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(54) **MACHINE TOOL AND METHOD FOR MACHINING HIGH PRECISION CUTTING TOOLS**

(57) The machine tool comprises a workpiece carrier assembly (1) for moving a workpiece (100) along a Z axis, and a carrier tool assembly (2) for moving a tool (21) along an X axis, orthogonal to the Z axis. The machine comprises also an optical measuring device (22) comprising an optical emitter (221) and a receptor (222) to produce a through beam in a vertical direction orthogonal to the plane defined by the X and Z axis. The optical measuring device (22) is displaceable in a direction parallel with the horizontal X axis, between an inoperative position in which said optical measuring device (22) is

not facing a workpiece carrier assembly (1) and operative positions in which said optical measuring device (22) is facing said workpiece carrier assembly (1) and the through beam is cut by the workpiece (100). The machine tool further comprises displacement measuring means (23) to detect the position of the optical measuring device (22) along the X axis in the operative positions and processing means to calculate, from the position of the optical measuring means (23), the position of the at least one cutting edge (101, 102, 103, 104) and the diameter of the workpiece (100).

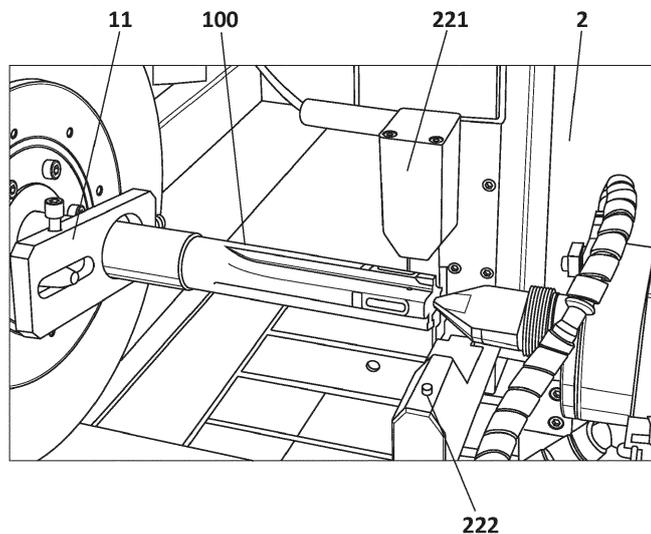


FIG. 2

EP 3 437 799 A1

Description

TECHNICAL FIELD

[0001] The present invention relates to a machine tool and method for machining workpieces and especially to grinding machines for machining high precision cutting tools, such as reamer tools.

STATE OF THE ART

[0002] It is known in the art to use horizontal grinding machines for the production of high precision cutting tools, such as PCD/PCBN (polycrystalline diamond / polycrystalline cubic boron nitride) reamer tools. For this machining operation, different grinding wheels are used with resin, ceramic, or metal-bonded on diamond abrasives.

[0003] Due to the high quality requirements in terms of dimensional accuracy and shape accuracy in the machining of these cutting tools, the existing machining methods and machines doesn't allow to machine the cutting tool in a single machining operation. Usually it is necessary to stop the grinding process and take out the machined cutting tool from the grinding machine and take it to the metrology laboratory for measuring purposes and apply machining corrections when needed. That machining corrections require returning the cutting tool to the grinding machine for another grinding operation before reaching the target dimensional value. This intermediate measurement could be needed more than one time which introduce a high time consumption on the machining process before getting a finished part. For each measurement needed there is the time wasted in dismantling the cutting tool from the grinding machine, the time to measure in the laboratory and the time to mount again the cutting tool in the grinding machine.

DESCRIPTION OF THE INVENTION

[0004] A first aspect of the invention relates to a machine tool, comprising
 a workpiece carrier assembly including a workpiece carrier holder for supporting a workpiece comprising at least one cutting edge (for example 1, 2 or 4 cutting edges), said workpiece carrier assembly being displaceable in a first direction parallel with an horizontal Z axis and said workpiece carrier holder being rotatable, at different operative speeds, around a C axis parallel with Z axis (the workpiece can rotate and move in Z direction);
 a tool carrier assembly configured for carrying at least one tool for machining the workpiece by rotating said tool around an axis parallel with said Z axis, said tool carrier assembly being displaceable in a second direction parallel with an horizontal X axis, said X axis being perpendicular to said Z axis. The tool carrier assembly is displaceable in said second direction between an inoperative position (in which said tool is not facing the workpiece

carrier assembly) and an operative position (in which said tool is facing said workpiece carrier assembly).

[0005] According to the invention the machine tool further comprises an optical measuring device comprising an optical emitter and a receptor to produce a through beam in a vertical direction orthogonal to the plane defined by the X and Z axis. The optical measuring device is displaceable in the second direction parallel with the horizontal X axis, between an operative position in which said optical measuring device is facing said workpiece carrier assembly and the through beam is cut by the workpiece and an inoperative position in which said through beam is not cut by the workpiece. In a preferred embodiment the optical measuring device comprises a laser head. In alternative embodiments the optical measuring device comprises a fiber optic or any other device capable of producing a light beam.

[0006] The machine tool further comprises displacement measuring means to detect the position of the optical measuring device (and consequently of the through beam) along the X axis in the operative positions. The machine also comprises processing means to calculate, from the position of the optical measuring device, the position of the at least one cutting edge and the diameter of the workpiece. In an embodiment the displacement measuring means comprise an optical scale or motor encoder in case of having an axis with ballscrew.

[0007] In an embodiment the optical measuring device is mounted on the tool carrier assembly such that the movement of the optical measuring device is obtained by the movement of the tool carrier assembly. In this embodiment the tool carrier assembly is rotatable around a B axis, orthogonal to the plane defined by the X and Z axis, and the optical measuring device is mounted in the tool carrier assembly at an angle in relation to the tool such that, upon rotation of the tool carrier assembly around axis B, the tool or the optical measuring device are placed facing the workpiece assembly.

