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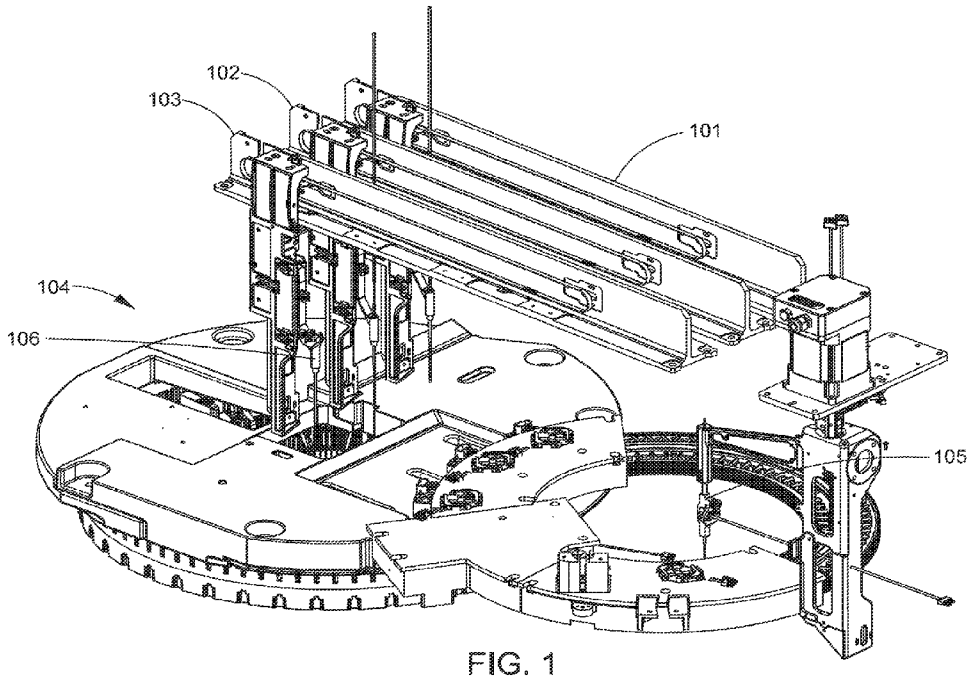

FIG. 1

(57) Abstract: One embodiment provides a method of automatically aligning an indexing machine with a robotic end effector including: inserting, using a robotic arm, a hunting tool into an aperture, the hunting tool comprising a pressure sensitive tip; detecting, using a plurality of sensing beams, a first location of the hunting tool within the aperture; rotating, using the robotic arm, the hunting tool 180 degrees; detecting, using the plurality of sensing beams, a second location of the hunting tool within the aperture; calculating a runout magnitude and a runout direction based on the first location, the second location, and the robotic arm; inserting, using the robotic arm, the hunting tool into a target; determining, using the pressure sensitive tip, a location of the hunting tool with respect to the target; and thereafter, adjusting the location of the hunting tool with respect to the aperture and target based on said determined location and said calculated runout magnitude and direction. Other aspects are described and claimed herein.

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[Continued on next page]

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AUTOMATED ALIGNMENT OF A TESTING SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application Serial No. 62/365,225 filed July 21, 2016, which is incorporated herein by reference in its entirety.

TECHNOLOGY FIELD

[0002] The present invention relates generally to an automated process for alignment of an indexing machine with regard to a robotic effector.

BACKGROUND

[0003] As the abilities of large scale automation increases, more and more processes are being transitioned to an operator-less environment. Lab testing systems generally require clearly defined reproducible results. This is because, in order to have a proper analysis, a huge number of tests must be performed, many of the tests being performed multiple times. Due to this repetitive nature, the testing process is perfectly suited to the automation process. However, because of the precise nature of the testing process, it can be difficult to accurately and consistently automate the majority of the steps involved. For example, using pipetting probes to sample tubes on a puck-based track is a very repetitive task. However, because of the variables involved and the precision required, it has proven difficult to fully automate this process.

[0004] Thus, currently, in order to perform the various steps of the testing process, some manual effort is required (e.g., alignment). This typically involves an operator visually inspecting the system and using various tools (e.g., tooling pins and plates) to adjust the pipette and sample tube. This is a slow and costly process when compared with a typical automation system. Thus, there is a need for a quicker, more efficient, and more robust method of performing automation with regard to pipette sampling.

SUMMARY

[0005] Accordingly, an embodiment provides an automated probe switch alignment system comprising: a robotic arm; a probe, having a sampling tip, attached to the robotic arm; a hunting tool attached to the robotic arm, the hunting tool having a pressure sensitive tip; wherein the sampling tip of the probe is aligned with a predetermined target, based on the alignment of the hunting tool; and wherein the hunting tool alignment is determined based on force detected at the pressure sensitive tip.

[0006] A further embodiment provides a probe runout sensor device comprising: a body having a top and bottom; the body comprising an aperture from the top to the bottom; the top of the body comprising: one or more sensing beams running across the aperture; wherein the one or more sensing beams detect the location of an object passing through the aperture.

[0007] Another embodiment provides a method of automatically aligning an indexing machine with a robotic end effector comprising: inserting, using a robotic arm, a hunting tool into an aperture, the hunting tool comprising a pressure sensitive tip; detecting, using a plurality of sensing beams, a first location of the hunting tool within the aperture; rotating, using the robotic arm, the hunting tool 180 degrees; detecting, using the plurality of sensing beams, a second location of the hunting tool within the aperture; calculating a runout magnitude and a runout direction based on the first location, the second location, and the robotic arm; inserting, using the robotic arm, the hunting tool into a target; determining, using the pressure sensitive tip, a location of the hunting tool with respect to the target; and thereafter, adjusting the location of the hunting tool with respect to the aperture and target based on said determined location and said calculated runout magnitude and direction.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] The foregoing and other aspects of the present invention are best understood from the following detailed description when read in connection with the accompanying drawings.

For the purpose of illustrating the invention, there is shown in the drawings embodiments that are presently preferred, it being understood, however, that the invention is not limited to the specific instrumentalities disclosed. Included in the drawings are the following Figures:

[0009] FIG. 1 is an illustrative view of an example system for automated alignment for an indexing machine with a robotic end effector.

[0010] FIG. 2 is an illustrative view of an example elongated hunting tool.

[0011] FIG. 3 is an illustrative view of an example elongated hunting tool with a cuvette ring slotted target.

[0012] FIG. 4 is an illustrative view of an example shortened hunting tool.

[0013] FIG. 5 is an illustrative view of an example shortened hunting tool with a cuvette ring slotted target.

[0014] FIG. 6 is an illustrative view of an example probe runout sensor.

[0015] FIG. 7 is an illustrative view of an example probe runout sensor with beams blocked by a probe tip.

[0016] FIG. 8 is a graphical view of an example sensor output along 360° circle boundary.

[0017] FIG. 9 is a graphical view of an example sensor output along 360° square boundary.

[0018] FIG. 10 is an illustrative view of an example gauge tool over a probe runout sensor.

[0019] FIG.11 is a graphical representation of runout magnitude and direction calculation.

DETAILED DESCRIPTION

[0020] Embodiments herein are directed to an automation system, which can be used to align a diagnostic instrument of robotic pipetting probes to sample tubes on puck-based tracks, cuvettes, or reagent packs in indexing rings. Advantageously, an embodiment's automation system provides robust and efficient mechanisms to ensure that the process of robotic pipetting is consistent and accurate.

[0021] As discussed herein, the ability to ensure proper alignment and operation of automated devices during a repetitive test is vital to ensuring the results are reproducible. However, current automation solutions either lack precision or are prohibitively expensive and, thus, not suitable replacements for a human operator. Because the experiments require extreme accuracy, precise tools and complex procedures are required that are manually performed by one or more trained field service technicians.

[0022] Accordingly, an embodiment provides an improvement via an ultra-accurate alignment system to ensure proper interaction between a probe and a target. The automated alignment system may utilize a probe switch and/or a probe runout sensor. Using one or more of these (i.e., the probe switch and runout sensor), an embodiment can simplify the process, while still achieving a highly accurate and repeatable alignment.

[0023] A further embodiment may utilize a long-reach high-resolution probe switch. The high-resolution probe switch may have a mechanical plunger at the tip for detecting surfaces (e.g., a surface in proximity to an application-specific target). In another embodiment, a mechanical plunger may utilize a spring-loaded low-force plunger to detect the surface of a target area. Additionally, or alternatively, an embodiment may comprise a rigid bearing system. This highly rigid bearing system may be able to more accurately detect an edge of a target. In another embodiment, a mechanical plunger, as discussed herein, may work in conjunction with a probe runout sensor.

[0024] The probe runout sensor, as further described herein, may precisely measure the magnitude (e.g., in millimeters, centimeters, inches, etc.) and direction (e.g., radians, degrees, etc.) of the probe. This may allow an embodiment to determine a straightness factor, or an amount of straightness error. Based on the determined straightness of the probe, a further embodiment may take an action to correct the straightness (e.g., adjust the magnitude or direction of the probe). By correcting the straightness, an embodiment is in a better position,

such that the true probe axis and tip are in correct alignment when moved to the center of a target, or to an individual indexing position within a set of rings.

[0025] Referring now to FIG. 1, an embodiment may have one or more robotic arms with probes 101, 102, 103 (e.g., linear, rotary, etc.). The robotic arm probes allow an embodiment to interface with various other testing equipment 104 (e.g., tracks, consumables, indexing ring, etc.). Another embodiment may also comprise a long-reach, high-resolution probe switch 105 with a spring-loaded, low-force plunger 105.

[0026] In one embodiment, an elongated (i.e., long) hunting tool 106 may be used. A non-limiting example of an elongated hunting tool 200 is shown in FIG. 2. The long hunting tool 200 may further include a reagent probe arm 201, as shown in FIG. 2. Additional non-limiting components of the long hunting tool 200, as shown in FIG. 2, may be: a sensor bracket 202, a wide sensor (e.g., Optek) 203, an e-clip 204, a bracket compression spring 205, a locking screw 206, a rod 207, a tube disk 208, a rod compression spring 209, a collar 210, a flange bushing 211, a hypo tube 213, a vertical tube 212, and a straight bushing 214. Optek is a registered trademark of Optek-Danualt GmbH Corporation in the United States of America and other countries. It should be appreciated by those skilled in the art, that one or more of each of the aforementioned components may be included in an embodiment (e.g., two e-clips).

[0027] As shown in FIG. 2, the maximum rotational offset (R.O.) allowed may be ± 0.33mm from the bottom of the collar 210 to the tip of the probe 215. It should be understood by those skilled in the art that the R.O., as shown in FIG. 2, is only a single, non-limiting example of an R.O. limit, and that in additional embodiments, the limit may be larger or smaller.

[0028] The long hunting tool 200, as shown in FIG. 2, may require varying levels of force during various activities. Illustrative non-restricting examples may be, for example, 2.7

ounces of initial force, 3 ounces of sensor force, and 3.7 ounces of over travel force. Thus, in one embodiment, the varied levels of force may result in a total travel of around 6 mm. In one non-limiting example, the long hunting tool 200 may be approximately 2mm longer than the reagent probe to ensure proper alignment. Additionally, as shown in FIG. 2, the hunting tool 200 may be removed by vertically withdrawing from the reagent probe arm 201 upward.

[0029] In a further embodiment, alignments may be performed with round targets 301 on an indexing reagent pack tray. Additionally, or alternatively, the alignments may be performed for slotted targets. Referring now to FIG. 3, an embodiment, such as the elongated hunting tool 200, may perform the alignments via a slotted target system 300 (e.g., on inner cuvette rings 303 and outer cuvette rings 302).

[0030] In another embodiment, a shortened (i.e., short) hunting tool 400 may be used. A non-limiting example of a shortened hunting tool 400 is shown in FIG. 4. The short hunting tool 400 may further include, as shown in FIG. 4, a sample probe 401. Additional non-limiting components of the short hunting tool 400, as shown in FIG. 4, may be: a lock bracket 402, a wide sensor (e.g., an Optek wide sensor) 403, a rod 404, a tube disk 405, a rod compression spring 406, an e-clip 407, a collar 408, a bracket 409, a flange bushing 411, a hypo tube 410, and a straight bushing 412. As with the long hunting tool, it should be appreciated by those skilled in the art, that one or more of each of the aforementioned components may be included in an embodiment (e.g., two e-clips) in the short hunting tool 400.

[0031] As shown in FIG. 4, the maximum R.O. allowed may be ± 0.23mm from the bottom of the collar to the tip of the probe. It should be understood by those skilled in the art that the R.O., as shown in FIG. 2, is only a single non-limiting example of a R.O. limit, and that in additional embodiments, the limit may be larger or smaller.

[0032] The short hunting tool, as shown in FIG. 4, may require varying levels of force during various activities. Illustrative non-restricting examples may be, for example, 2.7 ounces of initial force, 3 ounces of sensor force, and 3.7 ounces of over travel force. Thus, in one embodiment, the varied levels of force may result in a total travel of around 6 mm. In one non-limiting example, the short hunting tool may be approximately 2mm longer than the sample probe to ensure proper alignment. Additionally, as shown in FIG. 4, the short hunting tool may be removed by vertically detaching it from the reagent probe arm downward.

[0033] Using the short hunting tool, an embodiment may mount the short hunting tool to a sample probe arm and perform alignments. In a further embodiment, alignments may be performed with sample track pucks. Additionally, or alternatively, the alignments may be performed for a tip tray indexer that presents consumable tips. Referring now to FIG. 5, an embodiment may perform the alignments via a slotted target system 501 (e.g., on inner cuvette rings and outer cuvette rings).

[0034] In one embodiment, as discussed herein, a probe runout sensor 604 may be utilized to assist in the alignment process. For example, a probe runout sensor 604 may have one or more sensing beams running across an opening (i.e., an aperture) 605, such as that shown in FIG. 6. The probe runout sensor can have a body having a top and bottom. In an embodiment, the one or more sensing beams can include a horizontal beam 603 and a vertical beam 602. The two beam system shown in FIG. 6 is only one possible embodiment, various other embodiments (e.g., one beam, three beam, four beam, five beam, etc.) may also be used. The beams may be any type of known beam detection, for example, laser, infra-red, optical, photoelectric, etc. As shown in FIG. 6, an embodiment may have a probe runout sensor with dual thru-beams arranged orthogonally to each other. This allows for an embodiment to detect the offset of the pressure sensitive probe tip 601 with extreme accuracy. Because an embodiment knows where the bottom collar of the probe arm is (see

FIG. 2 and 4), it can determine the insertion point relative to the probe holder via robotic arm position.

[0035] Thus, in a further embodiment, the sensor may detect the position of the pressure sensitive probe tip 601 as it passes though the opening 605 of the probe runout sensor 604. As shown in FIG. 7, once the pressure sensitive tip 601 is low enough, it may intersect the one or more beams 602, 603, thus indicating the pressure sensitive probe tip 601 position relative to the arm positon. Thus, if the probe tip moves horizontally in a single direction, it may block or unblock one of the beams 602. In one embodiment, the pressure sensitive probe 601 may be restricted from proceeding further through the probe runout sensor 604 if it fails to block all of the beam sensors.

[0036] In one embodiment, it may be difficult if not impossible to remove or correct all the alignment issues because both long and short hunting tools are mechanical systems, which have typical limitations, such as: bearing clearances, machining and straightness errors, and mounting errors. Thus, the addition of a runout sensor allows for an embodiment to combine multiple systems together to help ensure the most accurate and aligned probe possible. Correcting for the runout allows an embodiment to increase the ability of an embodiment to find the center of a target. In order to correct the runout, the magnitude and direction (typically referred to as run/mag/dir) needs to be measured.

