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- (54) Benævnelse: **SKRUETRÆKKERANORDNING TIL EN ROBOTARM, FREMGANGSMÅDE TIL ANVENDELSE AF EN SKRUETRÆKKERANORDNING OG ET COMPUTERPROGRAMPRODUKT, DER KAN INSTALLERES PÅ EN STYREENHED TIL ROBOTARM**
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DESCRIPTION

BACKGROUND

Field of the Invention

[0001] The invention relates to a screwdriver apparatus as per the preamble of claim 1. An example of such an apparatus is disclosed by US 5 469 924 A.

[0002] The invention relates also to a method for operating a screw driver apparatus and to a computer program product capable of being installed in a robotic arm controller and of controlling a robotic screwdriver.

Description of Related Art

[0003] Industrial robots are used for automated manufacturing processes. They are programmable and capable of movement in three or more axes. Typical applications of robots include welding, painting, assembly, disassembly, packaging, labelling and testing. They have high endurance, speed and precision. The most commonly used robot configurations are articulated robots in the form of robotic arms. The links of a robotic arm are connected by joints allowing either rotational motion (such as in an articulated robot) or translational (linear) displacement. The links of the arm form a kinematic chain and the terminus called the tool flange. Often a manufacturer produces a generic robot arm that is then customised for a particular application.

[0004] The assembly of complex and delicate products such as computers often use robotic arms in the production process because of the speed and accuracy achievable with a robot can surpass that of a human operative. A particularly useful robot arm attachment in this respect is a screwdriver for installing and tightening screws. The speed and accuracy of such devices is a limiting factor in the production line, so any improvement in the speed at which the screwdriver head can move to the next location has a direct effect on the production capacity of a manufacturer. However, in recent years, as products have become ultra-compact and lightweight, relatively soft materials such as aluminium and plastic have been used, which increases the need for accuracy in screw tightening, as any misalignment or over tightening can destroy the product being assembled. Conventional screw tightening devices such as that disclosed in JP2017109259 attempt to address this problem by employing a feedback mechanism to detect the force on the screw and control a braking force applied to the device to make it larger than the weight of the tool. However, this still requires placing at least some force against the screw being installed, which still has the potential to damage the product being assembled. US2012/0067711 describes a robotic screw fastening assembly that

measures the relative positions of a screw against a placement surface and the unknown workpiece surface to eliminate measurement errors and to determine whether the screw is loose. The screw is still inserted using the conventional application of torque. A torque-judging feedback mechanism is used to control screw insertion and this torque could damage the workpiece.

[0005] It is therefore an object of the present invention to provide a stand-alone screw driver attachment for a robotic arm that does not damage the product being assembled.

SUMMARY OF THE INVENTION

[0006] The invention provides a screw drive apparatus as per claim 1, a method of operating a screw driver apparatus of the type claimed in claims 1 to 10 as per claim 11 and a computer program product capable of being installed in a robotic arm controller and of controlling a robotic screwdriver system to cause performance of the method of claim 11 as per claim 12.

[0007] Optional preferred features are defined by the dependent claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008]

Figure 1 is a representation of a generic robotic arm.

Figure 2 represents a screwdriver attachment for a robotic arm in accordance with an embodiment of the invention.

Figure 3 is a representation of the screwdriver attachment of Figure 2 on a robotic arm of the type shown in Figure 1.

Figure 4a is a cross sectional diagram of the embodiment of the screwdriver attachment of Figure 2.

Figure 4b is a cross sectional diagram of the jaws of the screwdriver attachment of the embodiment of Figure 2.

Figure 4c is bottom view of the screw gripper of the screwdriver attachment of the embodiment of Figure 2.

Figure 4d is side view of a typical screw for use in an embodiment of the invention.

Figure 4e is a top view of the screw shown in Figure 4d.

Figure 4f is a cross sectional view of the jaws of an embodiment with a screw in place.

Figure 4g is a cross sectional view of the tool tip of an embodiment engaged with the head of a screw in place in the jaws.

Figure 5 is a schematic diagram showing the elements of the control system of an embodiment of the screwdriver attachment.

Figure 6a is a cross sectional diagram showing the jaws of an embodiment in an open position and the tool tip engaged with the head of the screw just prior to installation of the screw.

Figure 6b is a cross sectional diagram showing the jaws open and the tool tip engaged with the head of the screw after installation of the screw.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0009] The screwdriver attachment in accordance with an embodiment of the invention allows for highly accurate and rapid installation of screws without applying any force in an axial direction into the screw itself. It is also possible to apply a controlled force to the screw as it is installed. This, in combination with the use of fast and accurate servomotors allows the rapid assembly of delicate parts and also a safety feature that allows a use to work closely with the attachment.

[0010] A typical robotic arm is shown in Figure 1. The arm 100 has a base 101 for mounting the arm on a surface 1000. The base 101 has a base joint 101 which allows for rotational movement between the base and a shoulder joint 102a. The shoulder joint 102a is joined to a first link 102. A second link 103 is rotationally connected to the other end of the first link 102 by an elbow joint 103a. At the other end of the second link 103 is a wrist 104 having a first joint 104a, second joint 104b and third joint 104b. A tool flange 105 is connected to the wrist. The tool flange has six degrees of movement because of the joints. Sometimes the tool flange is known as the 6th axis of the robotic arm. The tool flange 105 is a mechanical interface to which further equipment can be attached. Internal servomotors within the joints create controlled movement of the robotic arm and allow the tool flange 105 to move to any point in space around the robot arm within its range. The robotic arm is operated by control software running on hardware. When the robot arm is installed, the position of a central point on its base P_B is recorded as a set of 6 values; the 3 dimensional coordinates, (x, y, z) plus 3 values that determine the orientation of the plane of the base; pitch, yaw and roll. The robot arm could be mounted on a wall or other non-horizontal surface. P_B is a reference point against which all other positions are taken. The servo motors which control the arm have encoders which output an absolute value so the exact coordinates P_E of the tool flange are always known. The hardware may be integrated into the arm or an external computer may be attached to run the software.