[0008] In an embodiment the machine tool is an horizontal grinding machine for grinding reamer tools.

[0009] The workpiece can be a polycrystalline reamer comprising at least one cutting edge and the tool can be a grinding wheel selected from resin, ceramic or metal-bonded on diamond abrasives.

[0010] A second aspect of the invention relates to a method for machining workpieces. The method comprises subjecting a workpiece to a plurality of machining steps carried out by the machine tool of the invention as defined previously and in which, between at least two of said machining steps, a measure of a diameter of the workpiece is carried out from the movement of the optical measuring device along X axis.

[0011] The innovation of the application resides on the integration of an optical measuring device in a current conventional machine tool, such as horizontal grinding machines. The advantage of this integration allows to machine and measure these special workpieces, such as precision cutting tools, according to their dimensional

and shape requirements (without using external measuring equipment) inside the machine, getting the values of intermediate stages of the machining process (so the machine can compensate the dimensions of the workpiece) as well as the final values of the grinded workpieces. This new manufacturing method allows finishing the workpiece without taking it out and has a big positive impact on current time consumption in order to get a finished and measured workpiece in the end of the cycle.

[0012] In an embodiment the method comprises the following steps:

- a) define a first predefined diameter value greater than the final/target diameter value, for a diameter of the workpiece in correspondence with an at least first cutting edge,
- b) machine the workpiece with the tool to obtain the first predefined diameter,
- c) displace the tool carrier assembly along X direction until the through beam is cut by the workpiece, while the workpiece tool holder rotates the workpiece around C axis and determine the position of the at least one cutting edge and calculate a first machined diameter of the workpiece,
- d) compare the first machined diameter calculated with the final/target diameter value,
- e) if the first machined diameter is greater than the final/target diameter establish a second predefined diameter value lower than the first predefined diameter,
- f) machine the workpiece to obtain the second predefined diameter,
- g) repeat steps c) to e) until a machined diameter is equal to the final/target diameter.

[0013] In an embodiment the step c) comprises:

- c1) displace the tool carrier assembly along X direction until the through beam is cut by the workpiece, while the workpiece tool holder rotates the workpiece around C axis at a first rotational speed (for example greater than 200 rpm),
- c2) rotate the workpiece tool holder at a second rotational speed lower than the first rotational speed and detect the angular position of the workpiece carrier holder when the through beam is cut by the cutting edge of the workpiece, to determine the angular position of the first cutting edge,
- c3) if there is more than one cutting edge and the cutting edges are placed at a regular distance in the workpiece, calculate the position of all the cutting edges from the position determined in the previous step for the first cutting edge,
- c4) if there is more than one cutting edge and the cutting edges are placed at non regular distances in the workpiece, rotate the workpiece carrier holder at third rotational speed lower than the first rotational speed (preferably lower than the second rotational

speed) and detect the angular position of every cutting edge each time the through beam is cut by the reamer tool,

c5) rotate the workpiece carrier holder until the first cutting edge is placed in a plane parallel with the plane defined by Z and X axis,

c6) move the tool carrier assembly until the through beam is cut by the first cutting edge and measure a first position of the tool carrier assembly along X axis by means of a displacement measuring means,

c7) if there are more than one cutting edge, move the tool carrier assembly further from the first cutting edge until the through beam is cut by the second cutting edge, opposite to the first cutting edge, and measure a second position of the tool carrier assembly along X axis by means of displacement measuring means,

c8) if there is only one cutting edge, rotate the workpiece carrier holder 180° and move the tool carrier assembly further from position in step g) until the through beam is cut by the first cutting edge in the opposite position, and measure a second position of the tool carrier assembly along X axis by means of displacement measuring means,

c9) calculate a first machined diameter of the workpiece from the difference of first and second positions of the tool carrier assembly.

[0014] In an embodiment of the method step c2) comprises displacing the tool carrier assembly a further distance of 0.1 mm along the X direction, before rotating the workpiece.

[0015] In an embodiment of the method the optical measuring device is a laser head or a fiber optic device.

[0016] In an embodiment of the method the machine tool is an horizontal grinding machine for grinding reamer tools.

[0017] In an embodiment of the method the workpiece is a polycrystalline reamer comprising at least one cutting edge and the tool is a grinding wheel selected from resin, ceramic or metal-bonded on diamond abrasives.

[0018] With the machine of the invention is also possible to measure the run out of a workpiece following the steps of:

- rotate the workpiece until a first cutting edge is placed in a plane parallel to the plane defined by the axis X and Z,
- move the tool carrier assembly until the through beam is cut by the first cutting edge and measure a first position of the tool carrier assembly along X axis by means of the displacement measuring means,
- rotate the workpiece carrier assembly 180° and move the tool carrier assembly until the through beam is cut by a second cutting edge and measure a second position of the tool carrier assembly along X axis by means of the displacement measuring means,

- calculate the difference between the maximum and minimum (first and second positions) of the tool carrier assembly of previous steps.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] To complete the description and in order to provide for a better understanding of the invention, a set of drawings is provided. Said drawings form an integral part of the description and illustrate embodiments of the invention, which should not be interpreted as restricting the scope of the invention, but just as examples of how the invention can be carried out. The drawings comprise the following figures:

Figure 1 is a schematic perspective view of a machine tool in accordance with one possible embodiment of the invention.

Figure 2 is a schematic perspective illustrating the laser head in an operative position in relation to the workpiece.

Figure 3 shows a reamer tool with four cutting edges. Figures 4A, 4B, 4C, 4D, 4E and 4F schematically illustrate different steps of the invention.