[0037] In one embodiment, the output of the probe runout sensor may be a pair of distance-to-beam measurements (e.g., D1, D2) from the probe center along the sensor's X and Y coordinate system (e.g., defined at 45° to both beams). In a further embodiment, the points at the boundary of the sensing zone may be plotted at regular intervals in the XY space (e.g., given XY scale of 1 = 100% of the boundary radial distance). An embodiment may then map the distance-to-beam measurements (e.g., D1, D2) into DΘ space (e.g., beam distance vs. Θ sweep) for points along the boundary. This mapping may be done based on various

increments, (e.g., 1°, 5°, etc.) from 0° to 360°. Referring now to FIG. 8, in an embodiment, the circle boundary may take on the typical shape of sinusoidal curves with a 90° phase shift, such as that shown in FIG. 8. Alternatively, a square boundary, such as that in FIG. 9, adds a unique twist by the composition of sloped lines and harmonic curves with 45° nodes. This may be important, as it would generally be assumed that straight lines would exist between the direction-reversal peaks. However, straight lines may only result if the points along the boundary are equally spaced.

[0038] Because one of the keys to ensuring proper alignment is knowing the runout relative to a "perfectly straight tool" mounted in the tool holder, an embodiment may employ the use of a very straight gauge tool with equivalent mounting features. In an embodiment, a gauge tool may set the sensor "zero" point, which may then be passed anywhere through the sensing zone because it is determined via the mounting of the sensor relative to the robotic arm, such as that shown in FIG. 9, thus the zero point does not have to be at the beam intersection. Once calibrated, an embodiment may replace the gauge tool with the hunting tool (e.g., long or short) and repeat the process to determine the relative change in the XY position which will calculate the magnitude and direction of the runout (i.e., the run/mag/dir).

[0039] In another embodiment, the initial calibration is not required. Generally, the first calibration, using a gauge tool, will almost always have some small, but meaningful error, when determining run/mag/dir. Thus, an embodiment may be able to improve the process by marking with visual scribe lines 1001, 1002, 1003 at 180° from the hunt tools (e.g., short and long hunting tool), and the tool holder(s) mounted to the robotic arm, such as that shown in FIG. 10.

[0040] Firstly, an embodiment may align the tool and tool holder lines and pass the probe through the runout sensor. Next, an embodiment may rotate the tool 180°, or until the tool is once more aligned to the tool holder lines, and again pass through the runout sensor. By

preforming the above process, an embodiment is able to determine the relative change in XY position between the two points (e.g., where the probe intersects the runout sensor at both 0° and 180°), creating a line. This line may then be considered by an embodiment as a means of representing the diameter of the runout circle. Based on the newly determined runout circle diameter, a new "true zero" point may be projected as the midpoint of the determined diameter, with respect to the tool holder neutral axis by a theoretically straight tool. Thus, the run/mag/dir may be calculated from the midpoint to the tool tip after the second pass through the sensor. A non-limiting detailed example of the runout magnitude and direction process using the probe runout sensor and the probe switch is illustrated in FIG. 11.

[0041] Although the present invention has been described with reference to exemplary embodiments, it is not limited thereto. Those skilled in the art will appreciate that numerous changes and modifications may be made to the preferred embodiments of the invention, and that such changes and modifications may be made without departing from the true spirit of the invention. It is therefore intended that the appended claims be construed to cover all such equivalent variations as fall within the true spirit and scope of the invention.

CLAIMS

We claim:

1. An automated probe switch alignment system comprising:

a robotic arm;

a probe, having a sampling tip, attached to the robotic arm; and

a hunting tool attached to the robotic arm, the hunting tool having a pressure sensitive tip,

wherein the sampling tip of the probe is aligned with a predetermined target, based on the alignment of the hunting tool, and

wherein the hunting tool alignment is determined based on force detected at the pressure sensitive tip.

2. The system of claim 1, further comprising a reagent pipette,

wherein the hunting tool is an elongated hunting tool, and

wherein the reagent pipette alignment is based on the alignment of the elongated hunting tool.

3. The system of claim 2, wherein the predetermined target comprises one of: round targets on an indexing reagent pack, slotted targets on inner cuvette rings, and slotted targets on outer cuvette rings.

4. The system of claim 2, further comprising a housing attached to the robotic arm,

wherein the elongated hunting tool is inserted through the housing attached to the robotic arm.

5. The system of claim 4, wherein the elongated hunting tool is removable from the housing.

6. The system of claim 1, further comprising a sample pipette, wherein the sample pipette alignment is based on the alignment of the shortened hunting tool.

7. The system of claim 6, wherein the predetermined target comprises one of: sample track pucks, tip tray indexers for consumable tips, inner cuvette rings, and outer cuvette rings.

8. The system of claim 6, further comprising a housing attached to the robotic arm, wherein the housing is configured to be inserted into the shortened hunting tool.

9. The system of claim 6, wherein the shortened hunting tool is removable from the housing.

10. The system of claim 1, wherein the pressure sensitive tip of the hunting tool extends lower than the sampling tip of the probe.

11. A probe runout sensor device comprising:

a body having a top and bottom,

the body comprising an aperture from the top to the bottom,

the top of the body comprising:

one or more sensing beams running across the aperture,

wherein the one or more sensing beams detect the location of an object passing through the aperture.

12. The device of claim 11, wherein the one or more sensing beams comprise a plurality of sensing beams.

13. The device of claim 12, wherein the plurality of sensing beams determine, based on a predetermined movement pattern of the object, a position in a horizontal plane of the object, and wherein vertical alignment of the object is determined based the position in the horizontal plane.

14. The device of claim 11, wherein the object passing through the aperture is at least one of: a probe and a hunting tool.

15. A method of automatically aligning an indexing machine with a robotic end effector comprising:

inserting, using a robotic arm, a hunting tool into an aperture, the hunting tool comprising a pressure sensitive tip;

detecting, using a plurality of sensing beams, a first location of the hunting tool within the aperture;

rotating, using the robotic arm, the hunting tool 180 degrees;

detecting, using the plurality of sensing beams, a second location of the hunting tool within the aperture;

calculating a runout magnitude and a runout direction based on the first location, the second location, and the robotic arm;

inserting, using the robotic arm, the hunting tool into a target;

determining, using the pressure sensitive tip, a location of the hunting tool with respect to the target; and

thereafter, adjusting the location of the hunting tool with respect to the aperture and target based on said determined location and said calculated runout magnitude and direction.

16. The method of claim 15, further comprising inserting the hunting tool into a reagent pipette housing connected to the robotic arm.

17. The method of claim 16, further comprising:

removing the elongated hunting tool; and

inserting a reagent pipette,

wherein the alignment of the reagent pipette is based on the alignment of the elongated hunting tool.

18. The method of claim 15, further comprising inserting a sample probe housing into the hunting tool.

19. The method of claim 18, further comprising:

removing the shortened hunting tool; and

attaching a sample probe,

wherein the alignment of the sample probe is based on the alignment of the shortened hunting tool.