[0011] Figure 2 shows an embodiment of a screwdriver attachment 200 for a robotic arm. The screwdriver attachment 200 comprises a body section that contains control motors and other control hardware inside a housing 201. The screwdriver attachment 200 has a lower tool section 202 that is arranged to manipulate and install screws. A feed tube 203 is provided that can be connected to a suitable screw-feed system, such as a pneumatic system fed with air. Screw-feed systems are known in the art. A cable 204 provides a link to a screwdriver programming and control interface. The x and y coordinates define a plane while the z-direction is perpendicular to the x/y plane. The tool section is aligned with the z-direction.

[0012] Conventional screwdriver attachments rely on feedback from the servomotors of the robotic arm to establish how much force is being applied in the z-direction. This means that the screwdriver and the robotic arm must be able to communicate with each other, which increases the complexity of integrating these two units, as a user would need to know a deep level of programming for both systems. The problem is compounded because often, different manufacturers produce the screwdriver attachment and the robotic arm.

[0013] In the present invention, this problem is overcome by giving all of the z-direction force responsibility to the screwdriver attachment 200. The responsibility for positioning the tool in the correct place belongs to the robotic arm 100.

[0014] Figure 3 shows an embodiment of the robotic screwdriver attachment 200 installed on a robotic arm 100. The screwdriver 200 is attached to the tool flange 105 of the robotic arm 100. The screwdriver 200 is electronically connected to a screwdriver controller 301 by cable 302. A robot arm controller 303 is connected by a LAN cable 304. The robot arm controller 303 has a user interface 305. A standard pneumatic screw feeder 306 is provided to feed screws to the screwdriver 200. The screwdriver controller 301 controls the screw feeder 306 and they are connected to each other by cable 307. The screwdriver 200 has a sensor that can sense when a screw has arrived; the feeder 306 can be instructed to resend a screw if one doesn't arrive for any reason, or an alarm signal send to the screwdriver controller if repeated attempts to send a screw fail. Communication between the feeder 306 and the screwdriver 200 is via cable 308..

[0015] Figure 4a shows the components of an embodiment of the robotic screwdriver attachment. The components are located inside the housing 201. A tool 401 is provided, comprising a tool tip 402 and a shaft 403. The tool tip 401 has flat faces and a hexagonal cross-section and is arranged to engage with the head of a screw to be inserted. The shaft 403 has an axis about which it rotates and this axis defines the z-direction. The shaft 403 is connected to a tool motor 404. In this embodiment, the tool motor is a servomotor with an output torque of between 0-3.6 Nm, rotation speed of 5000 RPM and an encoder resolution of 131,072 pulses per revolution. or more. The tool motor 404 is fixed into a housing that is arranged to be movable up and down along a rail 405. The servomotor is connected to an external amplifier 404A that can control the position, speed and torque of the tool motor 404. The tool motor 404 has a rotary encoder that outputs the absolute angular position of the motor axle from which the position of the tool tip 402 can be determined.

[0016] The tool motor housing has a bracket supporting an internally threaded nut 406 that engages with an externally threaded shaft 407, such that rotation of the threaded shaft 407 causes the tool motor to move vertically along the rail 405 in the z-direction. The threaded shaft 407 is a ball screw with a 10mm pitch; other pitches could be used, for example 6mm, 8mm, 12mm, 14mm etc. This high helix, steep thread screw and nut arrangement allows for quick adjustment of small loads because a single turn causes the nut to travel a relatively long distance along the thread.

[0017] The threaded shaft 407 is connected to a z-direction motor 408. The z-direction motor 408 is a servomotor similar to the tool motor 404 but has torque in the range 0.2-0.4 Nm is required. The combination of a high performance servo motor, i.e. high speed and high accuracy, with a high pitch lead screw allows the position of the tool to be moved over large distances quickly but with very high accuracy. The z-direction motor 408 has a rotary encoder that outputs the absolute angular position of the motor axle and hence the angular position of the threaded shaft 407. The encoder is also enabled to count the absolute number of turns of the axle, so that the position of the nut 406 on the shaft is always known and correspondingly the position of the tool tip 402 in the z-direction, Z_T , is always known. For the type of z-direction motor specified above, its encoder has a resolution of 131,072 pulses per revolution. The threaded shaft has a pitch of 10mm per turn, therefore the position of the tool tip can be controlled and measured to an accuracy of around $\pm 0.05\text{mm}$. The z-direction motor has a speed of 5000 RPM. The threaded shaft is 290mm in length, therefore it would take 50 turns for the nut 406 to travel from one end of the lead screw to the other. Therefore the tool tip can be raised from its lowest position to its highest position in just under 1 second.

[0018] The tool 401 is movable inside a screw housing tube 409 that extends below the main housing 201. The length of the tool housing tube 409 is selected in relation to the accessibility required for the tool 401. A screw feed tube 409a is provided towards the top of the tool housing tube 408. The tool tip 402 is retractable by operating the z-direction servomotor 408 to above the entrance of the screw feed tube so that a screw may enter the tool housing tube 409. The end of the tool housing tube 409 has a screw gripper 410 which is a set of jaws to prevent a screw that enters the screw housing tube 409 from dropping out of the end before it is installed.

[0019] The jaw arrangement is shown in more detail in Figure 4b, which is a vertical cross-sectional view of the jaws. The housing tube terminates in a hinge portion that supports two jaws, 411a, 411b. The end profile of each jaw is semi-circular with a semi-circular aperture, so that when the jaws are closed, they together form a circular opening 412 as shown in Figure 4c through which the end of a screw can protrude. Figure 4c shows a bottom view of the screw gripper taken along the line AA in Figure 4d where the circular opening 412 can be seen. A cross-section of the jaws in a closed position is shown in Figure 4b, with a space between the jaws S_j large enough to accommodate the thread diameter of a screw to be installed. Each jaw has an internal lip 413a, 413b that provides a screw head shelf upon which the head of the screw to be installed can rest, prior to installation. The jaws of the screw gripper 410 are spring

loaded and are opened by pushing down on the screw. The position of the end of the jaws of the screw gripper, P_J , is a 3 dimensional coordinate and is always fixed in relation to the position of the tool flange P_T . The position of the jaws, P_J , provides a reference point from which all other positions in the screwdriver are measured. This point is fixed with reference to the screwdriver itself because it is fixed to the housing. The point moves relative to the robotic arm and therefore the robotic arm determines the position of this point. The robotic arm is programmed to move this point to the required screw installation position.