DESCRIPTION OF WAYS OF CARRYING OUT THE INVENTION

[0020] Figure 1 schematically illustrates an embodiment of a machine tool according to the invention. The machine tool illustrated in figure 1 is a grinding machine comprising a workpiece carrier assembly 1 including a workpiece carrier holder 11 for supporting a reamer tool 100 comprising four cutting edges 101, 102, 103, 104. The workpiece carrier assembly 1 is displaceable in a first direction parallel with an horizontal Z axis and the workpiece carrier holder 11 is rotatable around a C axis parallel with Z axis at different operative speeds.

[0021] The machine also comprises a tool carrier assembly 2 displaceable in a second direction parallel with an horizontal X axis, perpendicular to said Z axis, between several operative positions in which said tool carrier assembly 2 is facing said workpiece carrier assembly 1, and an inoperative position in which said tool carrier assembly 2 is not facing the workpiece carrier assembly 1.

[0022] The tool carrier assembly 2 supports a grinding wheel 21 for machining the reamer tool 100 by rotating said wheel 21 around an axis parallel with said Z axis. The tool carrier assembly 2 also comprises a laser head 22 arranged to produce a laser beam in a vertical direction orthogonal to the plane defined by the X and Z axis. The laser head is mounted on a C shaped configuration, with an emitter 221 in an upper position and a receptor 222 in a bottom position such that, when the laser head 22 moves in X direction, the reamer tool 100 can be placed at least partially between the emitter 221 and the receptor 222 and cut the laser beam, as can be seen in

figure 2.

[0023] The tool carrier assembly 2 is rotatable around a B axis, orthogonal to the plane defined by the X and Z axis. The laser head 22 is mounted in the tool carrier assembly 2 at an angle of 90° in relation to the grinding wheel 21 such that upon rotation of the tool carrier assembly 2 around axis B the grinding wheel 21 or the laser head 22 can be placed alternatively facing the workpiece assembly 1. In figure 2 the laser head 22 is represented in an operative position, facing the workpiece 100 whilst the grinding wheel 21 is rotated 90° in an inoperative rear position not facing the workpiece 100.

[0024] The machine further comprises an optical scale 23 to detect the position of the tool carrier assembly 2 and consequently the position of the laser head along the X axis in the operative positions.

[0025] Figure 2 shows in detail an embodiment of a reamer tool. The reamer tool illustrated comprises four polycrystalline cutting blades placed at the edges of opposing diameters, i.e. the cutting edges are displaced axially 90° from each other.

[0026] According to an embodiment of the invention the machining operation of a reamer tool with the grinding machine described previously will be as follows:

- define a first predefined diameter value greater than the final/target diameter value, for a diameter of the reamer tool in correspondence with a first pair of opposing cutting edges,
- machine the reamer tool 100 with the grinding wheel 21 to obtain the first predefined diameter,
- displace the tool carrier assembly 2 along X direction (at a speed between 10 and 500 mm/min) until the laser beam is cut by the reamer tool, while the workpiece tool holder 11 rotates the reamer around C axis at a first speed between 100 and 1000 rpm (preferably greater than 200 rpm), to detect an approximate position of the first cutting edges 101, 102, 103 or 104, as represented in figure 4A,
- displace the tool carrier assembly 2 a further distance of 0.1 mm along the X direction and rotate the workpiece tool holder 11 at a second speed lower than the first speed (preferably lower than 200 rpm) rpm and detect the angular position of the workpiece carrier holder 11 when the laser beam is cut by the cutting edge 101 of the reamer tool 100, to determine the angular position of the first cutting edge 101,
 - if the cutting edges are placed at a regular distance in the reamer tool 100, calculate the position of all the cutting edges 102, 103 and 104 from the position determined in the previous step for the first cutting edge 101,
 - if the cutting edges are placed at non regular distances in the reamer tool 100, rotate the workpiece carrier holder at a third speed lower than the first speed (preferably lower than the second speed) and detect the angular position of every cutting blade 102, 103 and 104 each time the laser beam is cut

by the reamer tool 100, as represented in figure 4B,
f) rotate the workpiece carrier holder 11 until the first cutting edge 101 is placed in a plane parallel to the plane defined by Z and X axis,

g) move the tool carrier assembly 2 until the laser beam cuts the first cutting edge 101 and measure a first position of the tool carrier assembly 2 along X axis by means of an optical scale 23, as illustrated in figure 4C,

h) move the tool carrier assembly 2 further from the first cutting edge 101 until the laser beam cuts the second cutting edge 102, opposite to the first cutting edge 101, and measure a second position of the tool carrier assembly 2 along X axis by means of an optical scale 23, as illustrated in figure 4D,

i) calculate a first machined diameter of the workpiece 100 from the difference of first and second positions of the tool carrier assembly 2,

j) compare the first machined diameter calculated with the final/target diameter value,

k) if the first machined diameter is greater than the final/target diameter establish a second predefined diameter value,

l) grind the workpiece to obtain the second predefined diameter,

m) repeat steps c) to l) until the first machined diameter is equal to the final/target diameter.

[0027] Figures 4E and 4F illustrate an embodiment in which the reamer tool 100 has only one cutting edge 101. In this embodiment after step g) and before step h), rotate the workpiece carrier holder 11 an angle of 180°. Thus in step h) the second cutting edge is the first cutting edge.

[0028] In this text, the term "comprises" and its derivations (such as "comprising", etc.) should not be understood in an excluding sense, that is, these terms should not be interpreted as excluding the possibility that what is described and defined may include further elements, steps, etc.

[0029] On the other hand, the invention is obviously not limited to the specific embodiment(s) described herein, but also encompasses any variations that may be considered by any person skilled in the art (for example, as regards the choice of materials, dimensions, components, configuration, etc.), within the general scope of the invention as defined in the claims.