20. The method of claim 16, further comprising inserting a sample probe housing into a second hunting tool.

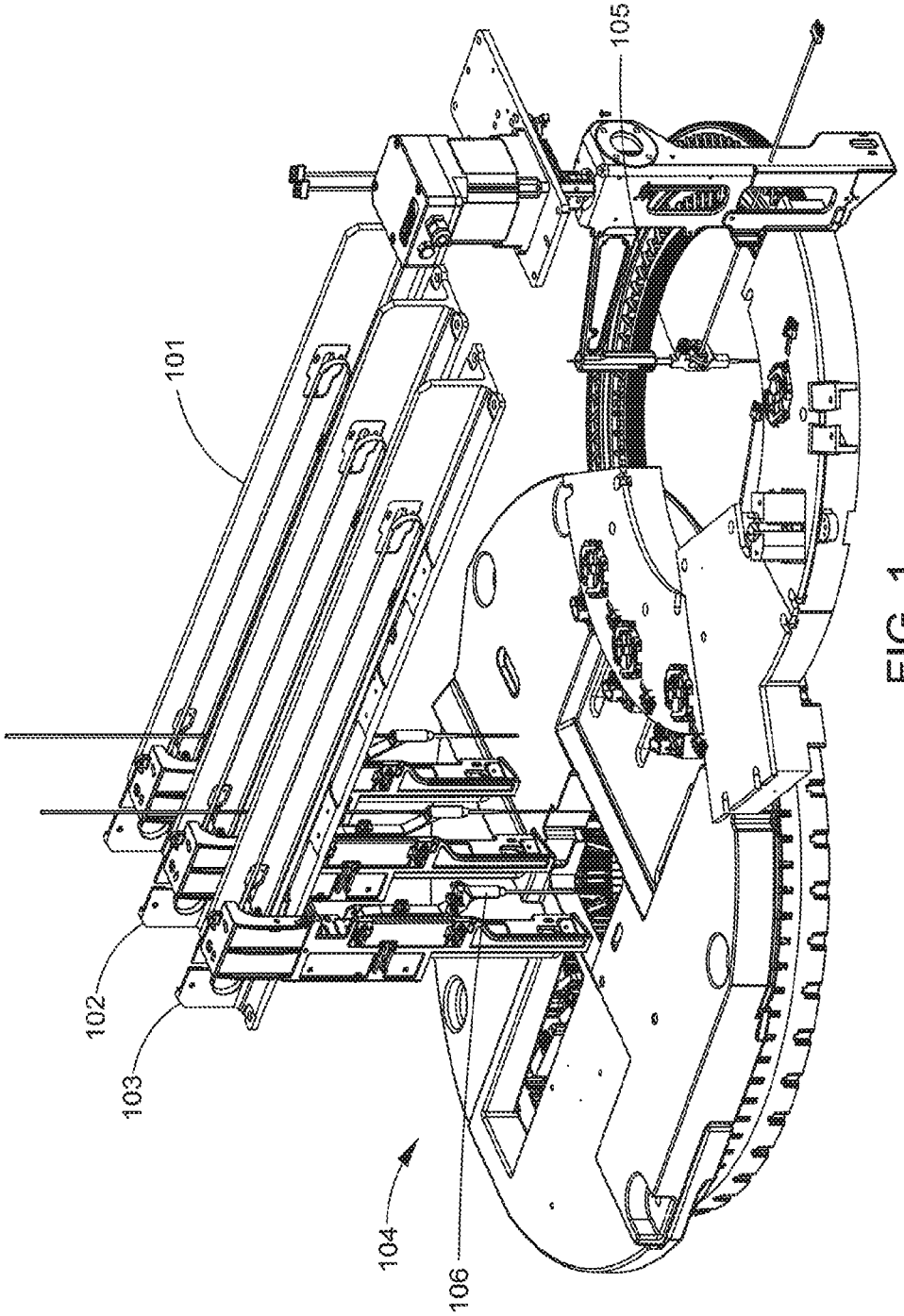


FIG. 1

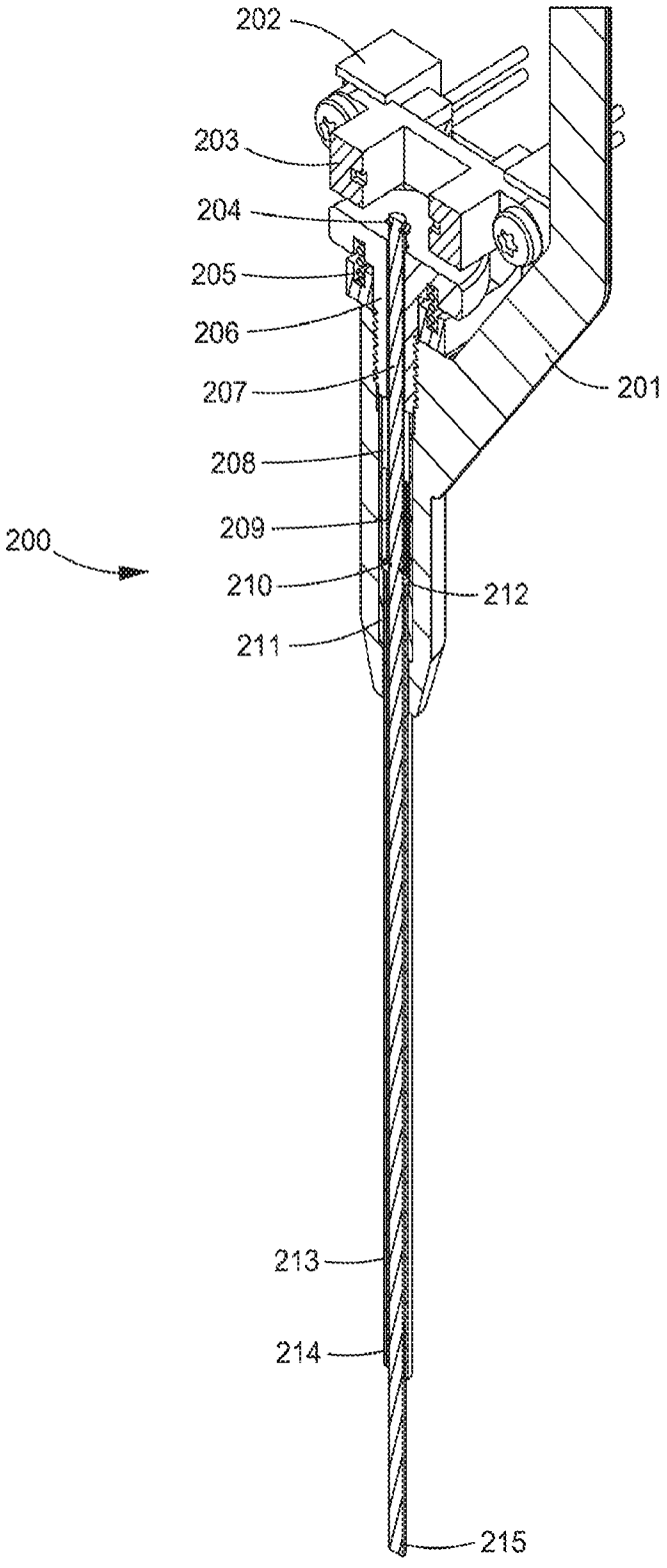


FIG. 2

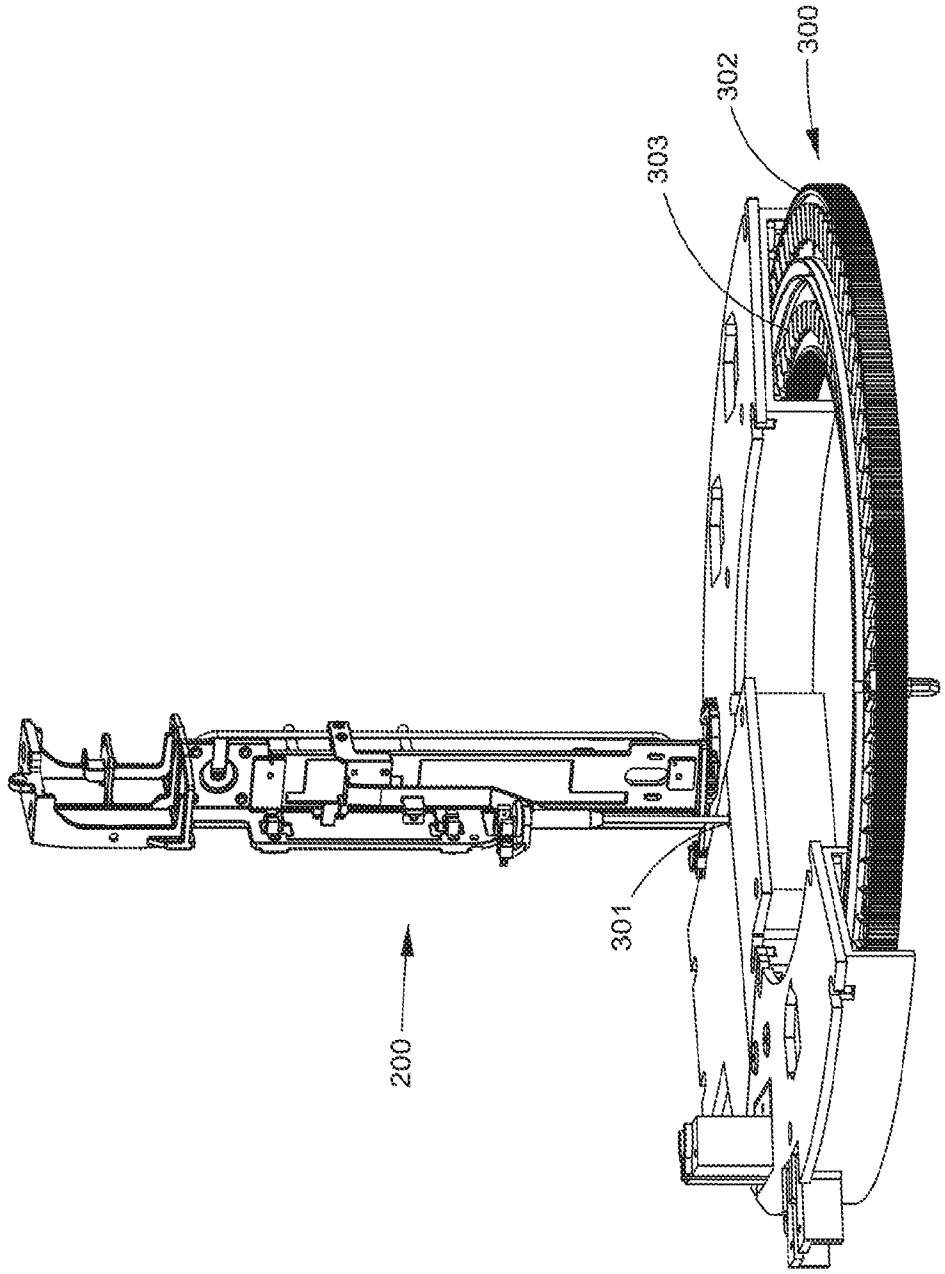


FIG. 3

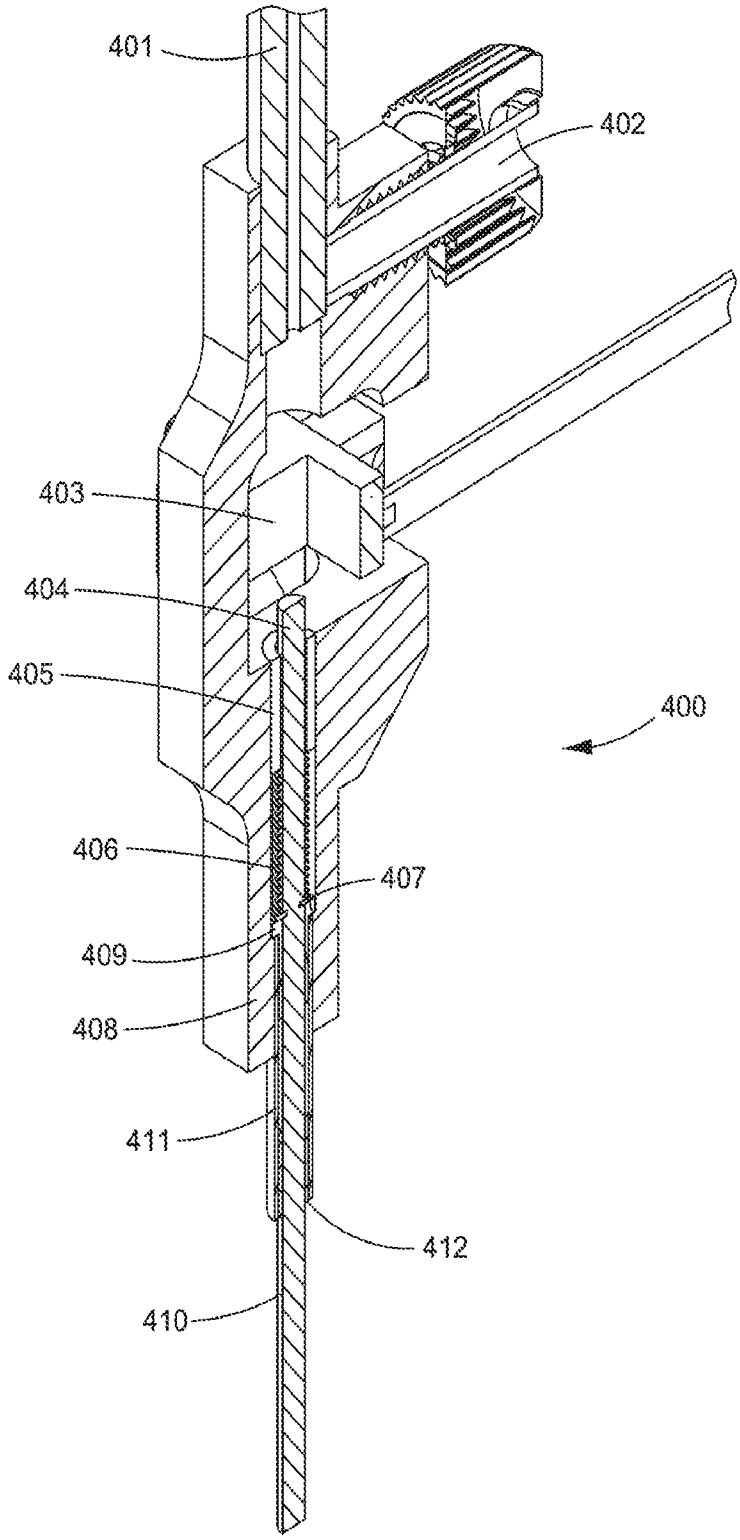


FIG. 4

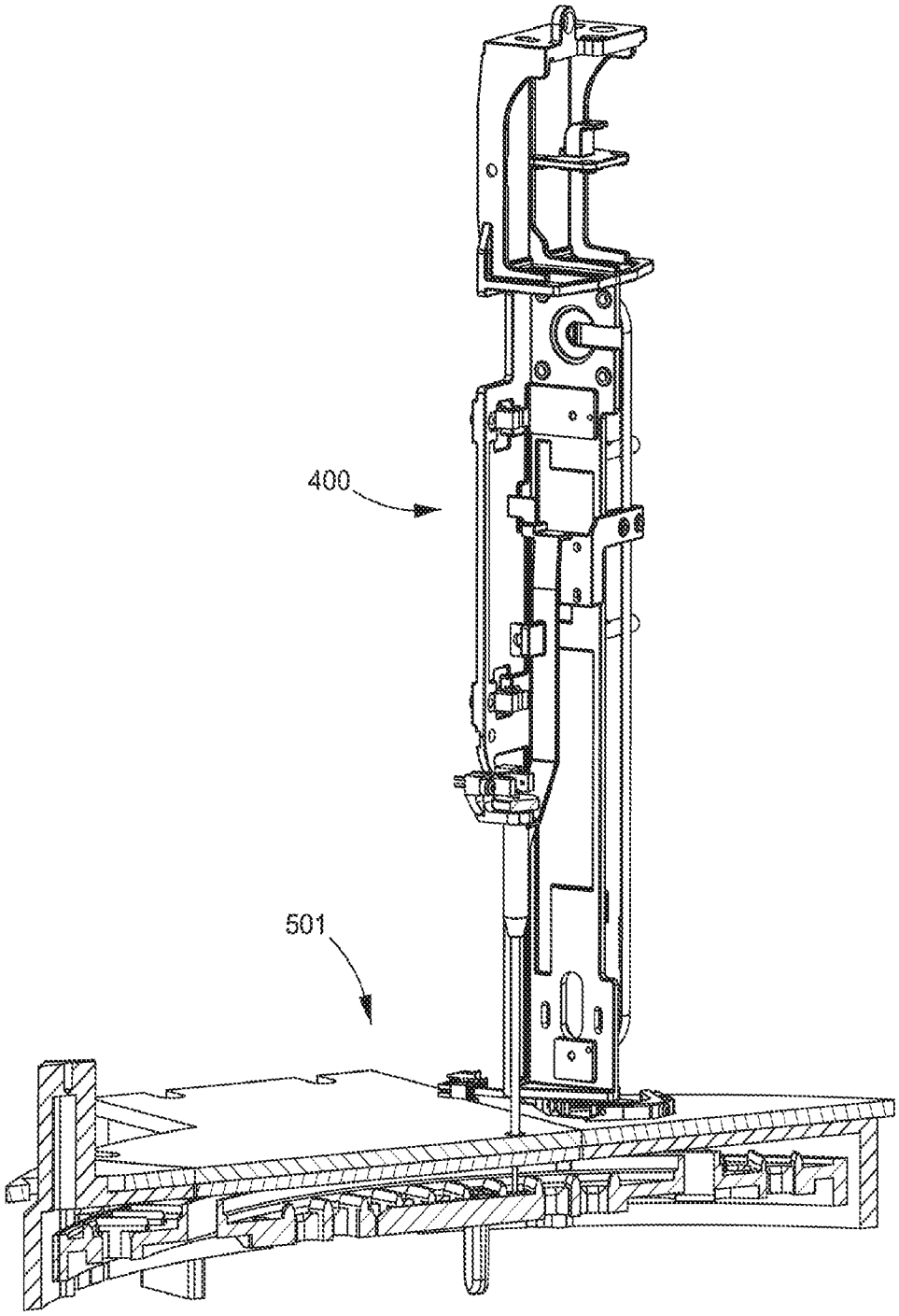


FIG. 5

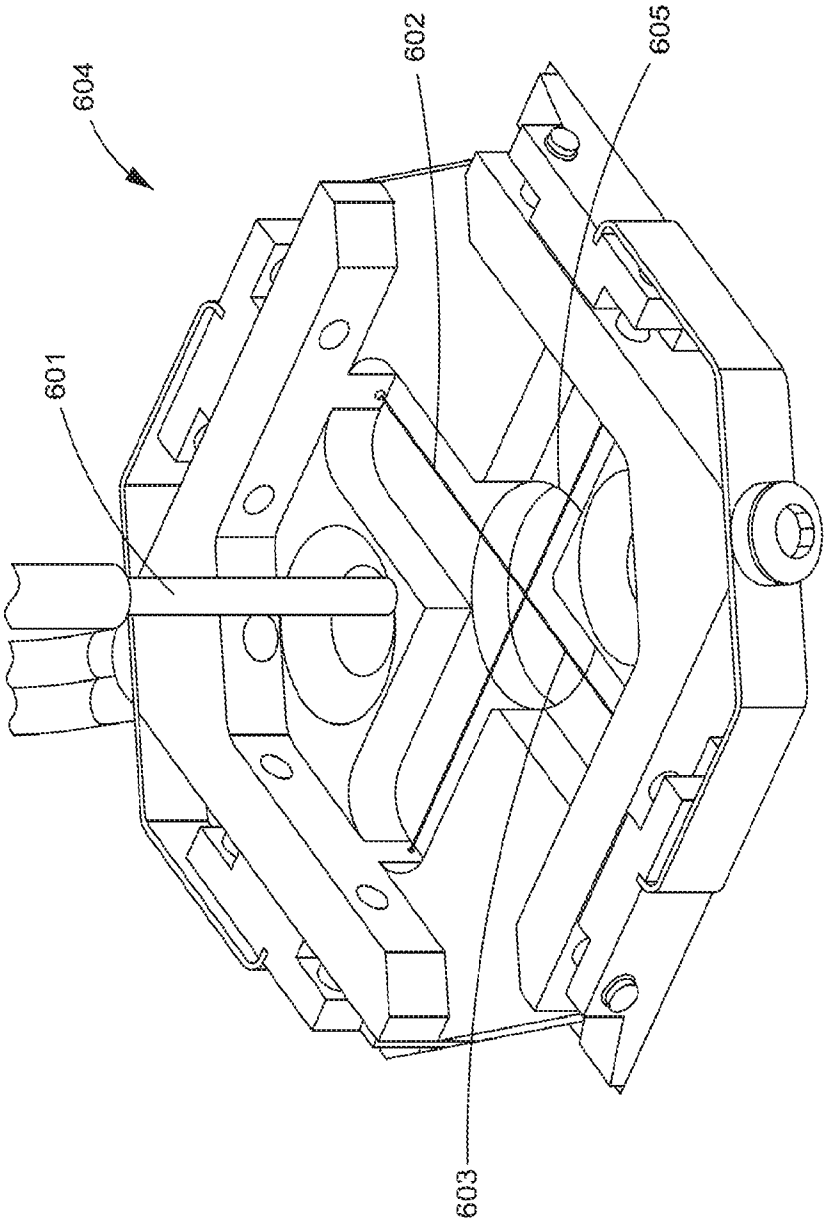


FIG. 6

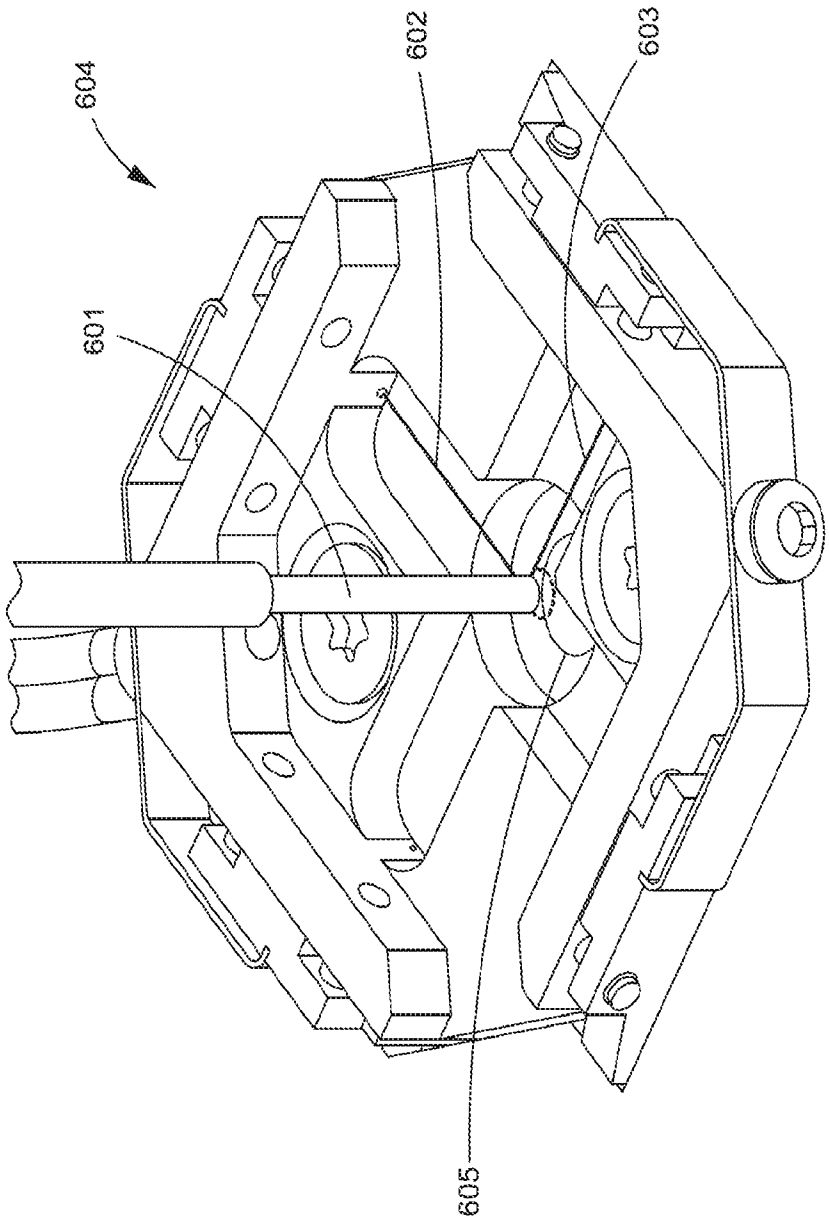


FIG. 7

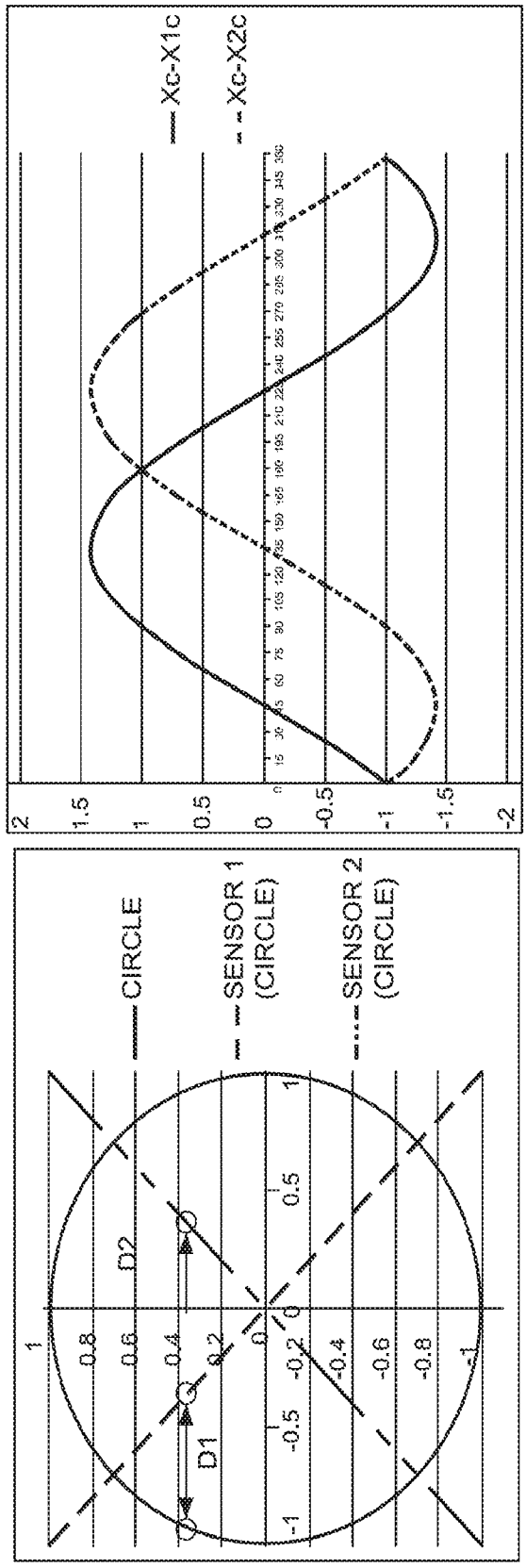
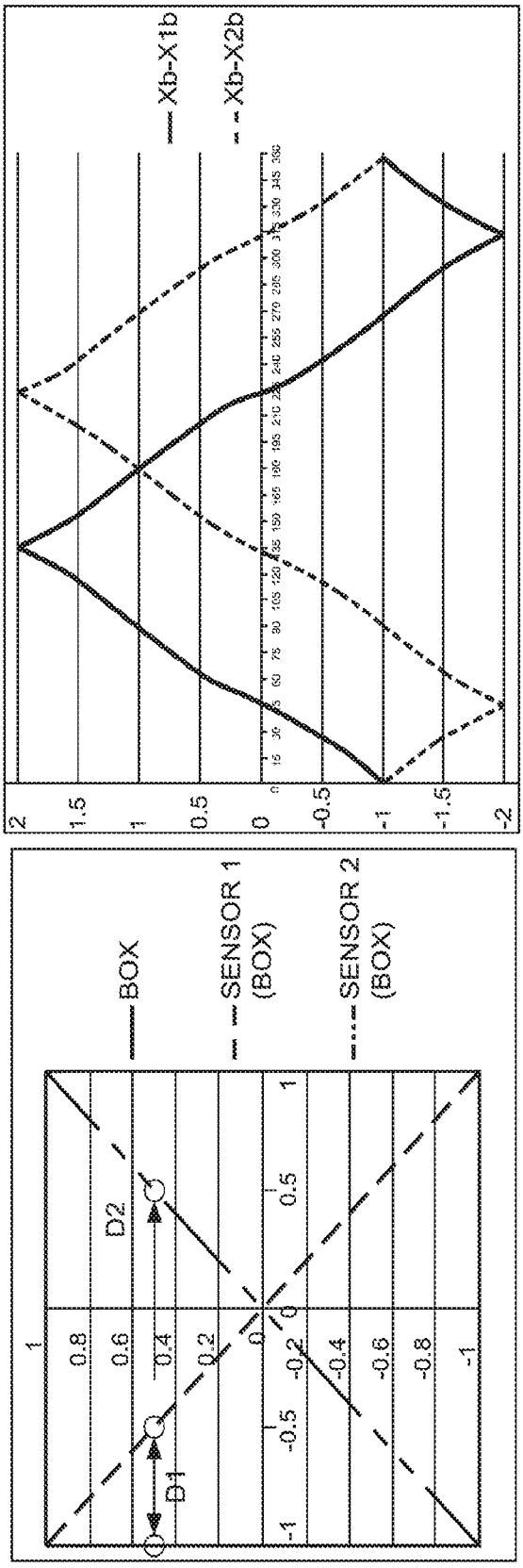


FIG. 8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Xb-X2b
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0.5
0
-0.5
-1
-1.5
-2
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SENSOR 1 (BOX)
SENSOR 2 (BOX)
D2
D1
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0.6
0.4
0.2
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-0.5

FIG. 9

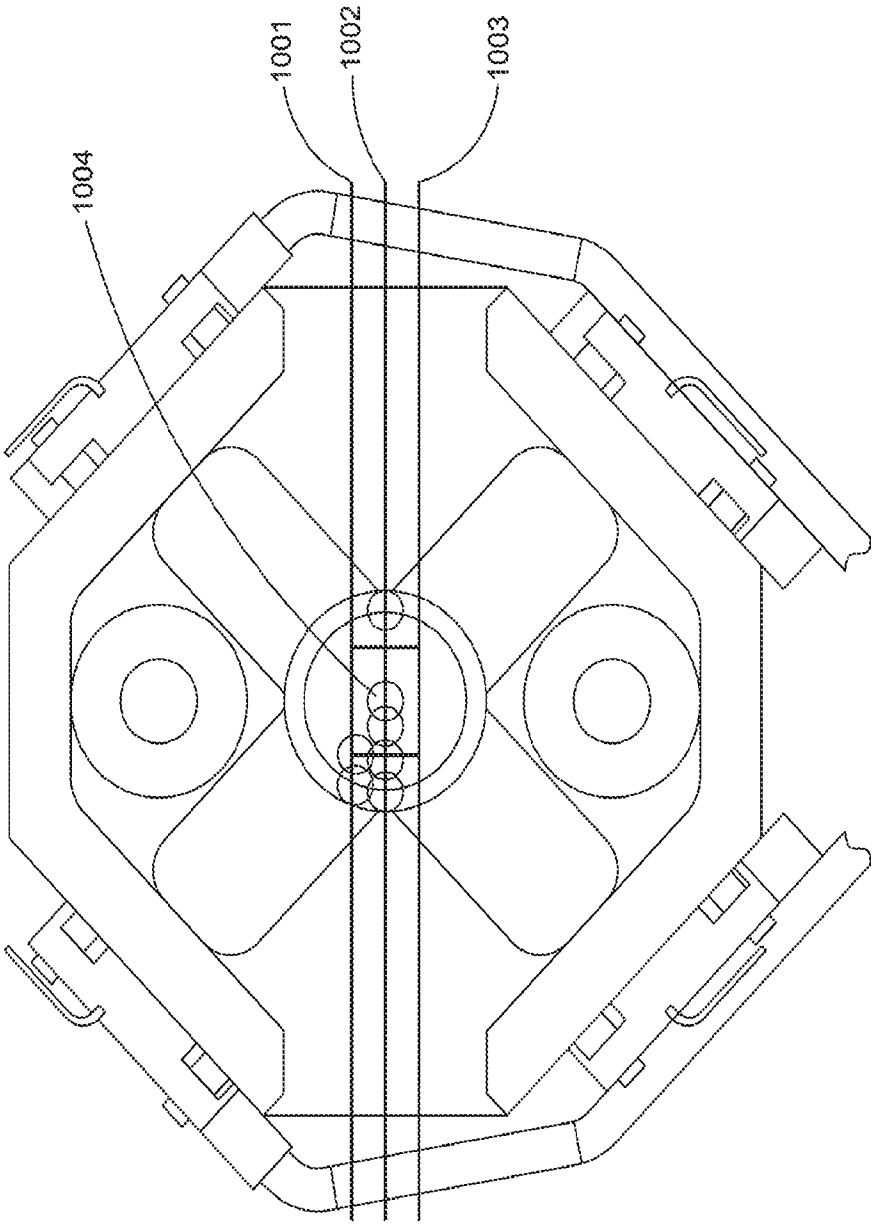

FIG. 10

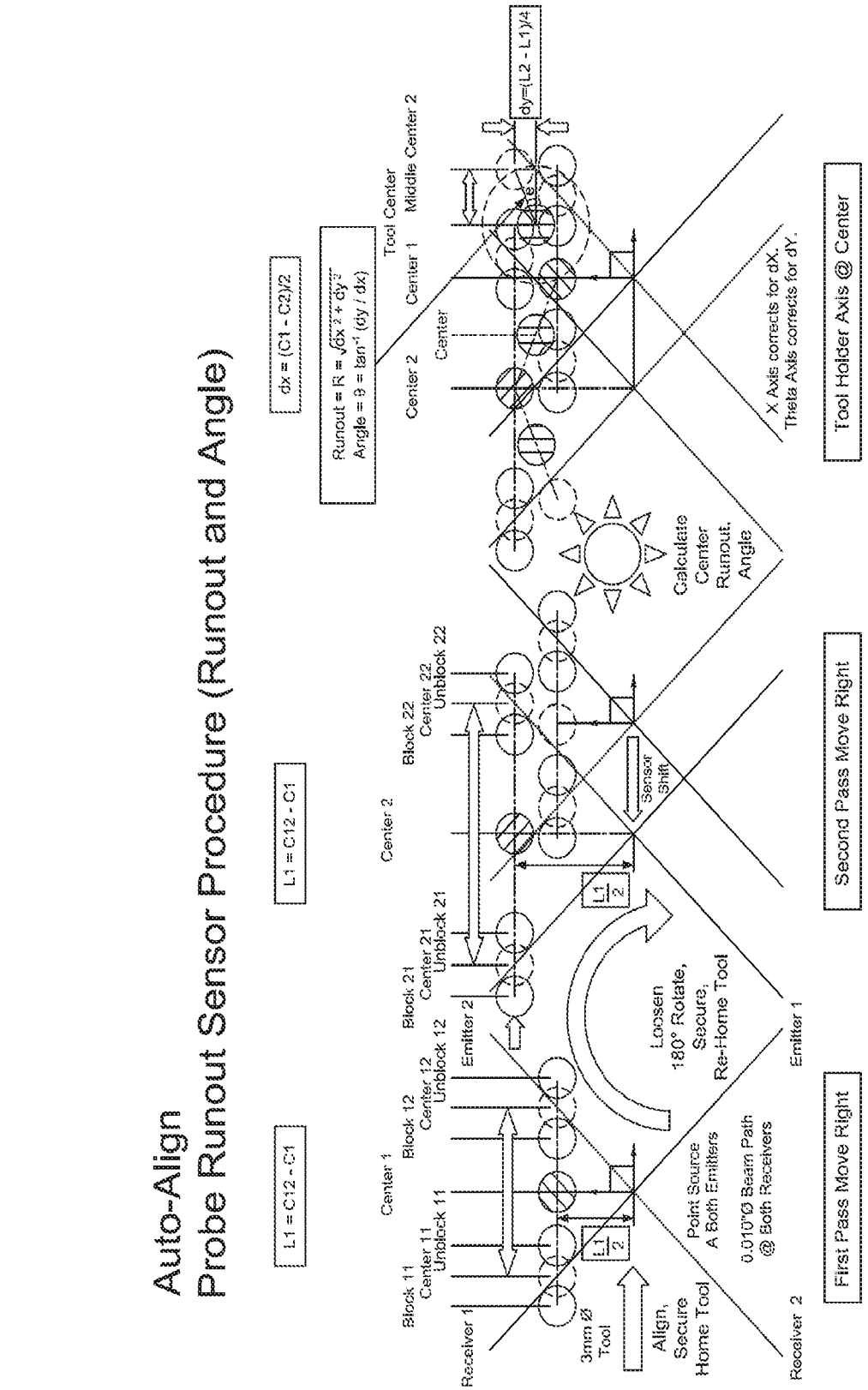
Auto-Align
Probe Runout Sensor Procedure (Runout and Angle)
L1 = C12 - C1
L1 = C12 - C1
dx = (C1 - C2)/2
Runout = R = √dx² + dy²
Angle = ϑ = tan⁻¹ (dy / dx)
dy=(L2 - L1)/4
Tool Center
Center 1
Middle Center 2
Center 2
Center
Block 11
Center 11
Unblock 11
Receiver 1
Block 12
Center 12
Unblock 12
Emitter 2
Block 21
Center 21
Unblock 21
Center 2
Block 22
Center 22
Unblock 22
Center 1
Sensor Shift
L1/2
L1/2
3mm Ø Tool
Align, Secure Home Tool
Point Source A Both Emitters
0.010"Ø Beam Path @ Both Receivers
Loosen 180° Rotate, Secure, Re-Home Tool
Emitter 1
Receiver 2
Calculate Center Runout, Angle
X Axis corrects for dX.
Theta Axis corrects for dY.
First Pass Move Right
