially identically distributed is understood to mean that a deviation from the accurate identical distribution by a few percent, for example by $\pm 5\%$, is also included. This leads to a slight unequal distribution which is often desired and is explicitly also set, in order to counteract an inclination to rattle, that is to say periodic resonance.

Overall, in the case of the rotary tool with six cutting edges, three cutting edges are therefore assigned to the first cutting edge group, which cutting edges are arranged in each case offset rotationally with respect to one another by approximately 120° . At the same time, three cutting edges are likewise assigned to the second cutting edge group, which cutting edges are likewise arranged offset rotationally with respect to one another approximately by 120° , the cutting edges of the second cutting edge group being spaced apart in each case by the same identical axial spacing from the cutting edges of the first cutting edge group. Said cutting edges all lie at an identical axial height. The second cutting edges are

arranged in each case between a leading and a trailing cutting edge of the first cutting edge group.

With regard to machining which is as homogeneous as possible, the cutting edges of the first and the second cutting edge group are therefore arranged alternately with respect to one another in the circumferential direction, and a cutting edge of the second cutting edge group therefore in each case follows a cutting edge of the first cutting edge group.

The first feed speed is preferably selected to be in the range between 0.01 and 0.05 mm axial feed per cutting edge. At the same time, the second feed speed is selected to be between approximately 5 times and 10 times the first feed speed. It usually lies in the range between 0.1 and 0.5 mm per cutting edge.

The first, slow feed speed automatically results in an axial minimum spacing in the case of a predefined distribution of the cutting edges around the circumference and also in the case of a predefined cutting edge distribution around the circumference. Here, said axial minimum spacing has to be selected to be sufficient, in order to ensure that the second cutting edge group does not come into engagement with the workpiece. The axial spacing is preferably selected to be approximately from two times to three times as great as said minimum axial spacing and is preferably set between 0.03 mm and 0.05 mm and at most preferably to 0.1 mm.

Very satisfactory results and highly accurate drilled holes can be formed with simultaneously high process speeds by way of said selected first and second feed speeds and the selected axial spacing.

In one expedient development, the cutting edges of the second cutting edge group are not arranged identically distributed between a leading and a trailing cutting edge of the first cutting edge group, but rather have different angular spacings from the leading and trailing associated cutting edge of the first cutting edge group. By way of this preferred embodiment, as uniform a distribution as possible of the cutting capacity to all teeth is achieved generally in an expedient

embodiment. The cutting capacity is namely not distributed homogeneously to the cutting edges of the first and the second cutting group depending on the selected second feed speed and the axial spacing. Here, cutting capacity is understood to mean in each case the axial penetration depth of a respective cutting edge into the workpiece at the selected feed speed.

Here, the angular spacing from the leading cutting edge is expediently greater than from the trailing cutting edge of the first cutting edge group. Here, the angular spacings are approximately in the ratio of 60 to 40.

Description of the Figures

In the following text, an exemplary embodiment of the invention will be explained in greater detail using the figures, in which, in each case in diagrammatic illustrations:

- fig. 1 shows a simplified illustration from the side of a frictional tool, shown in details, in engagement with a pilot-drilled workpiece, shown in section, in accordance with the prior art,
- fig. 2 shows a flattened illustration of the cutting edges of the frictional tool according to fig. 1 with the trajectories of the cutting corners at a predefined feed speed,
- fig. 3 shows an enlarged illustration of a cutting edge of that region of figure 2 which is identified by a circle, with supplementary explanations,
- fig. 4 shows a flattened illustration, similar to figure 2, of a frictional tool according to the invention with two cutting edge groups which are spaced apart from another by an axial spacing at a predefined slow feed speed,
- fig. 5 shows an illustration according to fig. 4, the trajectories of the cutting edges at a second, higher feed speed additionally being shown,
- fig. 6 shows a diagrammatic illustration of the angular distribution of the cutting edges of the first and the second cutting edge group,

- fig. 7 shows the flattened illustration according to figures 4 and 5 with the angular distribution of the cutting edges according to figure 6, and
- fig. 8 shows a flattened illustration of the trajectories of a rotary tool with three cutting groups with cutting edge groups which are offset in each case with respect to one another by an axial spacing.