[0020] The vertical z-axis position Z_S of the screw head shelves 413a, 413b is known in relation to P_J . Z_S is a fixed reference point. The z-axis position of the tool tip 402, Z_T is known from information provided by the encoder of the z-axis motor 408 and this is variable.

[0021] Figure 4d shows in more detail a side view of a screw 4001 to be installed. The screw 4001 has a head 414 with a hexagonal recess 415 for receiving the hexagonal-faced tool tip 402. A top-view of the screw head 414 is shown in Figure 4e. The screw has a thread 416, with a known pitch P_S . The thread 416 has a known length, L_T , between a screw thread tip 417 and the underside 418 of the head 414. The thread is orientated along an axis AA. The axis A' of the tool shaft 403, when engaged with the screw, aligns with this axis AA. This axis defines the z-direction. The screw head recess 415 has a known depth, L_R , and the bottom of the recess is a known distance, L_{HR} , from the underside of the head of the screw. Accurate knowledge of the dimensions of the screw are important for the invention to function because the distance between the tool tip and the screw is carefully maintained during installation of the screw 4001. The characteristics of each screw to be installed are recorded. The characteristics recorded include:

- Screw pitch, P_S
- Thread length, L_T
- Recess position, L_{HR}

[0022] The length of the thread of the screw L_T is used to calculate the absolute position of the end of the screw, P_{ES} , which protrudes a short way past the end of the jaws. This protrusion provides a starting length for the screw to engage with a component into which the screw is to be installed.

[0023] Figure 4f shows the jaw arrangement with a screw 4001 in place and with the tool tip 402 engaged, ready for joining together two components 4002a, 4002b. The components have a pre-drilled and threaded hole located at a known position P_H relative to the position of the base P_B of the robot arm. The position of the end of the screw P_{ES} is calculated from the position of the jaws P_J the length of the thread L_T and the position of the end effector P_E of the robotic arm relative to its base position P_B as shown in Figure 1.

[0024] Figure 4g is a close-up detail of the head 414 of the screw and the tool tip 402, where a gap, G, is defined between the end of the tool tip and the bottom of the screw head recess 415. This gap is maintained during the installation process and thus the only force applied to the screw is torque by the hexagonal faces of the tool tip engaging with the hexagonal faces of the recess. By maintaining the gap, there is no z-direction force applied. The gap between the tool tip and the screw is created initially by controlling the distance between the tool tip and a point on the screw gripper, which could be the end of the jaws, P_J.

[0025] The arrangement of the screwdriver controller 301 is shown schematically in Figure 5. A processor in the form of a programmable logic controller (PLC) 501 is in communication with a memory unit 502. The memory unit 502 includes a database for storing parameters characterising the screw type that is being installed and for storing information relating to the screw installation, including the absolute positions (x, y, z coordinates) of the holes into which the screws are to be installed and the speed at which the screw is to be installed and the torque to which the screw is to be tightened. Screw installation information can be entered manually or a teaching mode can be used, whereby the screwdriver is positioned manually and the coordinates and other parameters learned and stored so that the operating sequence can be for automated as described below.

[0026] The PLC 501 is arranged to execute a series of operations using the values stored in the database 502. The PLC 501 is arranged to transmit instructions to the tool motor amplifier 404A and to the z-direction motor 407A. It is also arranged to transmit instructions to the robotic arm controller 303

[0027] An interface 503 including a display and data entry means is attached to the PLC.

[0028] In use, an automated procedure, once programmed by the user would comprise the following steps:

1. 1. Initiation

- The user selects a screw type via the interface.
- The PLC 501 then calculates the offset between the position of the end of the screw, P_{ES} and the tool flange.
- The PLC calculates the number of turns to provide to the z-direction motor per turn of the tool tip, as a function of the pitch of the screw.
- The PLC then sends a signal to the z-direction motor amplifier to fully retract the tool tip and to load a screw from the feeder.
- The PLC then sends a signal to the robotic arm to move the screwdriver attachment so that P_{ES} is at the position of the first hole, P_H.

2. Installation

[0029] When $P_{ES} = P_H$, the threads of the screw and the threads of the hole on the work-piece 4002a are aligned and ready to engage. The PLC 501 sends a control signal to operate the z-position motor until the tool tip 402 is engaged in the screw head recess 415 leaving a predefined gap of 0.1mm between the end of the tool tip and the bottom of the recess in the screw head. The tool tip then presses down on the screw which opens the jaws, as shown in Figure 6a, and the screw will remain in place, captured between the work-piece 4002b and the tool tip 402. The PLC then operates the tool motor and the tool tip engages with the head of the screw to turn it. As the screw turns, it moves downwards into the threaded hole of the component, by a distance equal to the pitch of the screw, $Pitch_S$, multiplied by the number of turns, N_S , applied to the screw. The PLC operates the z-direction motor to turn the lead screw by a corresponding number of turns, N_{LS} , to maintain the gap G between the tool tip and the bottom of the recess in the screw head, or if a force is required to be applied, to move the tool tip towards a position below the screw head. The number of turns, N_{LS} applied to the lead screw by the z-direction motor as a function of the number of turns applied to the screw, N_S , is calculated by the PLC as follows:

For zero force to be applied in the z-direction throughout the screw installation process, the change in the z-coordinate of the position of the tool tip, ΔzP_T , should be kept equal to the change in the z-coordinate of the bottom of the screw, ΔzP_R :

$$\Delta zP_T = \Delta zP_R \quad (1)$$

[0030] The change in the z-coordinate of the bottom of the screw recess, ΔzP_R , is a function of the screw pitch, $Pitch_S$, and the number of turns applied to the screw, N_S :

$$\Delta zP_R = Pitch_S \times N_S \quad (2)$$

[0031] The change in the z-coordinate of the tool tip 402, ΔzP_T is dependent on the lead screw pitch $Pitch_{LS}$ and the number of turns of the lead screw 407, N_{LS} , applied by the z-direction motor 408:

$$\Delta zP_T = Pitch_{LS} \times N_{LS} \quad (3)$$

[0032] Combining equations (2) and (3) into equation (1), the number turns that must be applied to the lead screw by the z-direction motor 408 as a function of the number of turns that are applied to the screw by the tool motor 404 is given as

$$N_{LS} = N_S \times \frac{Pitch_S}{Pitch_{LS}} \quad (4)$$

[0033] The number of turns can be a whole number or a part of a whole number. For example, if the screw pitch is 0.5mm and the lead screw pitch is 10mm, the z-direction motor should move by 0.05 turns (or 6,550 pulses of the encoder for an encoder with 131,072 ppr

resolution) for each turn of the tool-tip motor.