Claims

1. Machine tool, comprising

a workpiece carrier assembly (1) including a workpiece carrier holder (11) for supporting a workpiece (100) comprising at least one cutting edge (101, 102, 103, 104), said workpiece carrier assembly (1) being displaceable in a first direction parallel with an horizontal Z axis and

said workpiece carrier holder (11) being rotatable, at different operative speeds, around a C axis parallel with Z axis;

a tool carrier assembly (2) configured for carrying at least one tool (21) for machining the workpiece (100) by rotating said tool (21) around an axis parallel with said Z axis, said tool carrier assembly (2) being displaceable in a second direction parallel with an horizontal X axis, said X axis being perpendicular to said Z axis; said tool carrier assembly (2) being displaceable in said second direction between an operative position and an inoperative position;

characterized in that the machine tool further comprises an optical measuring device (22) comprising an optical emitter (221) and a receptor (222) to produce a through beam in a vertical direction orthogonal to the plane defined by the X and Z axis, the optical measuring device (22) being displaceable in the second direction parallel with the horizontal X axis, between an operative position in which said optical measuring device (22) is facing said workpiece carrier assembly (1) and the through beam is cut by the workpiece (100) and an inoperative position in which the through beam is not cut by the workpiece (100), the machine tool further comprising displacement measuring means to detect the position of the optical measuring device (22) along the X axis in the operative position and processing means to calculate, from the position of the optical measuring means, the position of the at least one cutting edge (101, 102, 103, 104) and the diameter of the workpiece (100).

2. Machine tool according to claim 1, wherein the optical measuring device (22) is mounted on the tool carrier assembly (2), the tool carrier assembly (2) being rotatable around a B axis, orthogonal to the plane defined by the X and Z axis, the optical measuring device (22) being mounted in the tool carrier assembly (2) at an angle in relation to the tool (21) such that upon rotation of the tool carrier assembly (2) around axis B, the tool (21) or the optical measuring device (22) are placed facing the workpiece carrier assembly (1).

3. Machine tool according to claim 2, wherein the machine tool is an horizontal grinding machine for grinding reamer tools.

4. Machine tool according to any of the preceding claims, wherein the workpiece (100) is a polycrystalline reamer comprising at least one cutting edge (101, 102, 103, 104) and the tool (21) is a grinding wheel selected from resin, ceramic or metal-bonded on diamond abrasives.

5. Machine tool according to any of preceding claims wherein the optical measuring device (22) comprises a laser head or a fiber optic device.
6. Method for machining workpieces, comprising subjecting a workpiece to a plurality of machining steps carried out by a machine tool as per any of claims 1 to 5 in which, between at least two of said machining steps, a measure of a diameter of the workpiece is carried out from the movement of the optical measuring device (23) along X axis.
7. Method as per claim 6 comprising the steps of:
- a) define a first predefined diameter value greater than the final/target diameter value, for a diameter of the workpiece (100) in correspondence with an at least first cutting edge (101),
 - b) machine the workpiece (100) with the tool (21) to obtain the first predefined diameter,
 - c) displace the tool carrier assembly (2) along X direction until the through beam is cut by the workpiece (100), while the workpiece tool holder (11) rotates the workpiece (100) around C axis at a first rotational speed and determine the position of the at least one cutting edge (101) and calculate a first machined diameter of the workpiece (100),
 - d) compare the first machined diameter calculated with the final/target diameter value,
 - e) if the first machined diameter is greater than the final/target diameter establish a second predefined diameter value lower than the first predefined diameter,
 - g) machine the workpiece (100) to obtain the second predefined diameter,
 - h) repeat steps c) to e) until a machined diameter is equal to the final/target diameter.
8. Method as per claim 7 wherein step c) comprises the steps of :
- c1) displace the tool carrier assembly (2) along X direction until the through beam is cut by the workpiece (100), while the workpiece tool holder (11) rotates the workpiece (100) around C axis at a first rotational speed lower than the first rotational speed,
 - c2) rotate the workpiece tool holder (11) at a second rotational speed lower than the first rotational speed and detect the angular position of the workpiece carrier holder (11) when the through beam is cut by the cutting edge (101) of the workpiece (100), to determine the angular position of the first cutting edge (101),
 - c3) if there is more than one cutting edge and the cutting edges (101, 102, 103, 104) are placed at a regular distance in the workpiece (100), calculate the position of all the cutting edges (102, 103 and 104) from the position determined in the previous step for the first cutting edge 101,
 - c4) if there is more than one cutting edge and the cutting edges (101, 102, 103, 104) are placed at non regular distances in the workpiece (100), rotate the workpiece carrier holder (2) at a third rotational speed lower than the first rotational speed and detect the angular position of every cutting edge (102, 103 and 104) each time the through beam is cut by the reamer tool (100),
 - c5) rotate the workpiece carrier holder (11) until the first cutting edge (101) is placed in a plane parallel with the plane defined by Z and X axis,
 - c6) move the tool carrier assembly (2) until the through beam is cut by the first cutting edge (101) and measure a first position of the tool carrier assembly (2) along X axis by means of a displacement measuring means (23),
 - c7) if there are more than one cutting edge, move the tool carrier assembly (2) further from the first cutting edge (101) until the through beam is cut by the second cutting edge (102), opposite to the first cutting edge (101), and measure a second position of the tool carrier assembly (2) along X axis by means of displacement measuring means (23),
 - c8) if there is only one cutting edge, rotate the workpiece carrier holder (11) 180° and move the tool carrier assembly (2) further from position in step g) until the through beam is cut by the first cutting edge (101) in the opposite position, and measure a second position of the tool carrier assembly (2) along X axis by means of displacement measuring means (23),
 - c9) calculate a first machined diameter of the workpiece (100) from the difference of first and second positions of the tool carrier assembly (2).
9. Method as per any of claims 6, 7 or 8, wherein the first rotational speed is greater than 200 rpm.
10. Method as per any of claims 6, 7, 8 or 9, wherein the optical measuring device (23) is a laser head or a fiber optic device.
11. Method as per any of claims 6 to 10 wherein the machine tool is an horizontal grinding machine for grinding reamer tools.
12. Method as per any of claims 6 to 11 wherein the workpiece (100) is a polycrystalline reamer comprising at least one cutting edge (101, 102, 103, 104) and the tool (21) is a grinding wheel selected from resin, ceramic or metal-bonded on diamond abrasives.