Description of the Exemplary Embodiment

In the figures, identically acting parts are provided with the same designations.

The rotary tool which is configured as a frictional tool 2 has a tool head 4 with a plurality of cutting edges 6 which are arranged distributed around the circumference and are configured as cutting bars. The frictional tool 2 extends along a rotational axis which at the same time forms a center axis in the axial direction 8 from the tool head 4 to a rear shank 10 (shown only in details here) which is adjoined at the rear end by a clamping shank, by way of which the frictional tool 2 is clamped into a machine tool. In the exemplary embodiment, the cutting edges 6 extend parallel to the axial direction 8, beginning on the end side. As an alternative, they can also be of helical configuration. No further cutting edges are arranged in addition to the (reaming) cutting edges 6. Each cutting edge 6 is assigned a respective flute 12. During the precision machining of a drilled hole 14 of a workpiece 16, the frictional tool 2 rotates about the rotational axis in the rotational direction 18. Here, the frictional tool 2 is advanced in the feed direction 20 counter to the axial direction 8 which is shown. As a result of the superimposed movement directions, the individual cutting edges 6, more precisely the frontmost cutting edges, run along spiral trajectories 22 in relation to the workpiece 6.

Figure 2 shows the situation from figure 1 in a linearly flattened state. Here, the trajectories 22 are shown by obliquely running lines. Here, the inclination of the trajectories 22 is defined by the feed speed which is set. At a defined feed speed v , the cutting capacity of a respective cutting edge 6 is defined by the engagement length l of a respective cutting edge 6 in the axial direction 8, which engagement length l is defined at the same time by the spacing between two trajectories 22.

Here, the region which is shown using dashed lines in figure 2 specifies the material-removing volume and therefore the material-removing capacity of the fourth cutting edge 6.

The situation at the cutting corner at different feed speeds v_1 , v_2 is shown using the enlarged illustration according to figure 3:

The cutting edge 6 first of all has a clearance angle γ . At a low feed speed v_1 , the corresponding trajectory 22A has merely a small angle and, at a faster feed speed, the corresponding trajectory 22B (shown using a dashed line) has a greater angle of inclination. Here, the clearance angle γ in each case has to be greater than the angle of inclination which is defined by the feed speed v .

Embodiments according to the invention of the frictional tool 2 will now be explained in greater detail using figures 4 to 8. In the case of said frictional tool 2, the cutting edges 6 are divided into two cutting groups A, B, the cutting edges of cutting group A being provided with the designation 6A and those of the cutting group B being provided with the designation 6B. It is then of essential significance that the cutting edges 6A, 6B of the two cutting groups A, B are spaced apart from one another by an axial spacing x , that is to say the cutting edges 6B are arranged set back in the axial direction 8 by the axial spacing x . Here, the cutting edges 6A, 6B of a respective cutting group A, B are arranged in each case at the same axial height. As is also apparent, in particular, from figure 6, the cutting corners of all cutting edges 6A, 6B are arranged on a common cutting circle 24.

Figure 4 shows the machining situation at a low first feed speed v_1 . As can be seen using the trajectories 22A, the cutting edges 6B lie in each case in the "shadow" of the respectively leading cutting edge 6A on account of the set-back arrangement. The cutting edges 6B are therefore not in engagement with the workpiece 16 at the selected low feed speed v_1 . As a result, only a few cutting edges 6A are in engagement at the beginning of the machining operation, that is to say when the frictional tool 2 is moved up to the drilled hole 14 and is introduced into the latter. Highly accurate alignment of the frictional tool 2, in particular of its center axis with respect to the drilled-hole axis, is achieved as a result. In the ideal

case, said two axes should be oriented in an axially parallel manner and should coincide.