[0034] For a screw of length 50mm and pitch 0.5mm, the screw should be turned 100 times by the tool motor to be fully installed. For a lead screw pitch of 10mm, the z-direction motor should turn 5 times in the same time for the screw to be fully installed with zero force applied in the z-direction. A fully installed screw is shown in Figure 6b. The processor controls the speed at which the screw is turned and the torque to which it is tightened. The use of high precision AC servomotors allows the screw to be installed quickly, with a high accuracy and with zero force in the z-direction.

[0035] An alternative approach to achieving the objective of controlling the z-direction motion of the tool tip so that it follows the screw as it is installed is described below.

[0036] The tool tip starts screwing in the screw, the z-direction motor needs to be operated so that the tool tip follows the screw as the screw is installed. The movement of the tool tip along the z-axis is effected by triggering a defined number of encoder steps at a given speed, calculated as follows:

The user-defined parameters for the screwing operation are:

- Length of screw L_S .
- Screw thread pitch $Pitch_S$.
- Number of rotations R of the tool tip to fully install the screw ($= L_S \times Pitch_S$).
- Tooltip screwing speed S_s .
- Number of encoder steps in 360 degrees E_{360} .
- Number of encoder steps to move 1mm along the Z axis Z_E .

[0037] $Z_E = E_{360} \times Pitch_{LS}$, because pitch is the number of turns per mm, therefore the pitch of the Lead Screw, $Pitch_{LS}$, gives the number of turns of the Lead Screw, N_{LS} , required to move along the z-axis by 1mm.

[0038] The time it takes to install the screw T_S is given by:

$$T_S = L_S \times Pitch_S / S_s$$

[0039] The Length of the screw is converted to the number of encoder steps Z_{ES} required to follow the screw in the z-direction as it is screwed in:

$$Z_{ES} = L_S \times Z_E$$

$$Z_{ES} = L_S \times E_{360} \times Pitch_{LS}$$

[0040] The speed required for the z-axis motor is then given by:

$$S_{z,c} = Pitch_S \times S_s / Pitch_{LS}$$

[0041] This allows the tool tip to follow the screw, while maintaining a small gap between the tool tip and the screw recess and therefore apply zero pressure to the screw.

[0042] It is also possible to apply a controlled amount of force to the screw by moving the tool tip to a position slightly lower than the bottom of the recess in the screw. The distance that the tool tip is set to below the position of the screw will define the amount of force applied to the screw. By adjusting the starting point of the tool tip to a bit lower in relation to the screw, which initially is defined relative to the position of the jaws of the screw gripper, P_J , force during tightening will be applied to the fastener in the z-direction. This could be required for example if there is a spring washer placed between the screw and the component, and a small amount of force is required to compress the washer. Force can also be applied to correct for defects in the components being fixed together.

[0043] The screwing can be carried out in stages. The first stage involves slow rotation of the tool tip, around 500 RPM, as the screw catches the thread in the component. The second stage is the main rotation stage which can be much faster for screwing in the majority of the thread, at around 5,000 RPM. The third stage is again slower, at around 500 RPM as the screw is tightened to the required torque, which requires slower motion so that the torque can be measured.

3. Repetition

[0044] The PLC instructs the z-direction motor to retract the tool tip entirely, the jaws spring closed and a new screw to be loaded into place in the jaws. At the same time, the PLC instructs the robot arm to move the screwdriver attachment to the next position in the sequence. The process is then repeated. Fast and accurate control over the z-position of the tool tip allows for zero force in the z-direction, but also for the time between each screw installation to be minimised because a new screw can be loaded and put in place while the robotic arm is moving.

[0045] The screw may have a recess in its head that is cross-shaped or a flat channel and the tool tip would have a corresponding shape.

[0046] Different sized screws can be accommodated by simply changing the tool 401, as shown in Figure 7. The tool 401 includes the screw housing 409, the jaw assembly 410 and the screw feed input 701. The tool 401 attaches to the screwdriver housing 201 by a protruding tab 702.

REFERENCES CITED IN THE DESCRIPTION

Cited references

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Patent documents cited in the description

- US5469924A [0001]
- JP2017109259B [0004]
- US20120067711A [0004]

PATENTKRAV

1. Skruetrækkeranordning (200) til en robotarm (100), hvilken anordning er egnet til iskruning af skruer (4001) med en kendt stigning i en komponent (4002a, b), hvilken anordning omfatter;

5 et skrueværktøj (401) med en aksel (403), der kan rotere omkring en midterakse, hvilken aksel har en distal ende med en spids (402), der er egnet til at gå i indgreb med en skrue, hvilken aksel endvidere har en proksimal ende forbundet med både en værktøjsrotationsanordning (404) og en anordning (408) til lineær bevægelse af værktøjet,

10 hvor værktøjsrotationsanordningen (404) er indrettet til at rotere værktøjet (401) omkring midteraksen, og anordningen (408) til lineær bevægelse af værktøjet er indrettet til at bevæge værktøjet (401) langs midteraksen,

15 hvor værktøjsrotationsanordningen og anordningen til lineær bevægelse af værktøjet er indrettet til at blive styret afhængigt af skruens stigning, således at værktøjsspidsen (402) holdes i en konstant foruddefineret afstand i forhold til skruen, når den er i anvendelse, for at bevare en styret kraft på skruen, når skruen drejes, hvor skruetrækkeranordningen er **kendetegnet ved, at** den foruddefinerede afstand kan indstilles således, at der er en åbning mellem værktøjsspidsen (402) og skruen, således at, der, i anvendelse, påføres nul kraft langs midteraksen, når skruen isættes.