13. Use of the machine as per any of claims 1 to 5.

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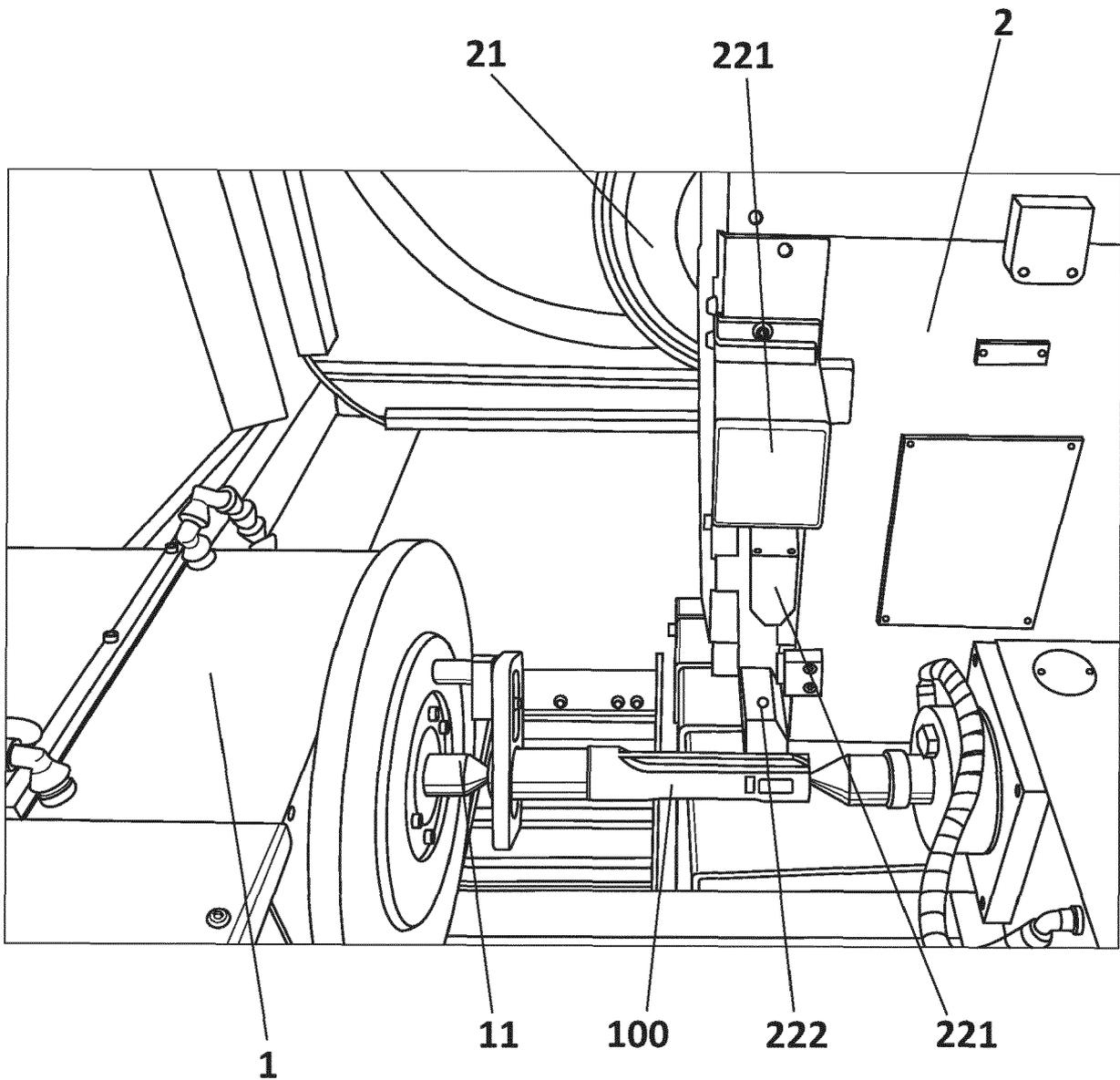