The illustration according to figure 5 then shows a situation when the frictional tool is advanced at a higher, second feed speed v_2 . Correspondingly, the associated trajectories 22B are also inclined at a greater angle, with the result that the cutting edges 6B of the second cutting edge group B then also come into engagement and contribute to the removal of material. The material-removing capacity is therefore then distributed to all six cutting edges 6A, 6B at the second feed speed v_2 .

As can be gathered from figure 5, however, the cutting capacity is distributed differently to the cutting edges 6A and 6B. The cutting edges 6A of the first cutting group A contribute a greater proportion of the material-removing capacity, which leads to premature wear.

In order to avoid this, an angular distribution of the cutting edges 6A, 6B is then performed, as can be gathered from figures 6 and 7. In general, depending on the selected second, higher feed speed v_2 , the angular spacing of a respective cutting edge 6B of the second cutting edge group B from the leading and trailing cutting edge 6A of the first cutting edge group is selected differently, with the result that the cutting edge 6B is arranged asymmetrically with regard to said two cutting edges 6A. As can be gathered, in particular, from figure 6, the angular spacing δ from the leading cutting edge is greater than the angular spacing ϵ from the trailing cutting edge 6A. Here, the angular spacing δ , ϵ is selected in such a way that the cutting capacity is distributed homogeneously to the cutting edges 6A, 6B, as is shown in figure 7. Here, the cutting capacity of the individual cutting edge groups A, B is shown in each case in the illustrations of figures 5 and 7 by the lower case letters a, b. As can be seen in figure 7, the cutting capacities a, b are identical.

In the exemplary embodiment, six cutting edges are provided for the frictional tool 2. Here, the cutting edges of the respective cutting edge group A, B are arranged in each case distributed at least substantially identically, that is to say in each case

have an angular spacing of 120° from one another. Slight deviations from said angular spacing are partially desired, in order to counteract an inclination to rattle.

In addition, fewer or more cutting edges 6 can also be provided. Typical parameter values for the different relevant variables result from the following table, in particular also depending on the diameter of the frictional tool.

Diameter, tool [mm]	≤8		8 - 25		≥ 25		
Number of cutting edges	4		6		8		
Number of cutting edges, group A	2		3		4		
Number of cutting edges, group B	2		3		4		
v1 feed speed [mm / cutting edge]	0.02	0.04	0.02	0.04	0.02	0.04	0.06
Limiting feed [mm / cutting edge]	0.048	0.052	0.048	0.052	0.048	0.052	0.15
v2 feed speed [mm / cutting edge]	0.12	0.2	0.12	0.2	0.12	0.2	0.3
Limiting axial spacing [mm]	0.01	0.02	0.01	0.02	0.01	0.02	0.03
x, axial spacing [mm]	0.03		0.03		0.03	0.03	0.1
δ, angular spacing from the leading cutting edge 6A	112.5	103.5	75	69	56.25	51.75	60
ε, angular spacing from the trailing cutting edge 6A	67.5	76.5	45	51	33.75	38.25	30

As can be gathered from this, the values for the first, slow feed speed typically lie in the range from 0.01 to 0.08 and, in particular, at 0.02 mm per cutting edge. The limiting feed specified in the table in millimeters per cutting edge and revolution results from the selected total number of cutting edges in the case of an assumed homogeneous distribution of the cutting edges in two cutting edge groups. Here, the limiting feed defines the minimum feed speed of the second higher feed speed, from which the cutting edges 6B of the second cutting edge group B also pass into engagement.

Furthermore, it can be gathered from the table that the second, higher feed speed typically lies in the range between 0.1 and approximately 0.8, preferably in the region of 0.2.