20 2. Skruetrækkeranordning ifølge krav 1, hvor værktøjsrotationsanordningen omfatter en værktøjsrotationsmotor (404), der er forbundet med værktøjet (401), og en værktøjsrotationsmotorstyreenhed (404a) til styring af værktøjsrotationsmotoren.

25 3. Skruetrækkeranordning ifølge krav 1 eller 2, hvor anordningen til lineær bevægelse af værktøjet omfatter en motor (408) til lineær bevægelse af værktøjet, en motorstyreenhed (407a) til lineær bevægelse af værktøjet til styring af motoren til lineær bevægelse af værktøjet.

30 4. Skruetrækkeranordning ifølge krav 3, hvor motoren (408) til lineær bevægelse af værktøjet er forbundet med en ledeskruer (407), der er parallel med midteraksen, hvilken ledeskruer har en kendt stigning, hvor værktøjet er forbundet med en møtrik (406) monteret på ledeskruen, således at rotation af ledeskruen bevirker, at værktøjet bevæger sig langs midteraksen.

5. Skruetrækkeranordning ifølge et hvilket som helst foregående krav, og som indbefatter

en hukommelsesenhed (502), hvilken hukommelsesenhed er indrettet til at lagre brugerdefinerbare parametre vedrørende den skruetype, der iskrues, indbefattende skruestigningen, og parametre vedrørende anordningen til lineær bevægelse af værktøjet, indbefattende ledeskruens stigning, skruehastigheden og momentet.

5

6. Skruetrækkeranordning ifølge et hvilket som helst foregående krav, og som indbefatter en processor (501), der er indrettet til at sende værktøjsrotationssignaler til værktøjsrotationsmotorstyreenheden om at rotere værktøjet og til at sende signaler om lineær bevægelse af motorstyreenheden til lineær bevægelse af værktøjet, hvor processoren er indrettet til at beregne signalerne om lineær bevægelse af værktøjet baseret på værktøjsrotationssignalerne og forholdet mellem skruens stigning og ledeskruens stigning.

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7. Skruetrækkeranordning ifølge krav 5 eller 6, hvor motoren til værktøjsrotationsanordningen og anordningen til lineær bevægelse af værktøjet er servomotorer med indkodere, og hvor hukommelsesenheden endvidere er indrettet til at lagre data vedrørende antallet af indkodertrin ved en fuld drejning af ledeskruen og antallet af indkodertrin, der er krævet for at bevæge et værktøj en kendt afstand langs midteraksen.

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8. Skruetrækkeranordning ifølge kravene 5 til 7, hvor hukommelsesenheden er indrettet til lagring af en brugerdefineret skruehastighed, hvorved skruen iskrues, og hvor processoren er indrettet til at styre motoren til værktøjets lineære bevægelseshastighed baseret på skruehastigheden og forholdet mellem skruens stigning og ledeskruens stigning.

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9. Skruetrækkeranordning ifølge et hvilket som helst foregående krav, og som indbefatter et skruehusrør (409) til modtagelse af en skrue fra en skruetilførselsanordning, en skruegriber (410) ved enden af husrøret til at gribe en skrue, og hvor husrøret og skruegriberen er aftagelige og kan udskiftes med en anderledes dimensioneret indretning for at muliggøre iskruning af skruer af forskellig størrelse.

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10. Robotskruetræktersystem, som omfatter et skruetrækkertilbehør (200) ifølge et af kravene 1 til 9, hvor skruetrækkertilbehøret styres af en skruetrækkerstyreenhed (301), hvilket system endvidere omfatter en robotarm (100) og en robotarmstyreenhed (303), hvor robotarmstyreenheden indbefatter en brugergrænseflade (305) til en bruger til indlæsning af instruktioner til styring af systemet.

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11. Fremgangsmåde til anvendelse af en skruetrækkeranordning af typen ifølge kravene 1 til 10, hvilken fremgangsmåde omfatter følgende trin:

styring af en værktøjsrotationsmotor (404) til at rotere en skrue,

5 styring af en motor (408) til lineær bevægelse af værktøjet til at bevare skruen i en forudbestemt afstand fra skruen, når skruen roteres, for at styre den kraft, der påføres skruen ved iskruning, hvilken fremgangsmåde er **kendetegnet ved, at** den foruddefinerede afstand kan indstilles således, at der er en åbning mellem værktøjet og skruen, således at der ved anvendelse påføres nul kraft langs midteraksen, når skruen iskrues.

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12. Computerprogramprodukt, der kan installeres i en robotarmstyrenehed, og til styring af et robotskruetrækkesystem til at bevirke udførelse af fremgangsmåden ifølge krav 11.