Second Pass Move Right
Tool Holder Axis @ Center

FIG. 11

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2017/042912

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - G01N 35/10; G01N 1/10; G01N 35/00; G01N 35/02; G01N 35/04 (2017.01)

CPC - G01N 35/1011; G01N 1/10; G01N 35/00; G01N 35/0099; G01N 35/02; G01N 35/025; G01N 35/04; G01N 35/10; G01N 35/1009; G01N 35/1016 (2017.08)

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)

See Search History document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

USPC - 422/63; 422/64; 422/65; 422/66; 422/67; 436/180 (keyword delimited)

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

See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 3,894,438 A (GINSBERG) 15 July 1975 (15.07.1975) entire document	1, 2, 4-6, 9, 10 --- 3, 7, 8
Y	US 7,457,686 B2 (DING et al) 25 November 2008 (25.11.2008) entire document	3, 7
Y	US 5,344,610 A (SHAW) 06 September 1994 (06.09.1994) entire document	8
A	WO 97/20186 A1 (AQUASMART PTY. LTD.) 05 June 1997 (05.06.1997) entire document	1-10
A	US 5,736,403 A (RIALL et al) 07 April 1998 (07.04.1998) entire document	1-10
A	US 2003/0187600 A1 (BARNES) 02 October 2003 (02.10.2003) entire document	1-10

☐ 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	Date of mailing of the international search report
23 October 2017	14 NOV 2017
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, VA 22313-1450 Facsimile No. 571-273-8300	Authorized officer Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2017/042912

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.:
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:
See extra sheet(s).