FIG. 1

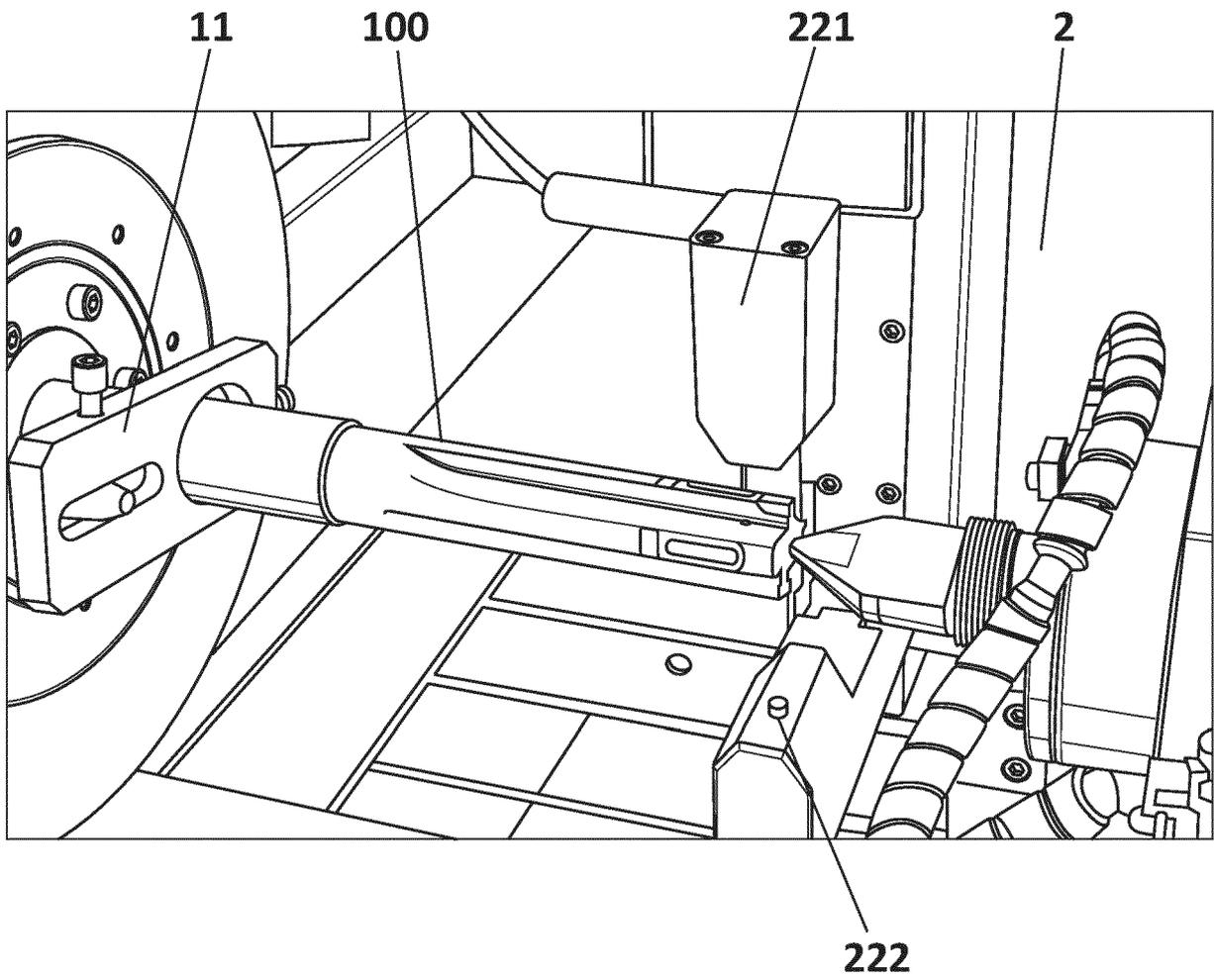


FIG. 2

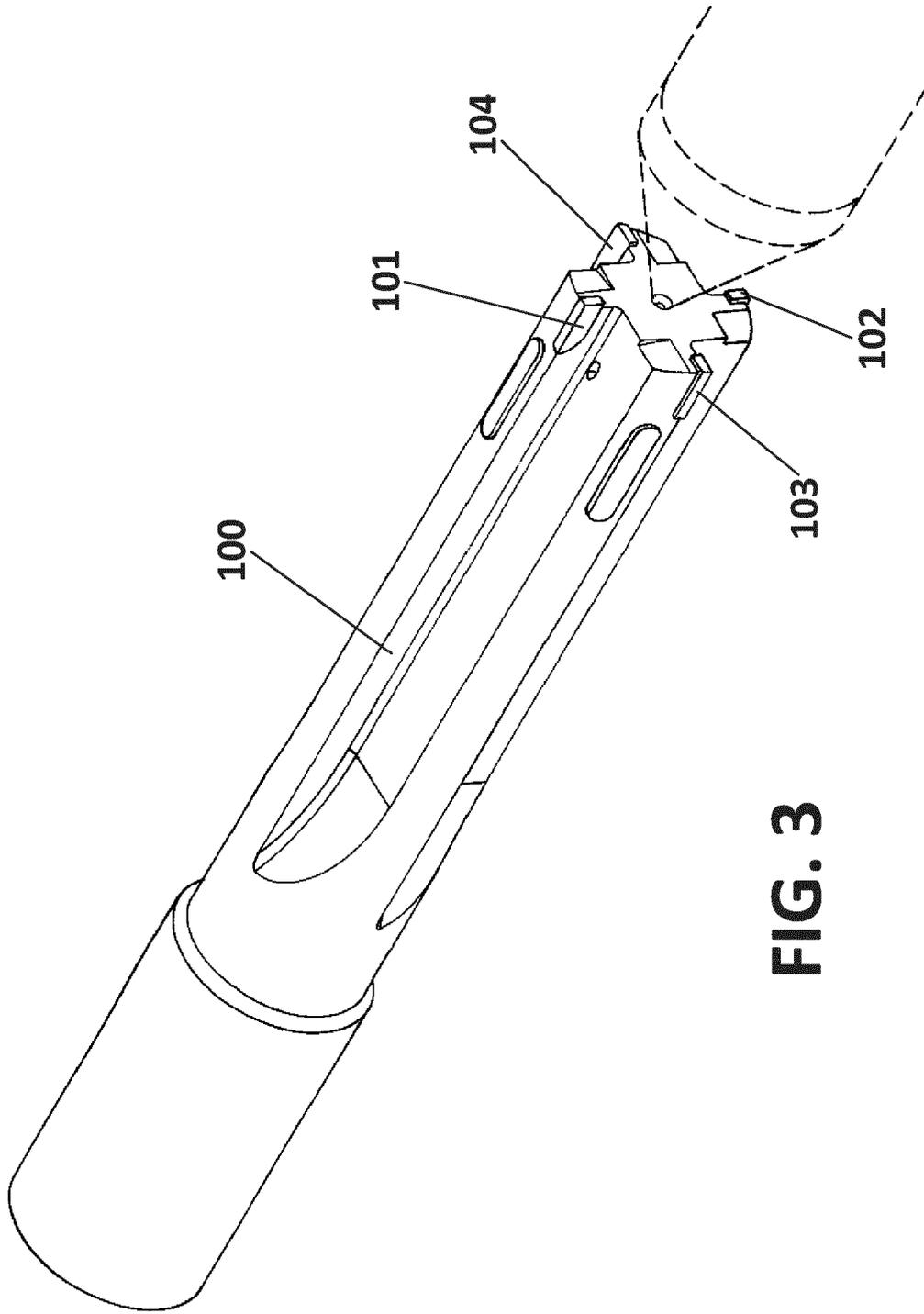


FIG. 3

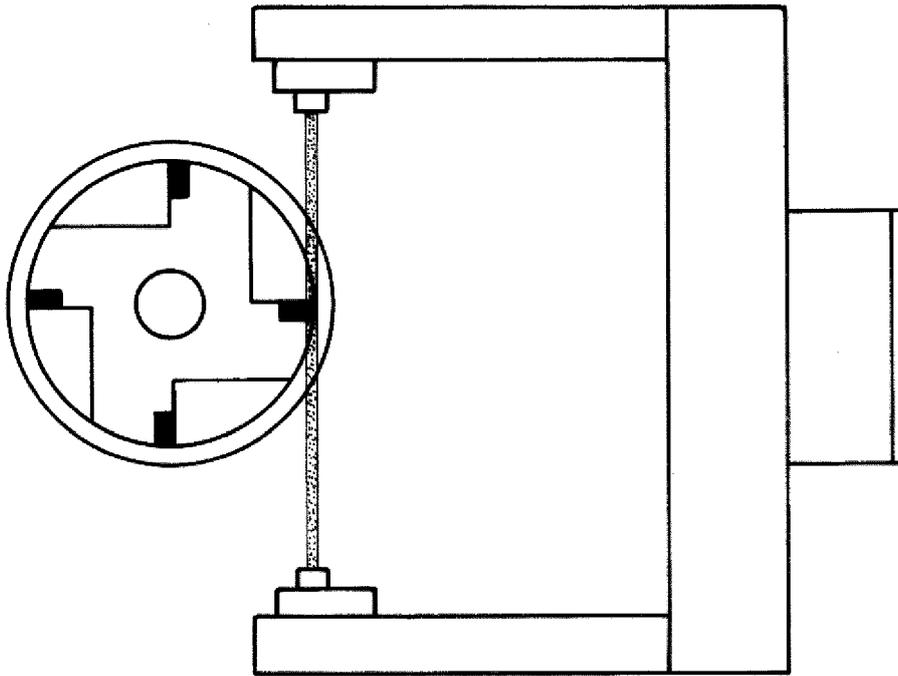


FIG. 4A

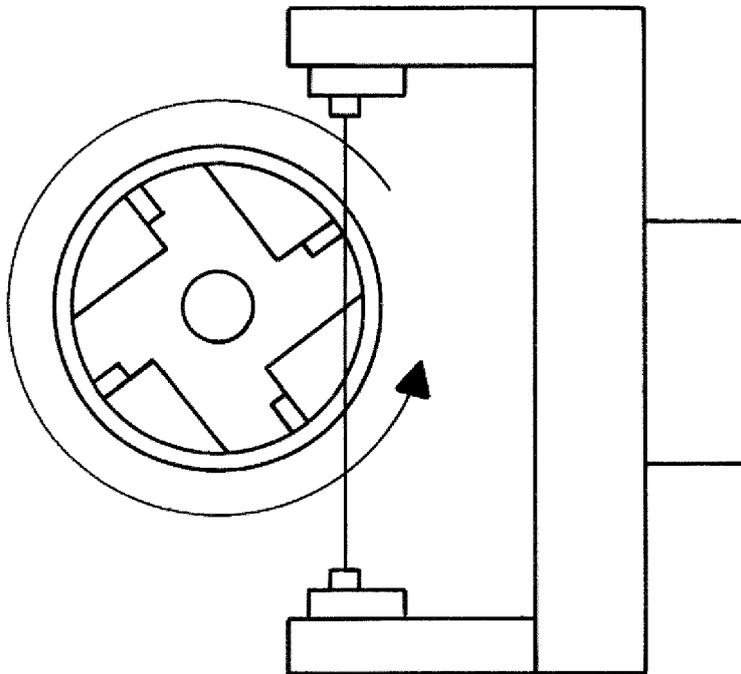


FIG. 4B

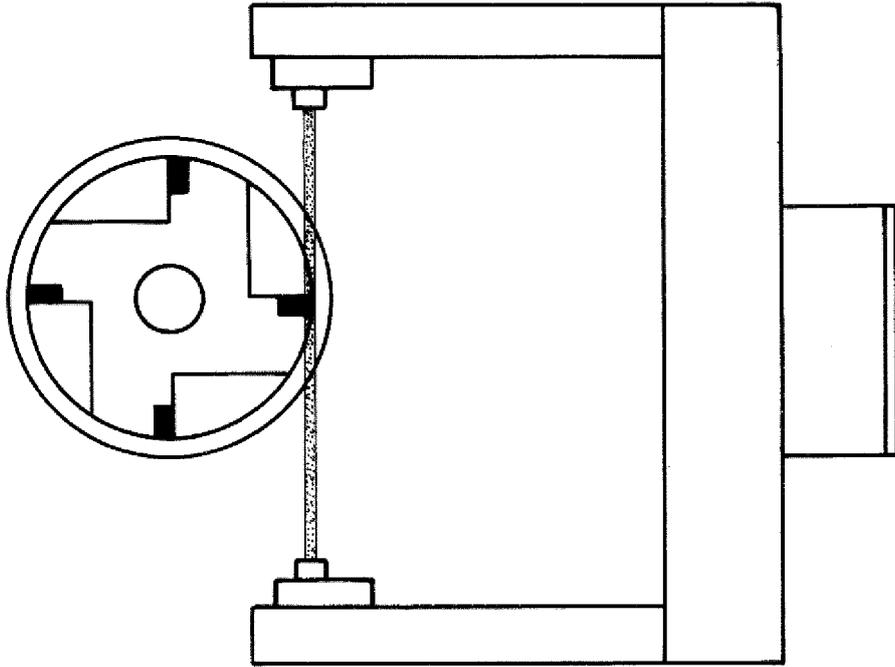


FIG. 4C