DRAWINGS

Fig. 1

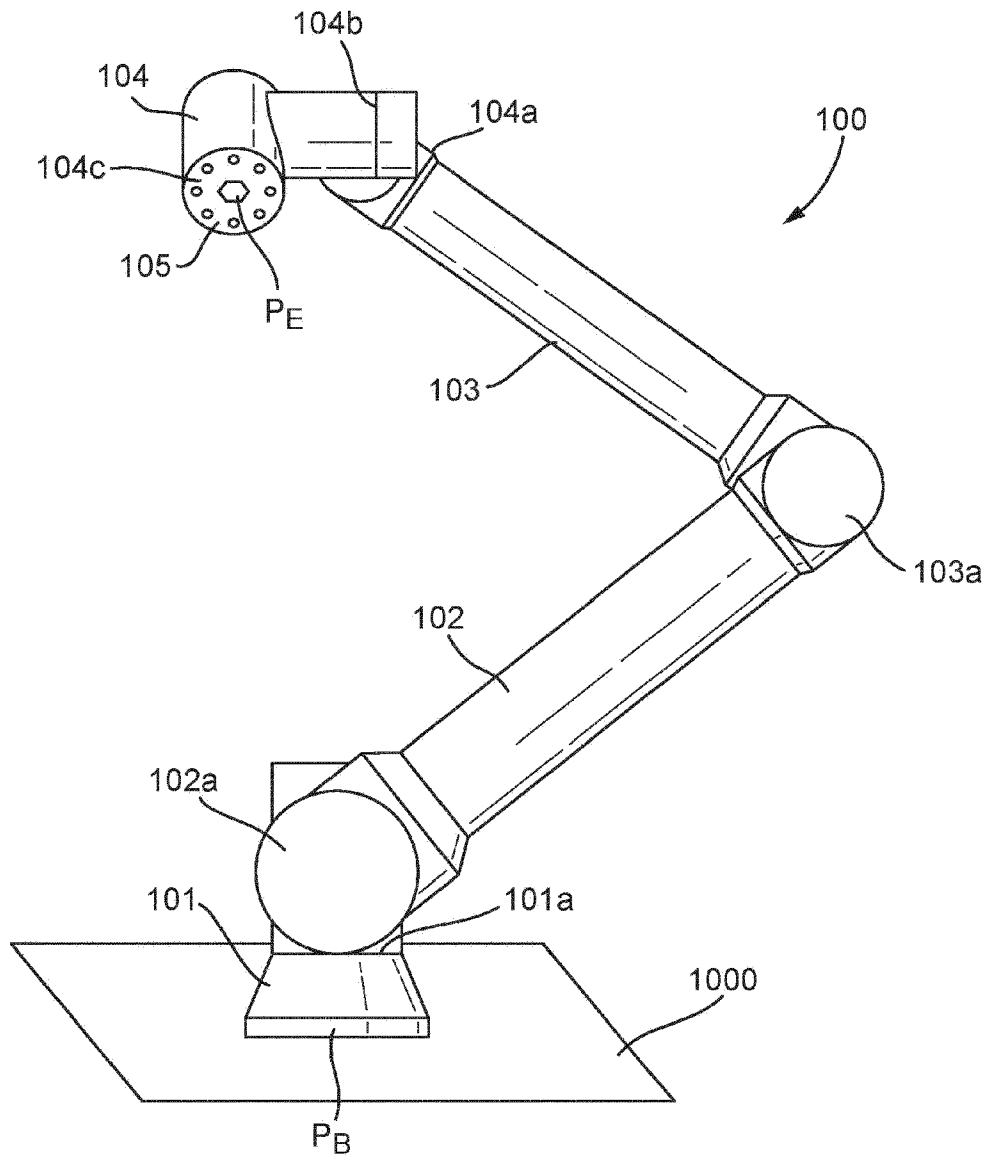


Fig. 2

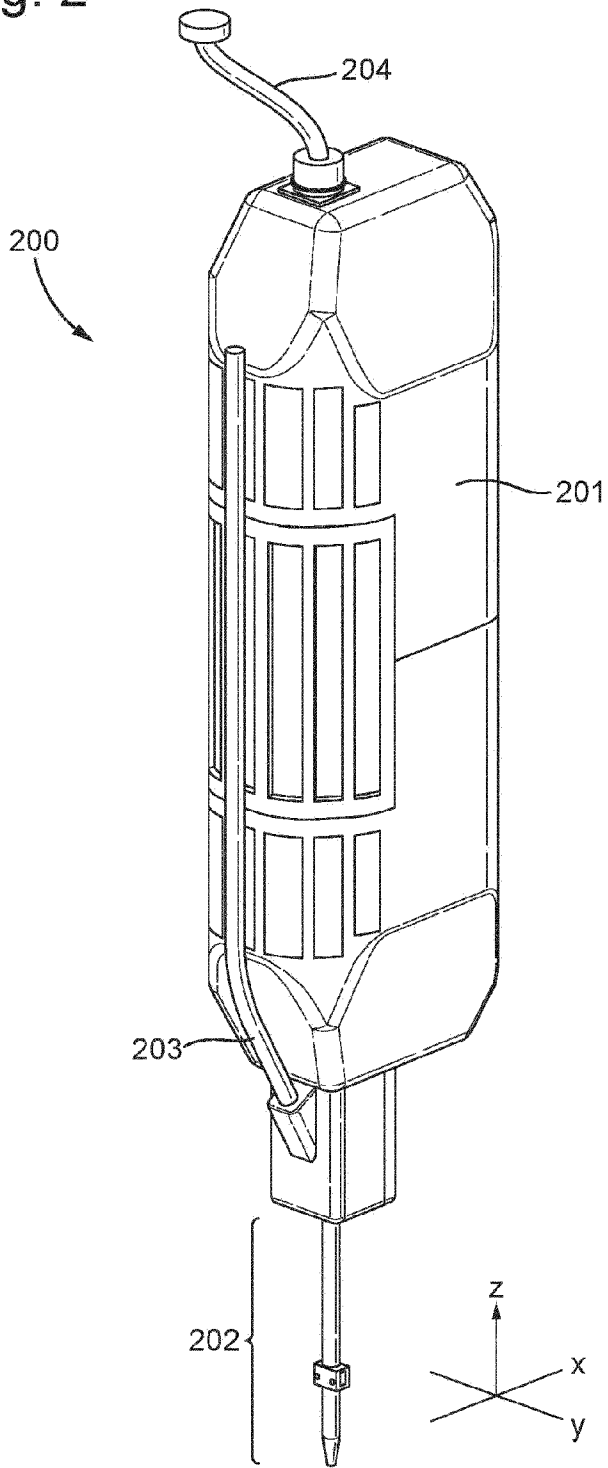


Fig. 3

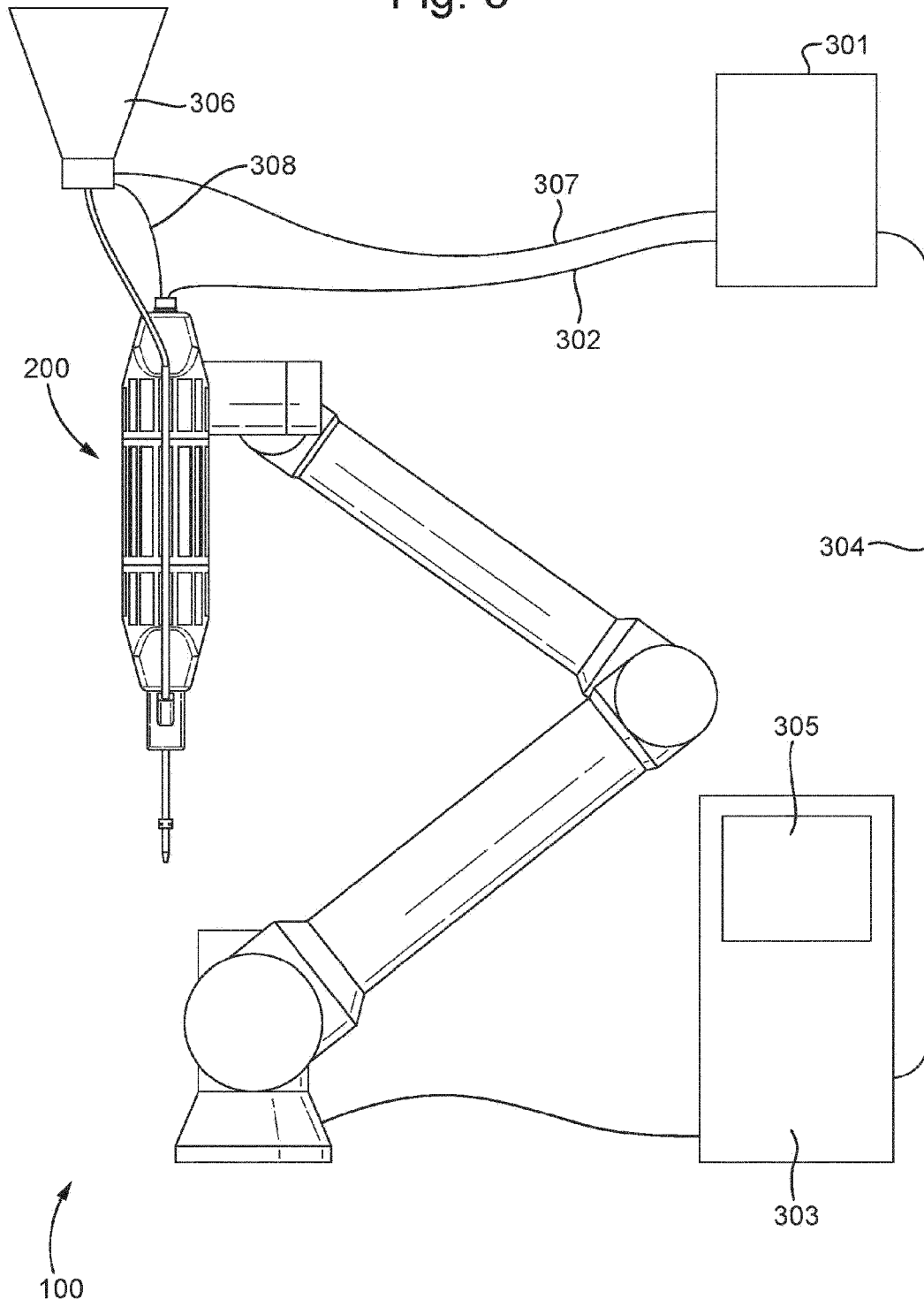


Fig. 4a