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 additional fees, this Authority did not invite payment of 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.:
1-10

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

International application No.
PCT/US2017/042912

Continued from Box No. III Observations where unity of invention is lacking

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees need to be paid.

Group I, claims 1-10 are drawn to an automated probe switch.
Group II, claims 11-14 are drawn to a probe runout sensor device.
Group III, claims 15-20 are drawn to a method of automatically aligning an indexing machine with a robotic end effector.

The inventions listed in Groups I, II, and III do not relate to a single general inventive concept under PCT Rule 13.1, because under PCT Rule 13.2 they lack the same or corresponding special technical features for the following reasons:

The special technical features of Group I, an automated probe switch comprising a probe having a sampling tip, attached to the robotic arm, wherein the sampling tip of the probe is aligned with a predetermined target, based on the alignment of a hunting tool, are not present in Groups II, III; the special technical features of Group II, a probe runout sensor device comprising a body having a top and bottom, the body comprising an aperture from the top to the bottom, the top of the body comprising:
one or more sensing beams running across the aperture, are not present in Groups I, II; and, the special technical features of Group III, a method of automatically aligning an indexing machine with a robotic end effector comprising rotating, using a robotic arm, a hunting tool 180 degrees, detecting, using a plurality of sensing beams, a second location of the hunting tool within the aperture, calculating a runout magnitude and a runout direction based on a first location, the second location, and the robotic arm; thereafter, adjusting the location of the hunting tool with respect to the aperture and target based on said determined location and said calculated runout magnitude and direction, are not present in Groups I, II.

Groups I, III share the technical features of an alignment system comprising a robotic arm, a hunting tool, the hunting tool having a pressure sensitive tip, wherein the hunting tool alignment is determined based on force detected at the pressure sensitive tip. However, these shared technical features do not represent a contribution over the prior art.
Specifically, US 7,457,686 B2 to Ding et al. teaches of an alignment system (Abstract regarding a method for aligning the position of a movable arm) comprising a robotic arm (robotic arm 3, Fig. 4), a hunting tool (metering head 5 including probe 6, Fig. 4), the hunting tool having a pressure sensitive tip (Col. 3, Lns. 56-62 regarding the measured response is the air pressure in the probe and the metering probe has a source of compressed air for expelling air out of the end of the probe and a pressure transducer for measuring the air pressure inside the metering probe), wherein the hunting tool alignment is determined based on force detected at the pressure sensitive tip (Col. 6, Lns. 10-22 regarding the pressure inside the metering tip is monitored as air is blown out of the tip...the relationship between the measured air pressure in the tip and the height of the tip above a flat surface of the alignment element can be determined).

Groups II, III share the technical features of an aperture wherein one or more sensing beams detect the location of an object passing through the aperture. However, these shared technical features do not represent a contribution over the prior art.
Specifically, WO 97/20186 A1 to Aquasmart Pty. Ltd. teaches of an aperture (aperture 11, Fig. 1) wherein one or more sensing beams (light emitter 5, beam of light 9, light receiver 15, Fig. 1) detect the location of an object passing through the aperture (Abstract regarding in use, the profile of an object passing through the aperture is determined).

Since none of the special technical features of the Groups I, II, and III inventions are found in more than one of the inventions, unity is lacking.

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G01N 35/04(2006.01)

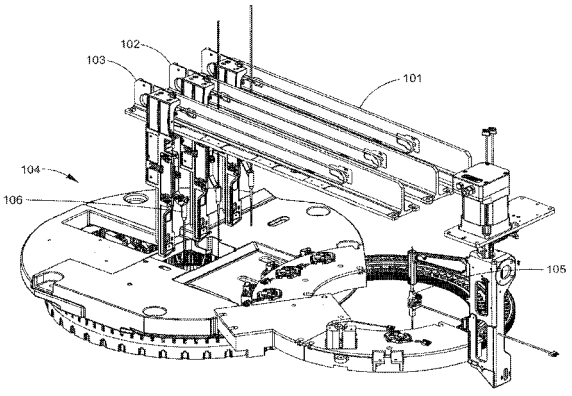
权利要求书2页 说明书5页 附图11页

(54)发明名称

测试系统的自动化对准

(57)摘要

一个实施例提供了自动地对准具有机器人末端执行器的标引机的方法,包括:使用机器人臂将搜寻工具插入到孔口内,搜寻工具包括压敏尖部;使用多个感测光束检测搜寻工具在孔口内的第一位置;使用机器人臂使搜寻工具旋转180度;使用多个感测光束检测搜寻工具在孔口内的第二位置;基于第一位置、第二位置和机器人臂计算跳动幅度和跳动方向;使用机器人臂将搜寻工具插入到目标内;使用压敏尖部确定搜寻工具相对于目标的位置;以及之后,基于所确定的位置和所计算的跳动幅度和方向来调节搜寻工具相对于孔口和目标的位置。本文描述并要求保护其他方面。



CN 109416372 A

1.一种自动化探针开关对准系统,包括:

机器人臂;

附接到所述机器人臂的探针,其具有采样尖部;以及

附接到所述机器人臂的搜寻工具,所述搜寻工具具有压敏尖部,

其中,基于所述搜寻工具的对准,所述探针的采样尖部与预定目标对准,以及

其中,基于在所述压敏尖部处检测到的力来确定搜寻工具对准。

2. 根据权利要求1所述的系统,还包括试剂移液管,

其中,所述搜寻工具是细长的搜寻工具,以及

其中,试剂移液管对准是基于所述细长的搜寻工具的对准而定的。

3.根据权利要求2所述的系统,其中,所述预定目标包括如下中的一者:在标引试剂包上的圆形目标;在内试管环上的开槽目标;以及在外试管环上的开槽目标。

4.根据权利要求2所述的系统,还包括附接到所述机器人臂的外壳,

其中,所述细长的搜寻工具被插入通过附接到所述机器人臂的所述外壳。

5.根据权利要求4所述的系统,其中,所述细长的搜寻工具是能够从所述外壳移除的。

6.根据权利要求1所述的系统,还包括样品移液管,其中,所述样品移液管对准是基于缩短的搜寻工具的对准而定的。

7.根据权利要求6所述的系统,其中,所述预定目标包括如下中的一者:样品轨道圆盘;用于可消耗尖部的尖部托盘标引器;内试管环;以及外试管环。

8.根据权利要求6所述的系统,还包括附接到所述机器人臂的外壳,

其中,所述外壳被构造成被插入到所述缩短的搜寻工具内。

9.根据权利要求6所述的系统,其中,所述缩短的搜寻工具是能够从所述外壳移除的。

10.根据权利要求1所述的系统,其中,所述搜寻工具的所述压敏尖部延伸成比所述探针的采样尖部更低。

11.一种探针跳动传感器装置,包括:

具有顶部和底部的本体,

所述本体包括从所述顶部到所述底部的孔口,

所述本体的所述顶部包括:

延伸跨越所述孔口的一个或多个感测光束,

其中,所述一个或多个感测光束检测传送通过所述孔口的物体的位置。

12.根据权利要求11所述的装置,其中,所述一个或多个感测光束包括多个感测光束。

13.根据权利要求12所述的装置,其中,所述多个感测光束基于所述物体的预定运动模式来确定所述物体在水平面中的位置,并且其中,基于所述水平面中的位置来确定所述物体的竖直对准。

14.根据权利要求11所述的装置,其中,传送通过所述孔口的所述物体是探针和搜寻工具中的至少一者。

15.一种自动对准具有机器人末端执行器的标引机的方法,包括:

使用机器人臂将搜寻工具插入到孔口内,所述搜寻工具包括压敏尖部;

使用多个感测光束来检测所述搜寻工具在所述孔口内的第一位置;

使用所述机器人臂将所述搜寻工具旋转180度;

使用所述多个感测光束来检测所述搜寻工具在所述孔口内的第二位置；

基于所述第一位置、第二位置和所述机器人臂来计算跳动幅度和跳动方向；

使用所述机器人臂将所述搜寻工具插入到目标内；

使用所述压敏尖部来确定所述搜寻工具相对于所述目标的位置；以及

之后，基于所确定的位置和所计算的跳动幅度和方向来调节所述搜寻工具相对于所述孔口和目标的位置。

16.根据权利要求15所述的方法，还包括：将所述搜寻工具插入到被连接到所述机器人臂的试剂移液管外壳内。

17. 根据权利要求16所述的方法，还包括：

移除细长的搜寻工具；以及

插入试剂移液管，

其中，所述试剂移液管的对准是基于所述细长的搜寻工具的对准而定的。

18.根据权利要求15所述的方法，还包括：将样品探针外壳插入到所述搜寻工具内。

19. 根据权利要求18所述的方法，还包括：

移除缩短的搜寻工具；以及

附接样品探针，

其中，所述样品探针的对准是基于所述缩短的搜寻工具的对准而定的。

20.根据权利要求16所述的方法，还包括：将样品探针外壳插入到第二搜寻工具内。

测试系统的自动化对准

[0001] 相关技术的交叉引用

本申请要求于2016年7月21日提交的美国临时申请序列号No.62/365,225的权益，该临时申请以其全部内容通过引用的方式被并入本文。

技术领域

[0002] 本发明总体上涉及用于标引机的关于机器人执行器的对准的自动化过程。

背景技术

[0003] 随着大规模自动化的能力提升，越来越多的过程被过渡到无人操作的环境。实验室测试系统大体需要清楚限定的可重复的结果。这是因为，为了获得正确的分析，必须执行大量的测试，许多测试被执行多次。由于该重复的性质，测试过程完美地适于自动化过程。但是，由于测试过程的精确的性质，可能难以准确地并且一致地自动化所涉及的多数步骤。例如，使用至基于圆盘的轨道上的样品管的移液探针是重复性非常大的任务。但是，由于所涉及的变量和所需要的精度，已经证明难以完全自动化该过程。

[0004] 因此，当前，为了执行测试过程的多个步骤，需要一些手动付出(例如，对准)。这典型地包括：操作者视觉地检查系统并且使用多种工具(例如，工具销和板)以调节移液管和样品管。当与典型的自动化系统比较时，这是慢的且成本高的过程。因此，存在执行关于移液管采样的自动化的更快速、更高效和更稳健的方法的需求。

发明内容

[0005] 因此，实施例提供了一种自动化探针开关对准系统，包括：机器人臂；附接到机器人臂的探针，其具有采样尖部；附接到机器人臂的搜寻工具，搜寻工具具有压敏尖部；其中，探针的采样尖部基于搜寻工具的对准而与预定目标对准；并且其中基于在压敏尖部处检测到的力来确定搜寻工具对准。

[0006] 另一实施例提供了一种探针跳动传感器装置，包括：具有顶部和底部的本体；本体包括从顶部到底部的孔口；本体的顶部包括延伸跨越孔口的一个或多个感测光束；其中，所述一个或多个感测光束检测经过孔口的物体的位置。

[0007] 另一实施例提供了一种自动地对准具有机器人末端执行器的标引机的方法，包括：使用机器人臂将搜寻工具插入到孔口内，搜寻工具包括压敏尖部；使用多个感测光束检测搜寻工具在孔口内的第一位置；使用机器人臂使搜寻工具旋转180度；使用多个感测光束检测搜寻工具在孔口内的第二位置；基于第一位置、第二位置和机器人臂计算跳动幅度和跳动方向；使用机器人臂将搜寻工具插入到目标内；使用压敏尖部确定搜寻工具相对于目标的位置；以及之后，基于所确定的位置以及所计算的跳动幅度和跳动方向调节搜寻工具相对于孔口和目标的位置。

附图说明

[0008] 从以下详细的描述(当结合所附附图被阅读时)最佳地理解本发明的上述方面和其他方面。为了阐述本发明的目的,在附图中示出了目前优选的实施例,但是要理解本发明不限于所公开的具体方案。被包括在附图中的是以下的图:

图1是用于具有机器人末端执行器的标引机的自动化对准的示例性系统的示意图。

[0009] 图2是示例性细长的搜寻工具的示意图。

[0010] 图3是具有试管环开槽目标的示例性细长的搜寻工具的示意图。

[0011] 图4是示例性缩短的搜寻工具的示意图。

[0012] 图5是具有试管环开槽目标的示例性缩短的搜寻工具的示意图。

[0013] 图6是示例性探针跳动传感器的示意图。

[0014] 图7是示例性探针跳动传感器的示意图,其中,光束被探针尖部遮挡。

[0015] 图8是沿360°圆形边界的示例性传感器输出的图示图。

[0016] 图9是沿360°方形边界的示例性传感器输出的图示图。

[0017] 图10是探针跳动传感器上的示例性测量工具的示意图。

[0018] 图11是跳动幅度和跳动方向计算的图示图。

具体实施方式

[0019] 本文的实施例涉及自动化系统,其可以被用于使机器人移液探针的诊断仪器对准到标引环中的基于圆盘的轨道、试管或试剂包上的样品管。有利地,实施例的自动化系统提供了稳健的和有效的机制以确保机器人移液的过程是一致且准确的。

[0020] 如本文所讨论的,在重复的测试期间确保自动化装置的正确对准和操作的能力对于确保结果可复现而言是至关重要的。但是,当前的自动化解决方案要么缺乏精度要么是贵得惊人的,因此不是人类操作员的合适替代。因为实验需要极高的精度,所以需要精确的工具和复杂的程序,其被一个或多个训练过的现场服务技术人员来手动地执行。

[0021] 因此,实施例经由极度准确的对准系统来提供改进,以确保探针和目标之间的适当相互作用。自动化对准系统可以利用探针开关和/或探针跳动传感器。通过使用这些(即,探针开关和跳动传感器)中的一者或多者,实施例可以简化过程,同时仍然实现高度准确的和可重复的对准。

[0022] 又一实施例可以利用长距高分辨率的探针开关。高分辨率的探针开关在尖部处可以具有用于检测表面(即,邻近专用的目标的表面)的机械柱塞。在另一实施例中,机械柱塞可以利用装载有弹簧的低力柱塞来检测目标区域的表面。附加地或替代性地,实施例可以包括刚性支承系统。该高度刚性的支承系统可以能够更准确地检测目标的边缘。在另一实施例中,如本文所讨论的机械柱塞可以与探针跳动传感器相结合地工作。

[0023] 如本文进一步描述的,探针跳动传感器可以精确地测量探针的幅度(例如,以毫米、厘米、英寸等为单位)和探针的方向(例如,弧度、角度等)。这可以允许实施例确定平直度因子或平直度误差的量。基于所确定的探针平直度,又一实施例可以采取行动以修正平直度(例如,调节探针的幅度或方向)。通过修正平直度,实施例处于更好的位置,使得真正的探针轴线和尖部在当被移动到目标的中心或被移动到环组内的单个标引位置时处于正确的对准。

[0024] 现在参考图1,实施例可以具有带有探针101、102、103(例如,线性的、旋转的等)的一个或多个机器人臂。机器人臂探针允许实施例与多个其他的测试仪器104(例如,轨道、消耗品、标引环等)接口。另一实施例还可以包括带有装载有弹簧的、低力柱塞105的长距、高分辨率的探针开关105。

[0025] 在一个实施例中,可以使用细长的(即,长的)搜寻工具106。在图2中示出细长的搜寻工具200的非限制性示例。长搜寻工具200还可以包括试剂探针臂201,如图2中所示。如图2中所示,长搜寻工具200的附加的非限制性部件可以是:传感器托架202、宽阈传感器(例如,Optek)203、e形夹204、托架压缩弹簧205、锁紧螺钉206、杆207、管盘208、杆压缩弹簧209、颈圈210、凸缘衬套211、海波管213、竖直管212和直衬套214。Optek是Optek-Danualt GmbH Corporation在美国和其他国家的注册商标。本领域的技术人员应当理解,每种上述部件中的一个或多个可以被包括在实施例中(例如,两个e形夹)。