Taking the number of cutting edges into consideration (in the case of a uniform distribution to the two groups), the first feed speed v_1 then results in a limiting axial spacing which has to at least be maintained, in order to ensure that merely the cutting edges 6A of the first cutting edge group are in engagement. In order to set a sufficient tolerance spacing here, the axial spacing x is preferably selected to be in the range from approximately 0.03 to 0.08 mm.

Finally, the last two lines of the table indicate typical values for the angular spacing δ from the leading and ϵ from the trailing cutting edge. Here, the angular spacing from the leading cutting edge δ is defined by the angular spacing between two first cutting edges 6A plus the quotient from the axial spacing in millimeters divided by the second, higher feed speed in millimeters per degree.

In the case of a total of four cutting edges, the angular spacing δ therefore lies approximately in the range between 100 and 115°, depending on the selected axial spacing and the second feed speed. In the case of six cutting edges, the angular spacing δ lies in the range from approximately 65 to 80° and, in the case of eight cutting edges, it lies in the range from approximately 50 to 65° (in each case in the case of an at least approximately identical distribution of the first cutting edges 6A).

Finally, figure 8 shows a situation with a third cutting edge group C with third cutting edges 6C. In this exemplary embodiment, the frictional tool 2 then has a total of nine cutting edges, that is to say three cutting edges 6A, 6B, 6C for each group. A switchover to a third feed speed v_3 which is defined by a third trajectory 22C is additionally also provided.

The consideration as described in conjunction with figures 4 to 7 with regard to the selection of the angular spacing between the individual cutting edges 6A, 6B, 6C can also be transferred to this variant in a corresponding manner.

In the machining method with a frictional tool 2 of this type, the procedure is then such that the frictional tool 2 is first of all advanced at the low feed speed v_1 at the beginning of the machining operation and is switched over to the higher feed speed v_2 after reaching a predefined axial position within the workpiece 16. As a result, first of all only the cutting edges of the first cutting group A are in engagement at the beginning of the machining method, and subsequently all cutting edges are in engagement with the same material-removing capacity. Here, the switchover takes place after an axial feed Δx in the range from 0.2 mm to 0.5 mm (cf. figure 1 with respect to the axial feed Δx).

For the angular distribution of the individual cutting edges 6A, 6B, the additional cutting capacity at the machining start of the cutting edges 6A can also be taken into consideration in addition, with the result that this is also compensated for by corresponding angular positioning of the cutting edges 6A, 6B for a respective application.

Page 13

Claims

1. A rotary tool (2) for precision machining of a drilled hole (14) in a workpiece (16), in particular a frictional tool, having a tool head (4) which extends in the axial direction (8) and has a plurality of cutting edges (6) on its circumference, which cutting edges (6) are arranged on an identical cutting circle (24),

wherein

the cutting edges (6) are divided into a first cutting edge group (A) and a second cutting edge group (B) and the two cutting edge groups (A, B) are spaced apart from one another in the axial direction (8) by an axial spacing (x) which is selected in such a way that, at a predefined first feed speed (v1), only the cutting edges (6A) of the first cutting edge group (A) are in engagement with the workpiece (16), and that, at a predefined second feed speed (v2) which is faster than the first feed speed (v1), the cutting edges (6A, 6B) of both the first and the second cutting edge group (A, B) are in engagement with the workpiece (16).
2. The rotary tool (2) as claimed in claim 1,

wherein

the cutting edges (6A, 6B) of the first and the second cutting edge group (A, B) are arranged alternately with respect to one another.
3. The rotary tool (2) as claimed in claim 1 or 2,

wherein

the two cutting edge groups (A, B) have the same number of cutting edges (6A, 6B).
4. The rotary tool (2) as claimed in one of the preceding claims,

wherein

the cutting edges (6A, 6B) of a respective cutting edge group (A, B) are arranged substantially identically distributed around the circumference.
5. The rotary tool (2) as claimed in one of the preceding claims,

Page 14

wherein

the first feed speed (v_1) lies at from 0.01 to 0.05 mm axial feed per cutting edge and the second feed speed (v_2) lies between 5 times and 10 times the first feed speed (v_1).