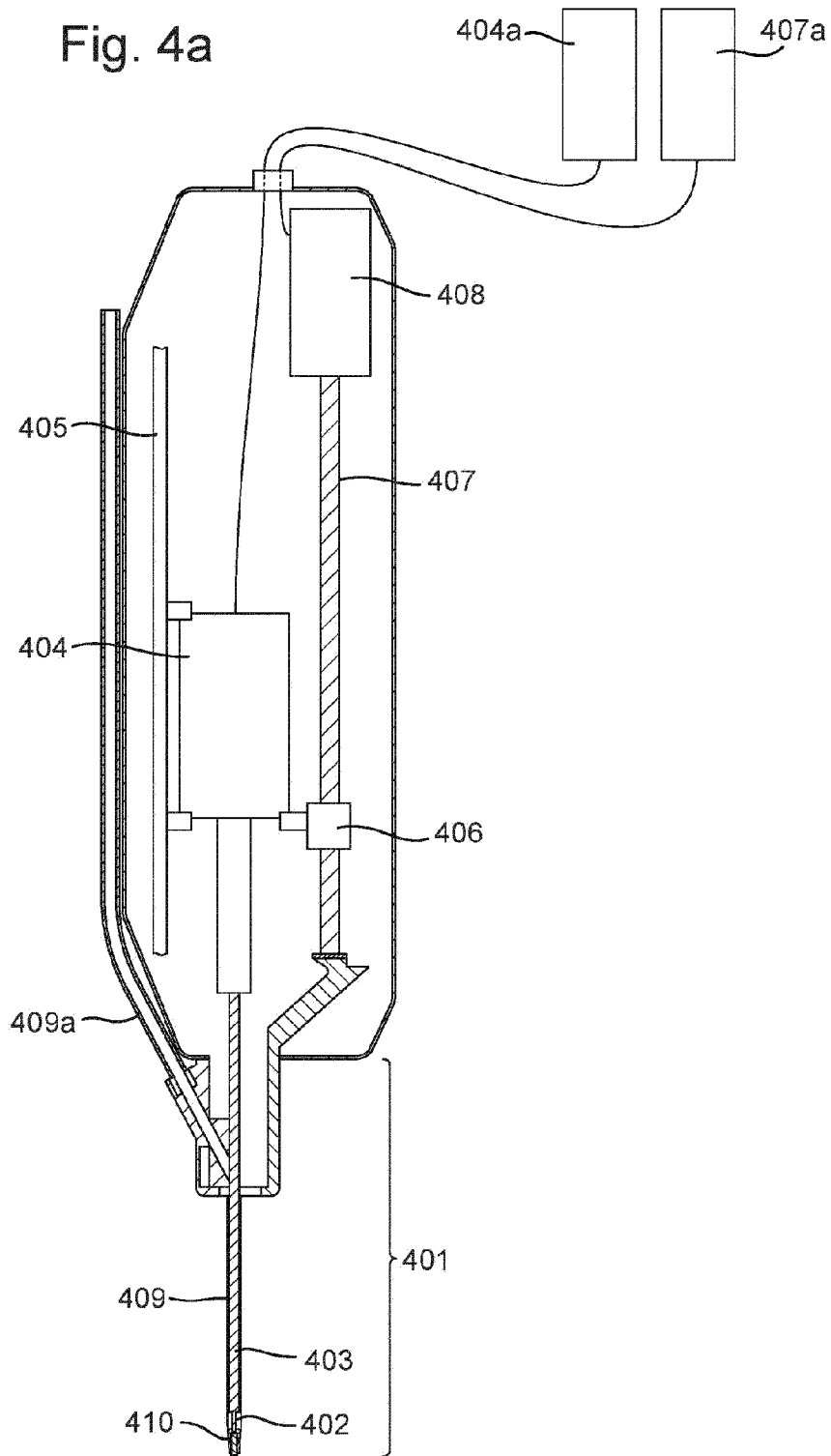


Fig. 4b

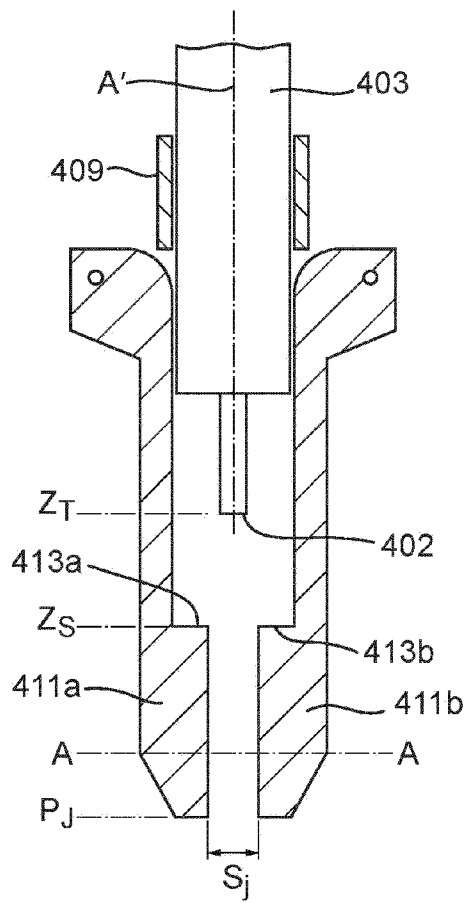


Fig. 4d

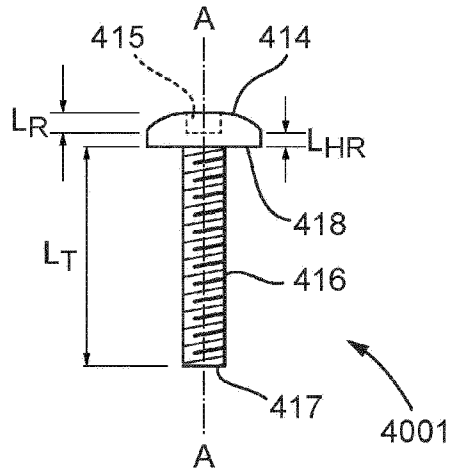


Fig. 4c

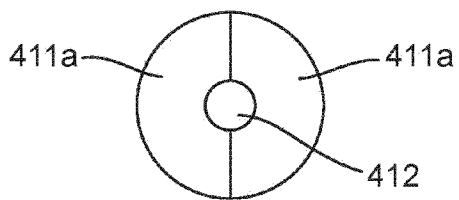