[0026] 如图2中所示,从颈圈210的底部到探针215的尖部,所允许的最大旋转偏移量(R.O.)可以是±0.33mm。本领域技术人员应当理解,如图2中所示的R.O.是R.O.限值的仅仅单个的非限制性示例,并且在附加的实施例中,限值可以更大或更小。

[0027] 如图2中所示的长搜寻工具200在不同活动期间可能需要变化水平的力。阐述性非限制性示例可以是例如2.7盎司的初始力、3盎司的传感器力以及3.7盎司的过行程力。因此,在一个实施例中,变化水平的力可以导致约6mm的总行程。在一个非限制性示例中,长搜寻工具200可以比试剂探针长约2mm以确保正确对准。附加地,如图2中所示,搜寻工具200可以通过从试剂探针臂201向上竖直地取出而被移除。

[0028] 在又一实施例中,可以针对标引试剂包托盘上的圆形目标301来执行对准。附加地或替代性地,可以针对开槽目标执行对准。现在参考图3,诸如细长的搜寻工具200的实施例可以经由开槽目标系统300(例如,在内试管环303和外试管环302上)来执行对准。

[0029] 在另一实施例中,可以使用缩短的(即,短的)搜寻工具400。在图4中示出缩短的搜寻工具400的非限制性示例。如图4中所示,短的搜寻工具400还可以包括样品探针401。如图4中所示,短的搜寻工具400的附加的非限制性部件可以是:锁紧托架402、宽阈传感器(例如,Optek宽阈传感器)403、杆404、管盘405、杆压缩弹簧406、e形夹407、颈圈408、托架409、凸缘衬套411、海波管410和直衬套412。本领域的技术人员应当理解,如长搜寻工具一样,每种上述部件中的一个或多个可以被包括在短的搜寻工具400中的实施例中(例如,两个e形夹)。

[0030] 如图4中所示,从颈圈的底部到探针的尖部,所允许的最大的R.O.可以是±0.23mm。本领域的技术人员应当理解的是,如图2中所示出的R.O.是R.O.限值的仅仅单个的非限制性示例,并且在附加的实施例中,该限值可以更大或更小。

[0031] 如图4中所示的短的搜寻工具在不同活动期间可能需要变化水平的力,阐述性的非限制性示例可以是例如2.7盎司的初始力、3盎司的传感器力和3.7盎司的过行程力。因此,在一个实施例中,变化水平的力可以导致约6mm的总行程。在一个非限制性示例中,短的搜寻工具可以比样品探针长约2mm以确保正确对准。附加地,如图4中所示,短的搜寻工具可以通过将其从试剂探针臂向下竖直地分离而被移除。

[0032] 使用短的搜寻工具,实施例可以将短的搜寻工具安装到样品探针臂并且执行对准。在又一实施例中,可以利用样品轨道圆盘来执行对准。附加地或替代性地,可以针对包

括可消耗尖部的尖部托盘标引器来执行对准。现在参考图5,实施例可以经由开槽目标系统501(例如,在内试管环和外试管环上)来执行对准。

[0033] 在一个实施例中,如本文所讨论的,可以使用探针跳动传感器604以辅助对准过程。例如,探针跳动传感器604可以具有延伸跨越开口(即,孔口)605的一个或多个感测光束,例如如图6中所示的。探针跳动传感器可以具有带有顶部和底部的本体。在实施例中,所述一个或多个感测光束可以包括水平光束603和竖直光束602。图6中所示的两光束系统是仅仅一个可能的实施例,也可以使用多个其他的实施例(例如,一个光束、三个光束、四个光束、五个光束等)。光束可以是公知光束检测的任何类型的,例如,激光的、红外的、光学的、光电的等。如图6中所示,实施例可以具有探针跳动传感器,其带有彼此正交地布置的两个对射光束。这允许实施例以极高精度检测压敏探针尖部601的偏移量。因为实施例知道探针臂的底部颈圈在何处(见图2和图4),其可以经由机器人臂位置来确定相对于探针固持器的插入点。

[0034] 因此,在又一实施例中,当压敏探针尖部传送通过探针跳动传感器604的开口605时,传感器可以检测压敏探针尖部601的位置。如图7中所示,一旦压敏尖部601足够低,那么其可以交汇一个或多个光束602、603,从而指示相对于臂位置的压敏探针尖部601位置。因此,如果探针尖部沿单个方向水平地移动,其可以遮挡或解除遮挡其中一个光束602。在一个实施例中,如果压敏探针未能成功遮挡所有的光束传感器,则压敏探针601可能被阻止更远地行进通过探针跳动传感器604。

[0035] 在一个实施例中,可能难以(如果并非不可能的话)移除或修正所有的对准问题,因为长的和短的搜寻工具均是机械系统,其具有典型的限制,诸如:轴承间隙、机加工和平直度误差以及安装误差。因此,跳动传感器的添加允许实施例将多个系统组合在一起以有助于确保可能的最准确的和对准的探针。修正跳动会允许实施例增加实施例的找到目标中心的能力。为了修正跳动,需要测量幅度和方向(典型地被称为跳动/幅度/方向(run/mag/dir))。

[0036] 在一个实施例中,探针跳动传感器的输出可以是沿传感器的X和Y坐标系(例如,定义在相对于两个光束均为45°处)的从探针中心的一对至光束的距离的测量值(例如,D1、D2)。在又一实施例中,可以在XY空间(例如,假设XY刻度1等于边界径向距离的100%)中以规则的间距绘制在感测区域的边界处的点。然后,实施例可以针对沿边界的点将至光束的距离的测量值(例如,D1、D2)绘制到DΘ空间(例如,光束距离对比Θ横掠)中。可以基于多种增量(例如,1°、5°等)从0°到360°来完成该绘制。现在参考图8,在实施例中,圆形边界可以采取具有90°相移的典型形状的正弦曲线,例如如图8中所示的。替代性地,诸如图9中的方形边界通过具有45°节点的倾斜线和谐波曲线的组合添加了独特的扭曲。这可能是重要的,这是因为通常会假定在方向反转的峰值之间会存在直线。但是,仅当沿边界的点等距地间隔开时才可能会得到直线。

[0037] 因为确保正确对准的关键之一是知道相对于安装在工具固持器中的“完全笔直的工具”的跳动,实施例可以采用具有等同的安装特征的非常笔直的测量工具的使用。在实施例中,测量工具可以设定传感器“零”点,其然后可以被传送到贯穿感测区域的任何地方,因为其经由传感器相对于机器人臂的安装来确定,例如如图9中所示的,因此,零点不一定得在光束交汇处。一旦被校准,实施例可以将测量工具替换为搜寻工具(例如,长的或短的)并

且重复该过程以确定XY位置的相对改变，其将计算跳动的幅度和方向(即，跳动/幅度/方向)。

[0038] 在另一实施例中，不需要初始校准。通常，当确定跳动/幅度/方向时，使用测量工具得到的第一校准将几乎总是具有一些小的、但是有意义的误差。因此，通过如下操作，实施例可以能够改善该过程：用与搜寻工具(例如，长的和短的搜寻工具)和安装到机器人臂的工具固持器成180°的可视划线1001、1002、1003作标记，诸如图10中所示的。

[0039] 首先，实施例可以对准工具和工具固持器线，并且将探针传送通过跳动传感器。然后，实施例可以将工具旋转180°，或者直到工具被再次对准到工具固持器线，并且再次传送通过跳动传感器。通过执行以上过程，实施例能够确定在两个点(例如，探针在0°和180°两者处交汇跳动传感器的地方)之间XY位置的相对改变，从而得到线。然后，该线可以被实施例视为表示跳动圆的直径的手段。基于新确定的跳动圆直径，新的“真正零”点通过理论上笔直的工具可以相对于工具固持器中性轴线被投影为所确定直径的中点。因此，在第二次传送通过传感器之后，可以计算从中点到工具尖部的跳动/幅度/方向。在图11中阐述了使用探针跳动传感器和探针开关的跳动幅度和方向过程的非限制性详细的示例。

[0040] 尽管已经参考示例性实施例描述了本发明，本发明不限于此。本领域的技术人员将理解到，可以对本发明的优选实施例进行多种改变和变型，并且这种改变和变型可以被进行而不脱离本发明的真正精神。因此，旨在的是，所附权利要求被解释为涵盖落入本发明的真正精神和范围内的所有这种等同的变化。