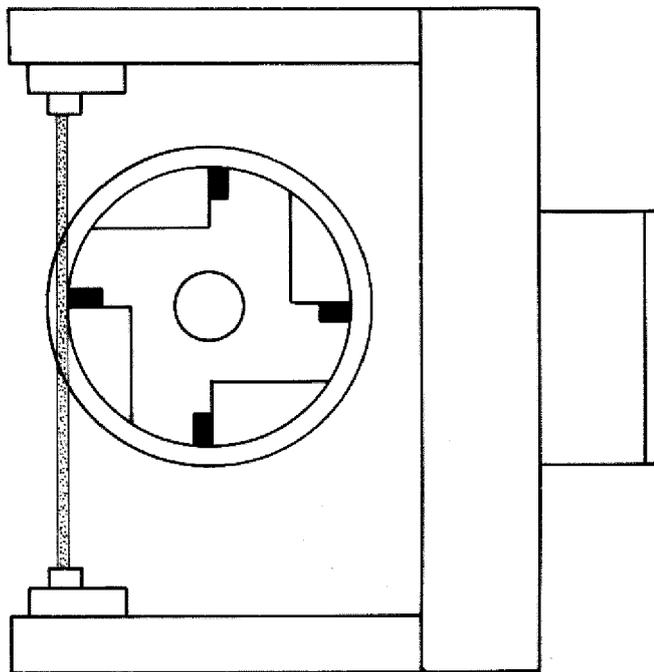


FIG. 4D

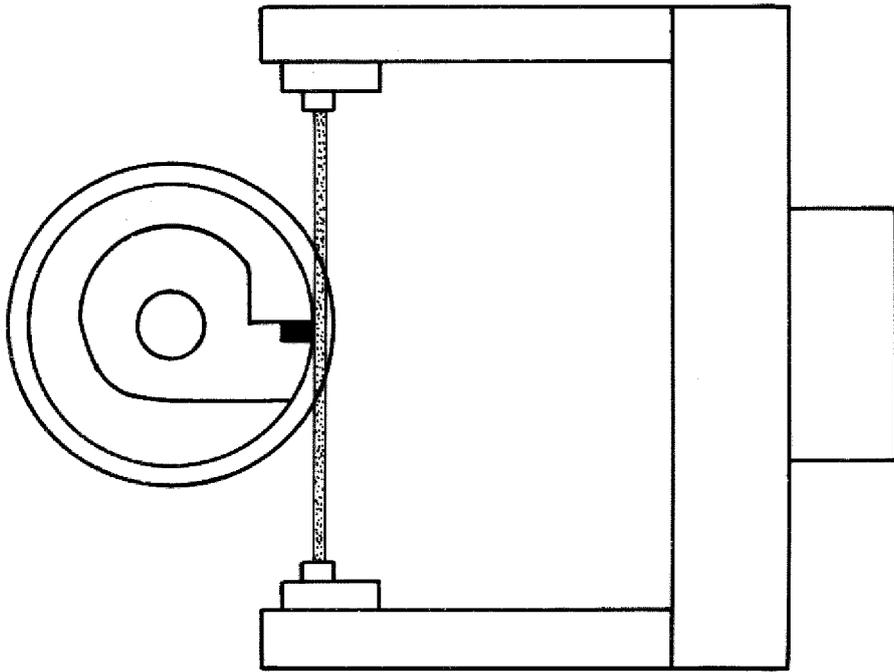


FIG. 4E

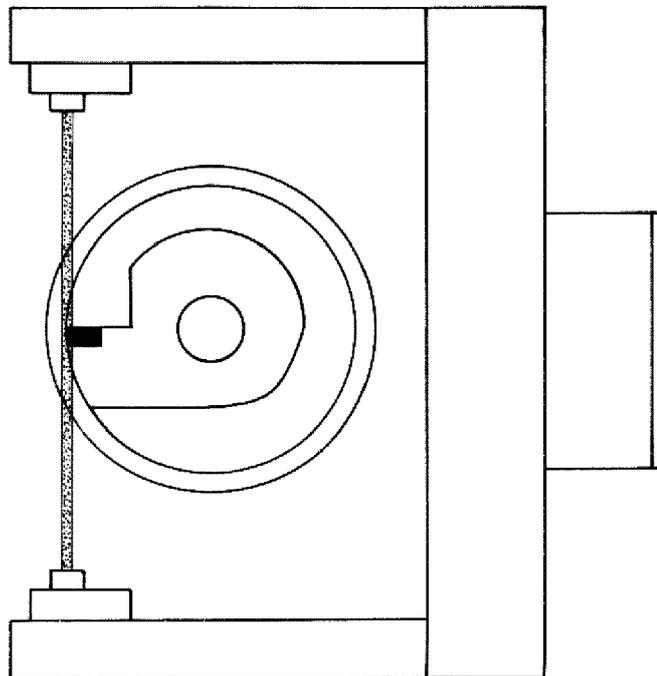


FIG. 4F



EUROPEAN SEARCH REPORT

Application Number
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| DOCUMENTS CONSIDERED TO BE RELEVANT | | | |
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ANNEX TO THE EUROPEAN SEARCH REPORT
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5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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