6. The rotary tool (2) as claimed in one of the preceding claims,

wherein

the axial spacing (x) lies between 0.03 mm and 0.1 mm.

7. The rotary tool (2) as claimed in one of the preceding claims,

wherein

a respective cutting edge (6B) of the second cutting edge group (B) is arranged asymmetrically at different angular spacings (δ , ϵ) with respect to the leading and trailing cutting edge (6A) of the first cutting edge group (A).

8. The rotary tool (2) as claimed in claim 7,

wherein

the angular spacing (δ) from the leading cutting edge (6A) of the first cutting edge group (A) is selected in such a way that, at a predefined second feed speed (v_2), the cutting capacity of the cutting edges (6A, 6B) of the first and the second cutting edge group (A, B) are identical.

9. The rotary tool (2) as claimed in claim 7 or 8,

wherein

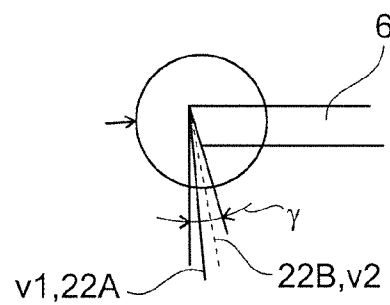
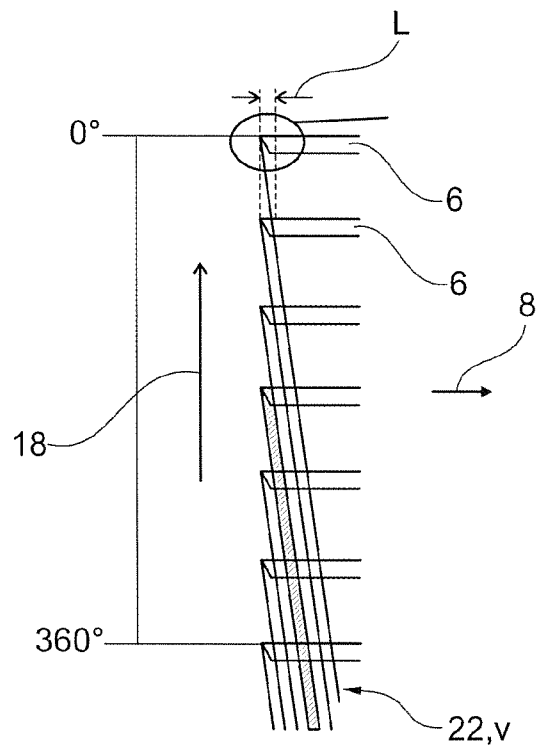
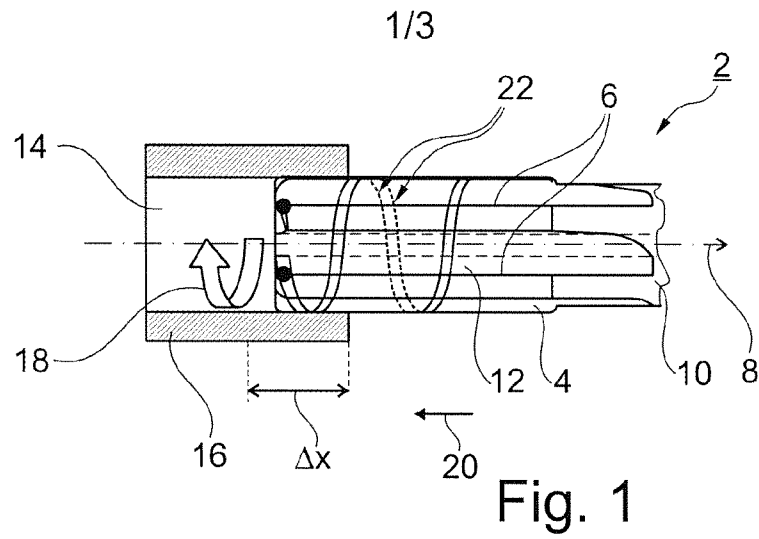
the angular spacing (δ) from the leading cutting edge (6A) is greater than from the trailing cutting edge (6A) of the first cutting edge group (A).