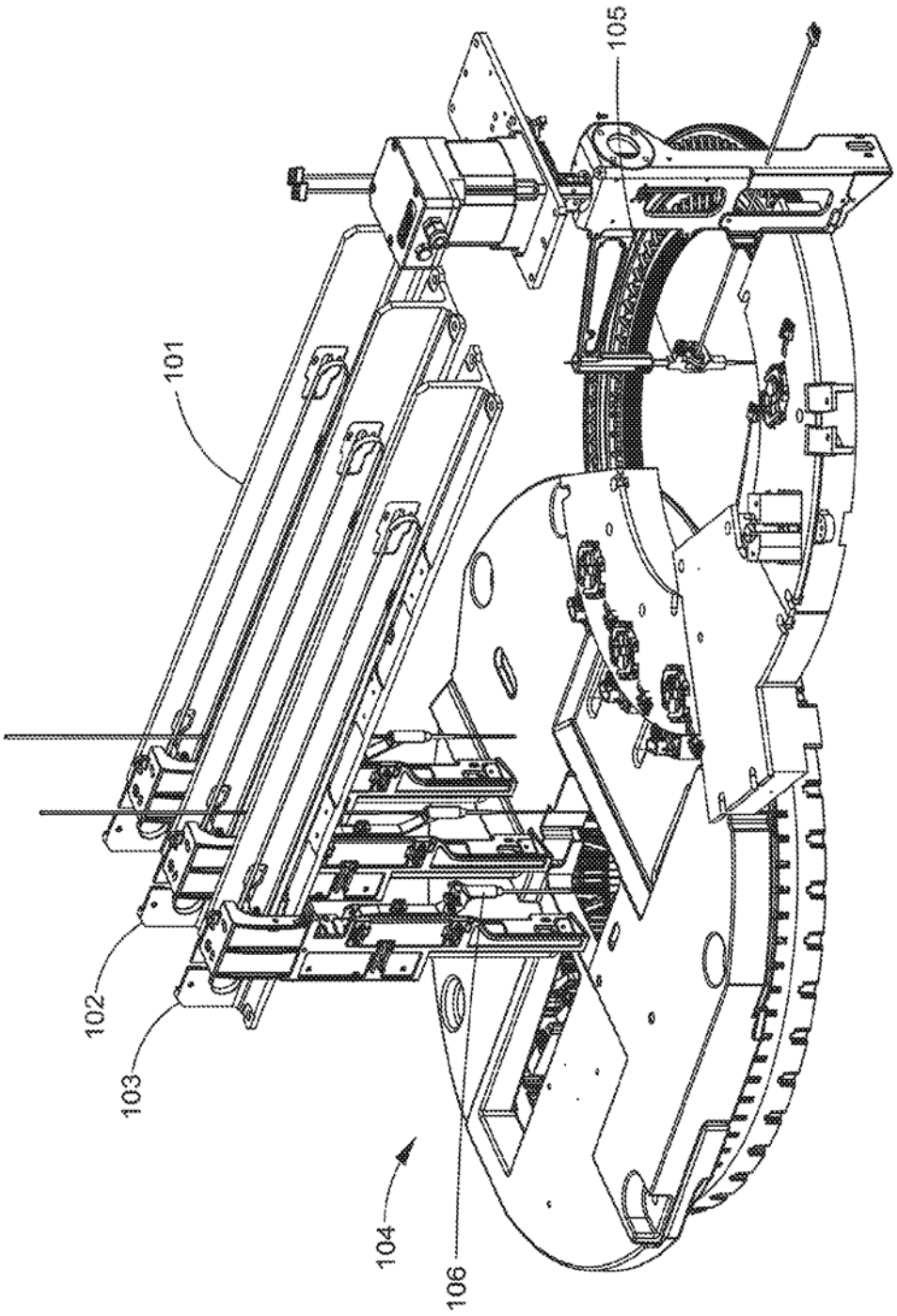


图 1

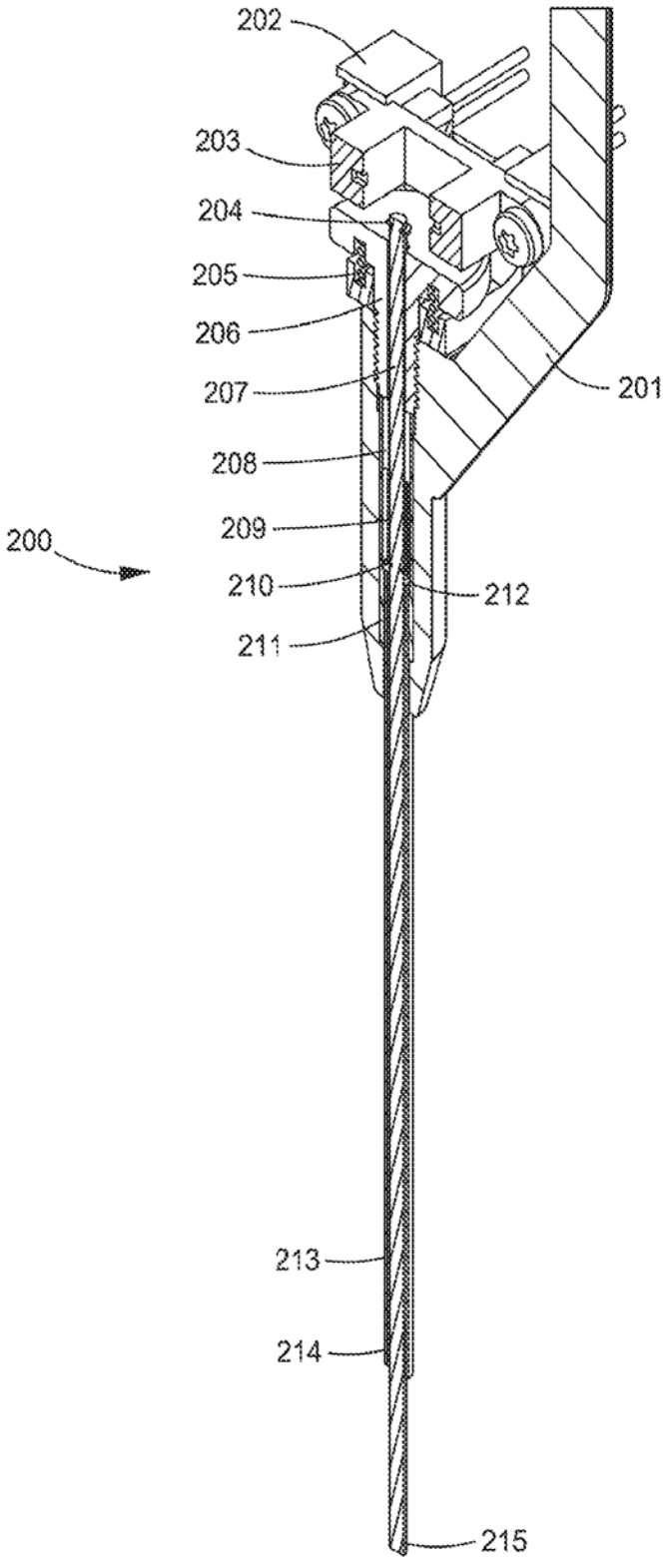


图 2

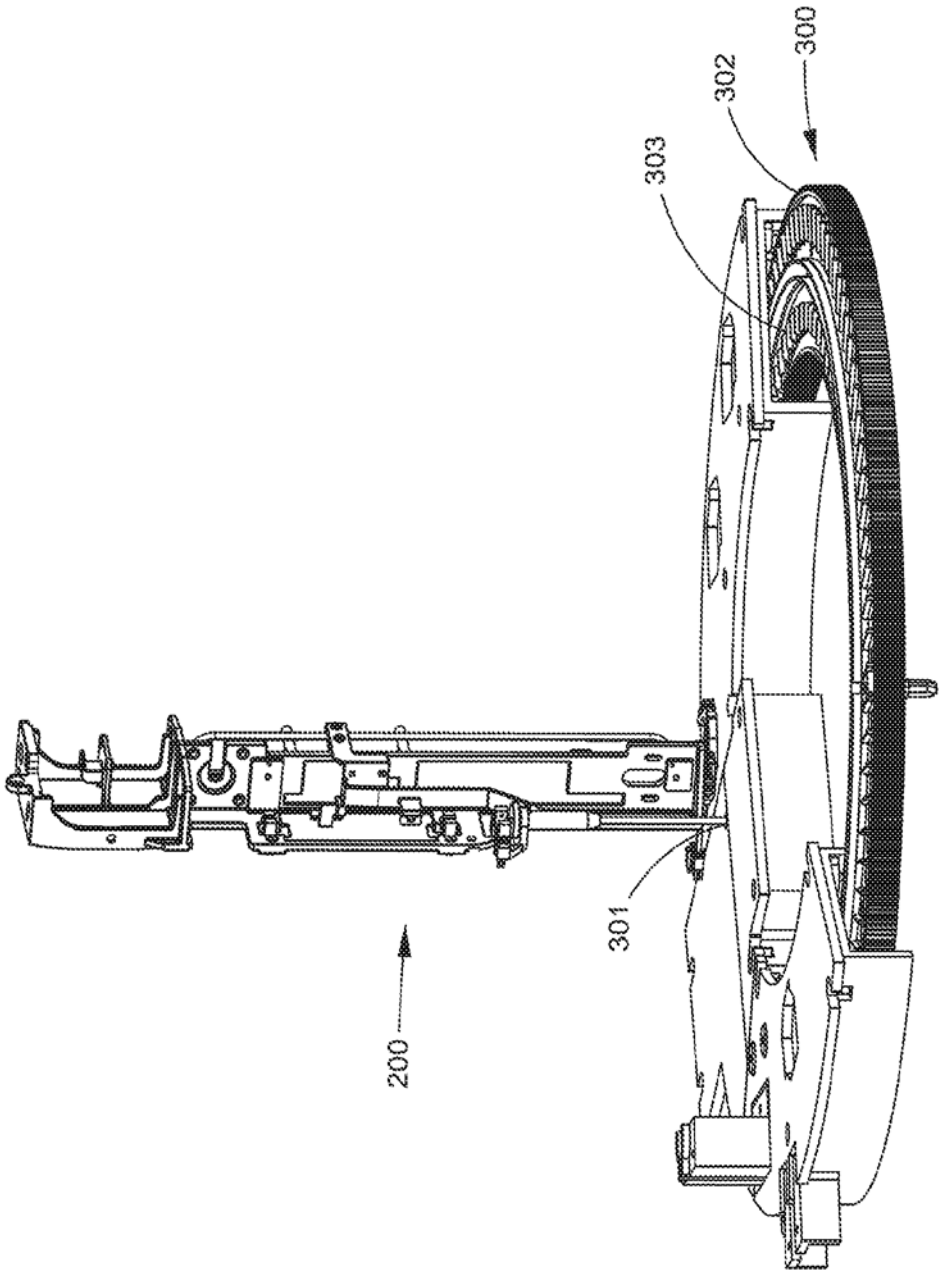


图 3

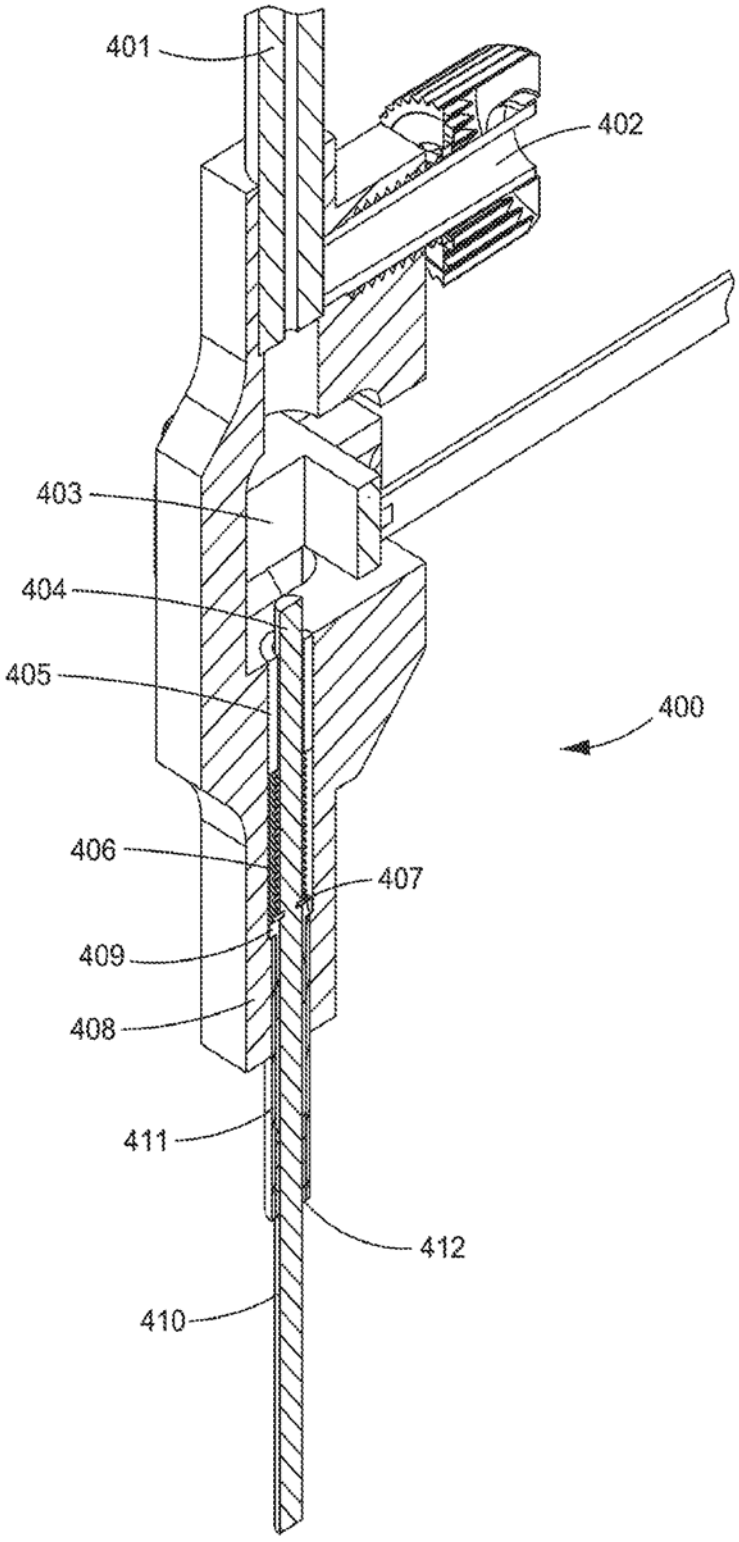


图 4

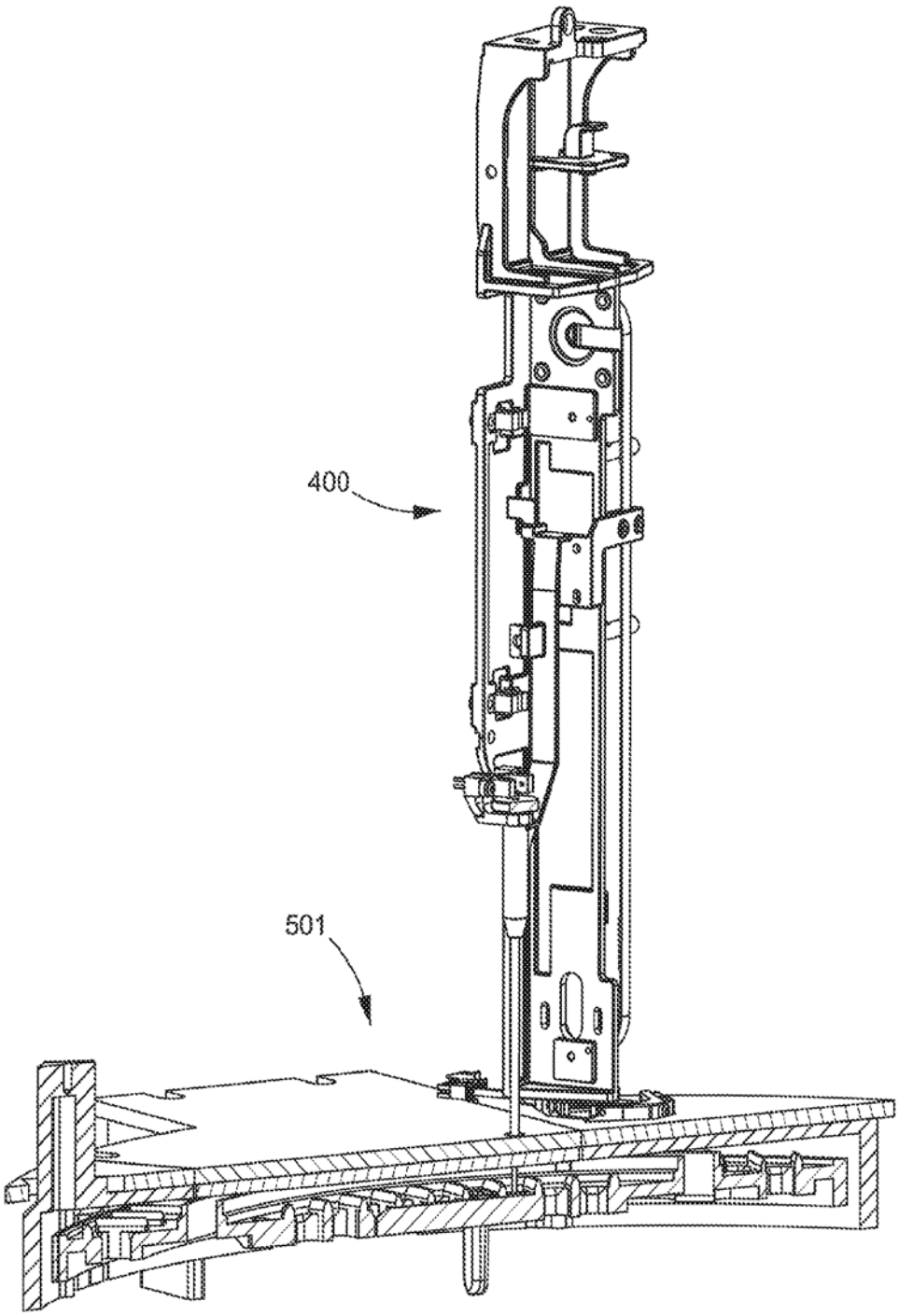


图 5

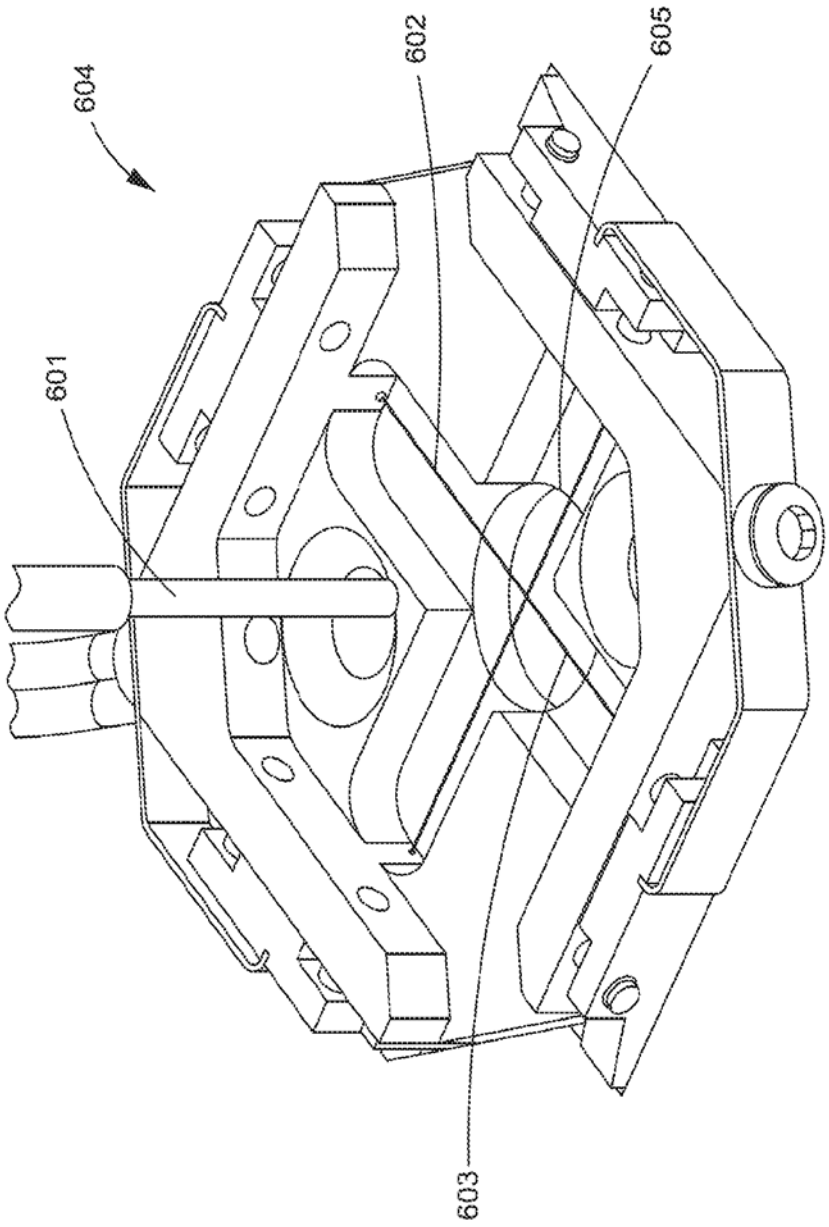


图 6

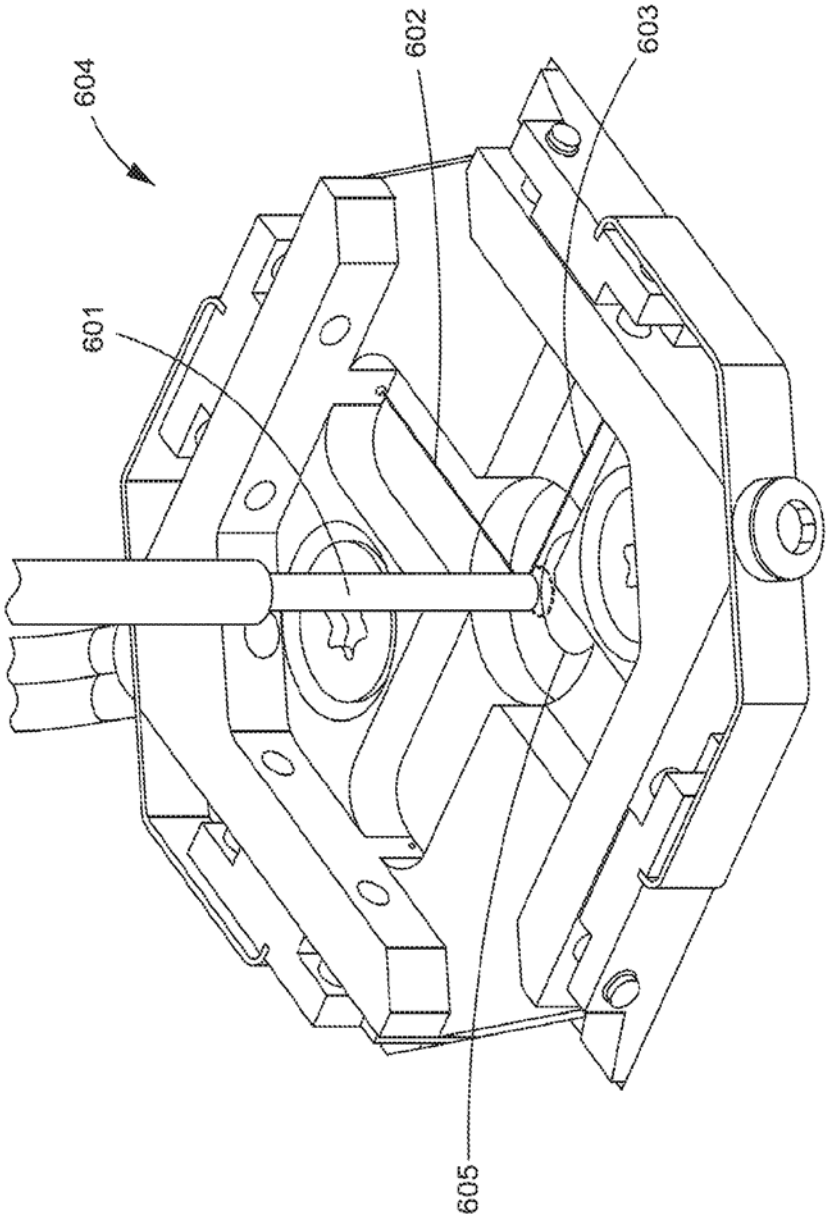


图 7

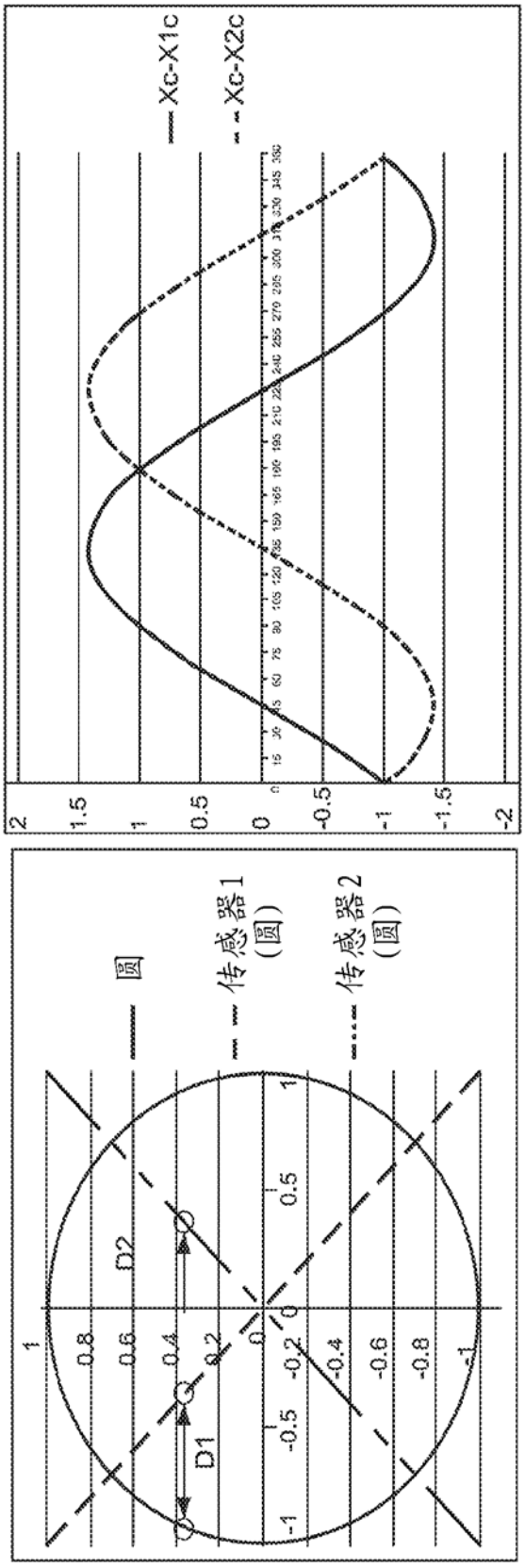


图 8

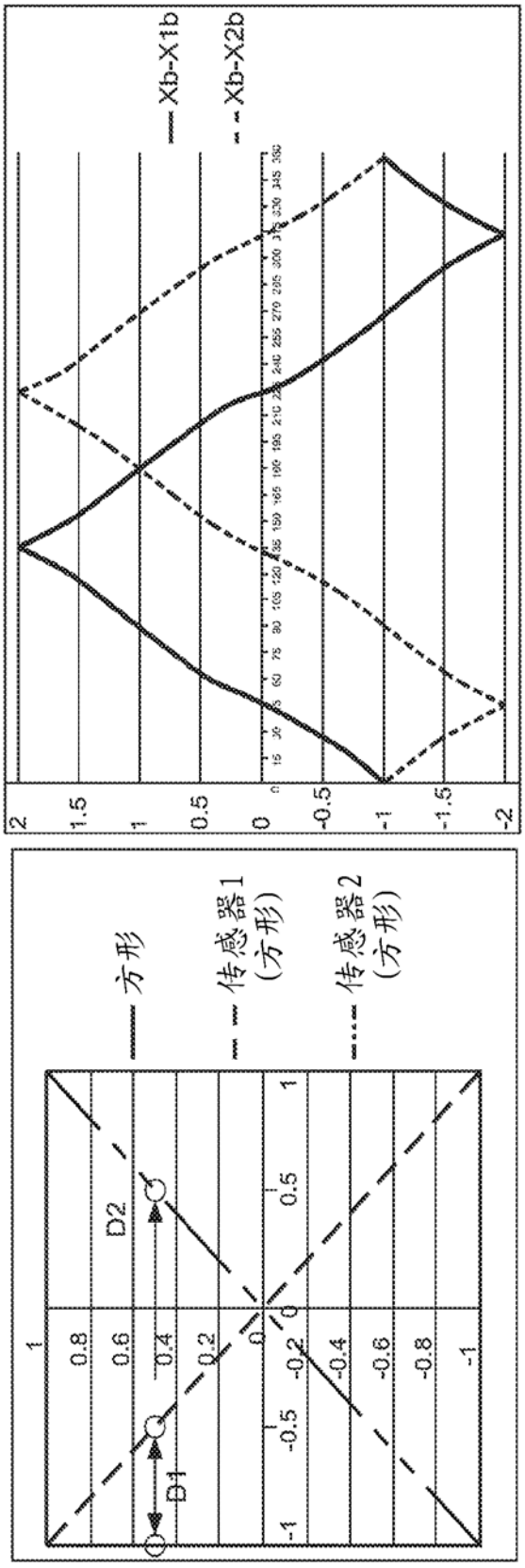


图 9