10. The rotary tool (2) as claimed in one of the preceding claims,

wherein

more than two cutting edge groups (A, B, C) are provided and the cutting edges (6A, 6B, 6C) of each cutting edge group (A, B, C) are spaced apart axially from the cutting edges of the other cutting edge groups (A, B, C).

11. A method for precision machining of a workpiece (16) with the aid of a rotary tool (2) as claimed in one of the preceding claims, in which method, at the beginning of the machining, a first slower feed speed (v_1) is set, and the feed speed (v) is increased after a predefined axial feed (Δx).
12. The method as claimed in claim 11, wherein a switchover is made to a second, higher feed speed (v_2).
13. The method as claimed in claim 11 or 12, wherein a switchover is made to the higher feed speed (v_2) at an axial feed (Δx) between 0.2 mm and 0.5 mm.



2/3

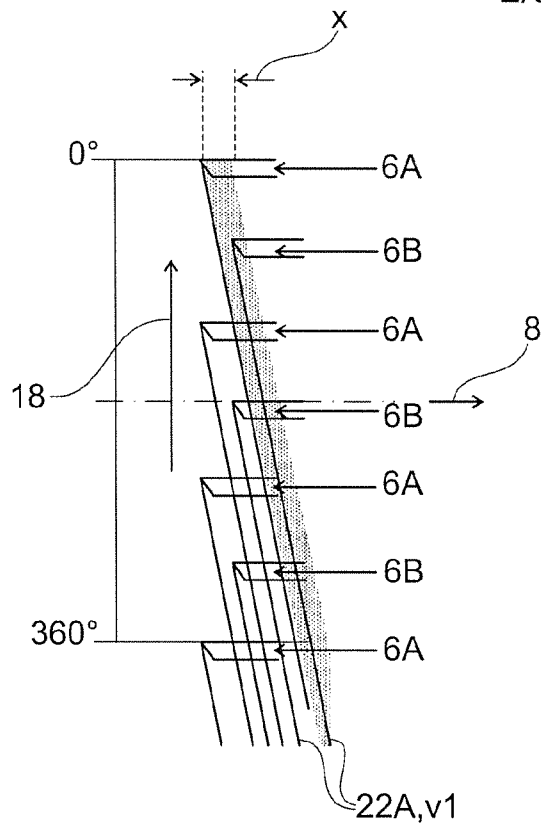


Fig. 4

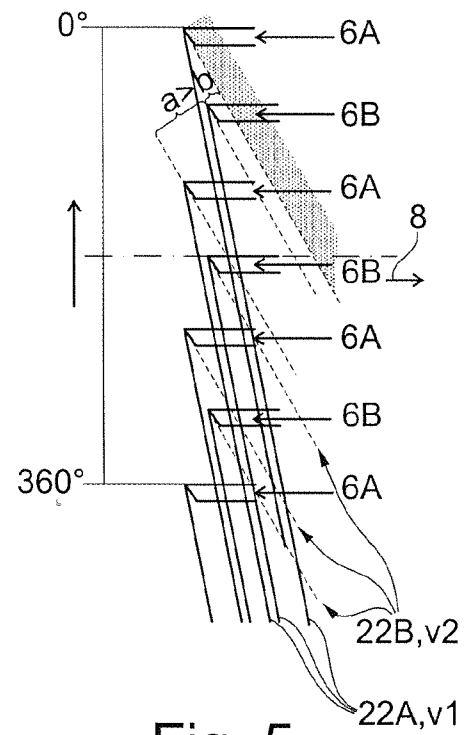


Fig. 5

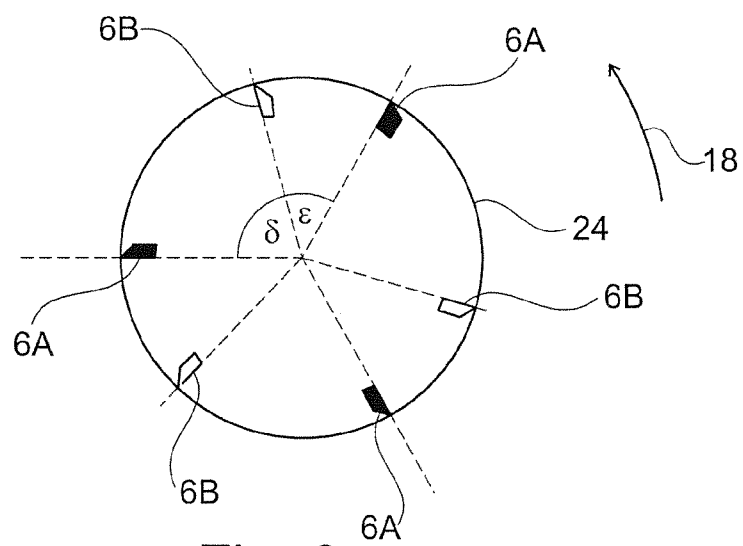


Fig. 6

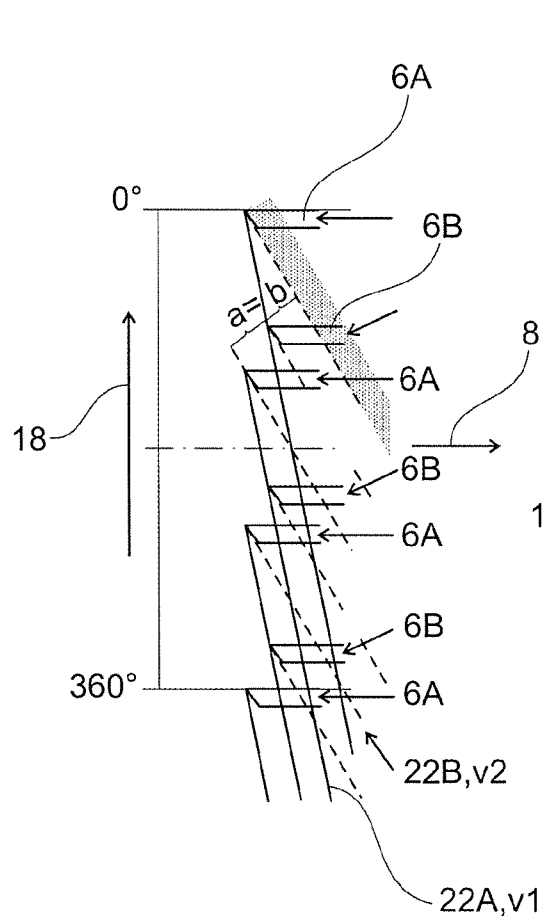


Fig. 7

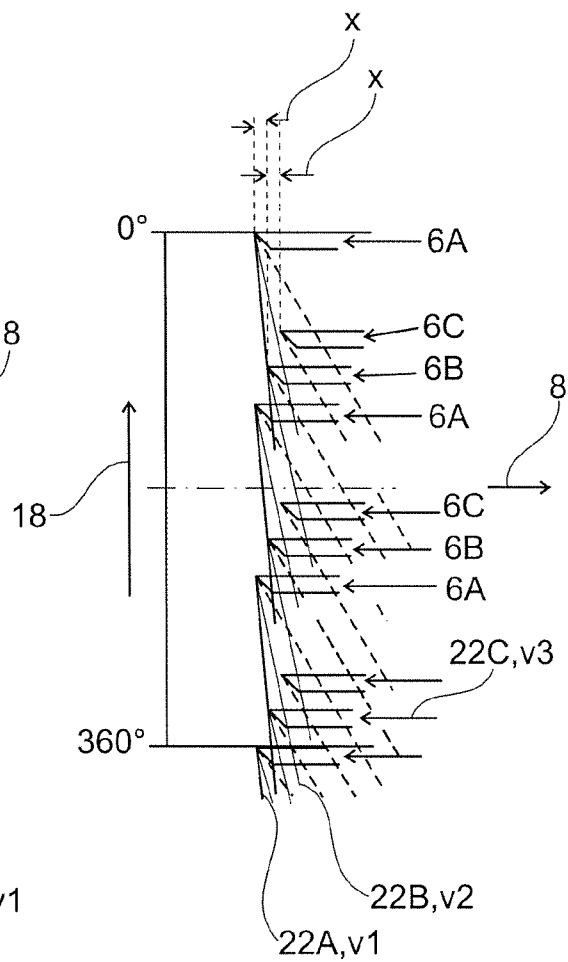


Fig. 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/062225**A. CLASSIFICATION OF SUBJECT MATTER****B23B 39/04(2006.01)i, B23B 29/03(2006.01)i, B26F 1/16(2006.01)i**

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B23B 39/04; B23B 51/08; B23B 51/00; B23B 51/02; B23D 77/00; B23P 15/46; E21B 9/02; B23B 29/03; B26F 1/16

Documentation 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 models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: drill, reamer, boring, burnish, cutter, cutting edge, group, and speed

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2013-0004253 A1 (KAUPER et al.) 03 January 2013 See abstract, paragraphs [0035]-[0039], and figures 1-3.	1-3
A	US 2008-0152445 A1 (JENSEN et al.) 26 June 2008 See abstract, paragraphs [0042]-[0044], and figures 3A-3C.	1-3
A	US 2005-0169721 A1 (SCHULTE, PAUL MARTIN) 04 August 2005 See abstract, paragraphs [0026]-[0029], and figures 1-3.	1-3
A	US 4294319 A (GUERGEN, KARLHEINZ) 13 October 1981 See abstract, column 4, line 55 - column 5, line 8, and figure 3.	1-3
A	US 2003-0175085 A1 (PROKOP, HERMANN F.) 18 September 2003 See abstract, paragraph [0046], and figure 4.	1-3



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

18 June 2014 (18.06.2014)

Date of mailing of the international search report

18 June 2014 (18.06.2014)

Name and mailing address of the ISA/KR

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INTERNATIONAL SEARCH REPORTInternational application No.
PCT/US2013/062225**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.: 8, 12
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:
Claims 8, 9, 12 and 13 are unclear, because they directly or indirectly refer to multiple dependent claims which do not comply with PCT Rule 6.4(a).
3. ☒ Claims Nos.: 4-7, 9-11, 13
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/US2013/062225

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2013-0004253 A1	03/01/2013	CN 102847995 A DE 102011106416 A1 FR 2977176 A1 JP 2013-013997 A KR 10-2013-0004432 A	02/01/2013 03/01/2013 04/01/2013 24/01/2013 10/01/2013
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US 2005-0169721 A1	04/08/2005	CA 2555128 A1 CA 2555128 C MX PA06008772 A US 7207752 B2 WO 2005-076811 A2 WO 2005-076811 A3	25/08/2005 16/03/2010 23/01/2007 24/04/2007 25/08/2005 03/11/2005
US 4294319 A	13/10/1981	None	
US 2003-0175085 A1	18/09/2003	DE 10204105 A1 DE 50303762 D1 EP 1334787 A1 EP 1334787 B1 ES 2266651 T3 US 6929434 B2	28/08/2003 27/07/2006 13/08/2003 14/06/2006 01/03/2007 16/08/2005