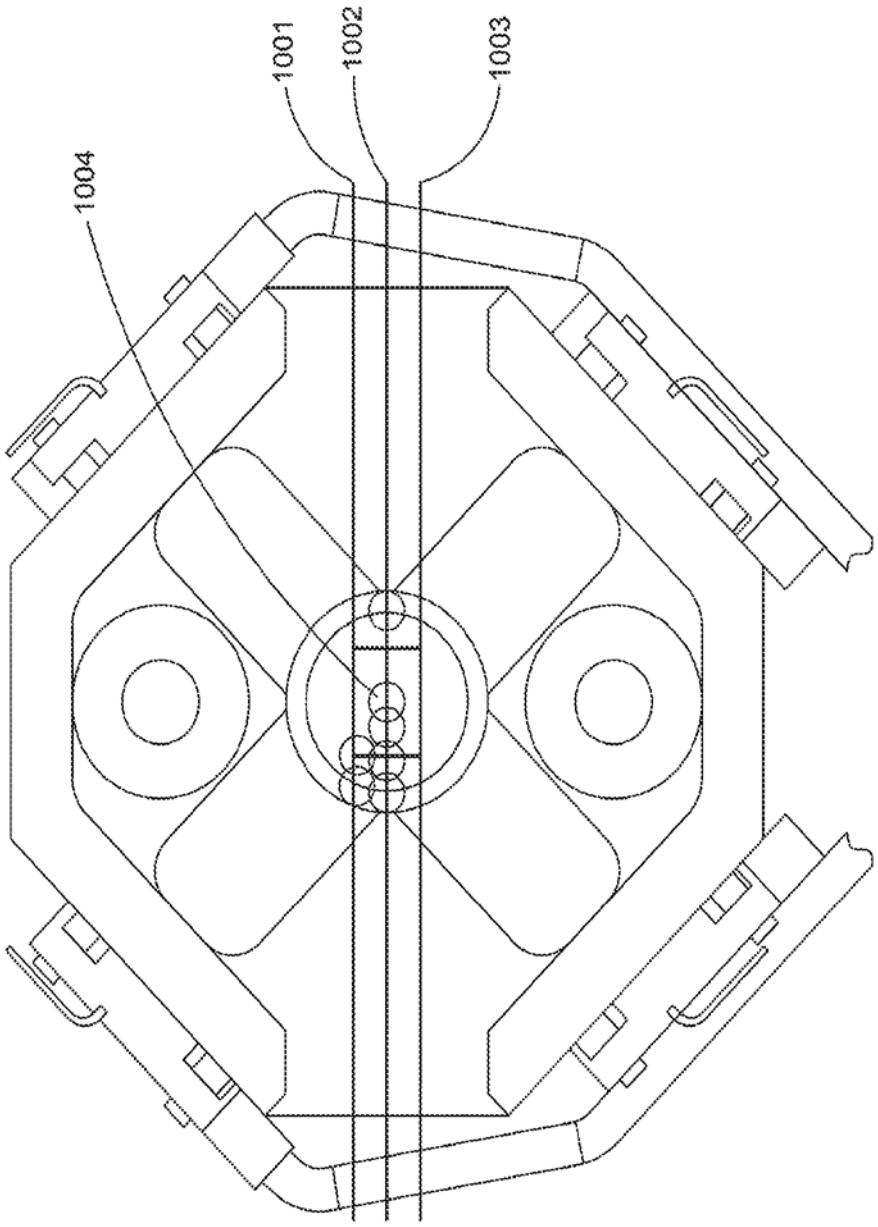


图 10

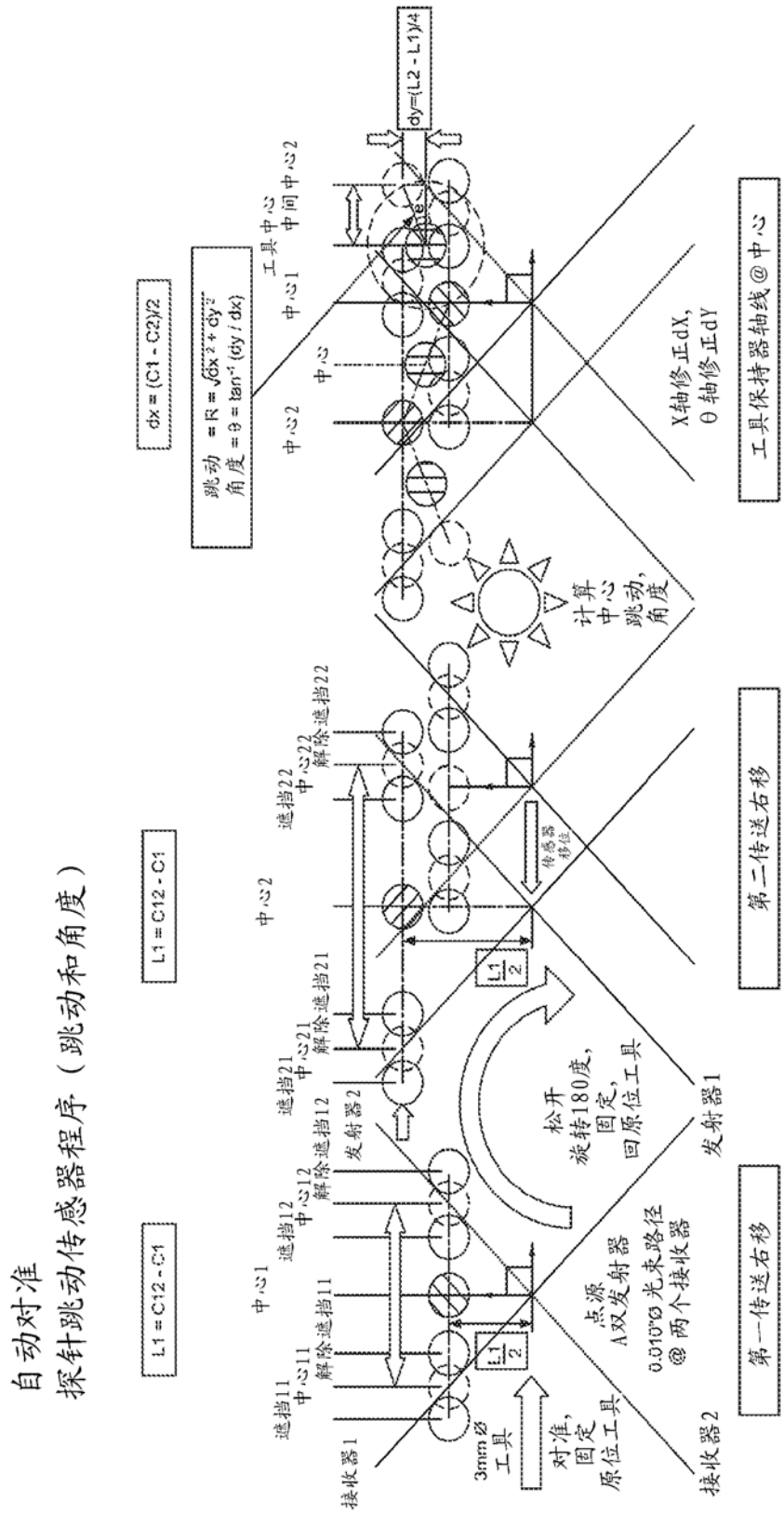

自动对准
探针跳动传感器程序（跳动和角度）
L1 = C12 - C1
L1 = C12 - C1
dx = (C1 - C2)/2
跳动 = R = √(dx² + dy²)
角度 = ϑ = tan⁻¹ (dy / dx)
dy=(L2 - L1)/4
工具中心
中间中心2
中心1
中心2
中心
遮挡11
中心11
解除遮挡11
遮挡12
中心12
解除遮挡12
发射器2
遮挡21
中心21
解除遮挡21
中心2
遮挡22
中心22
解除遮挡22
传感器移位
L1/2
L1/2
计算中心跳动，角度
X轴修正dX，
θ轴修正dY
工具保持器轴线@中心
第二传送右移
松开
旋转180度，
固定，
回原位工具
发射器1
点源
A双发射器
0.010"Ø光束路径
@两个接收器
3mmØ
工具
对准，
固定
原位工具
接收器1
接收器2
第一传送右移

图 11