Fig. 4e

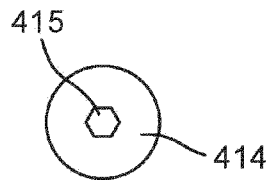


Fig. 4f

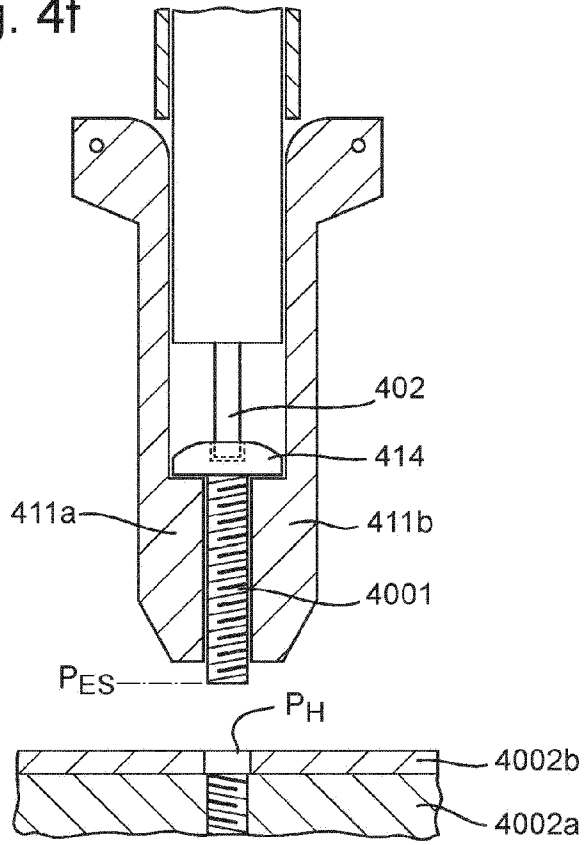


Fig. 4g

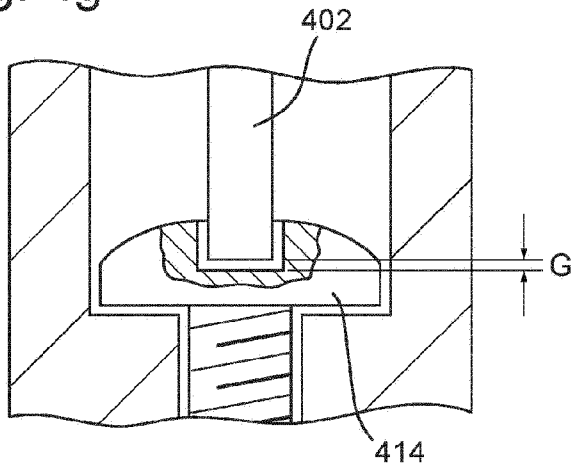


Fig. 5

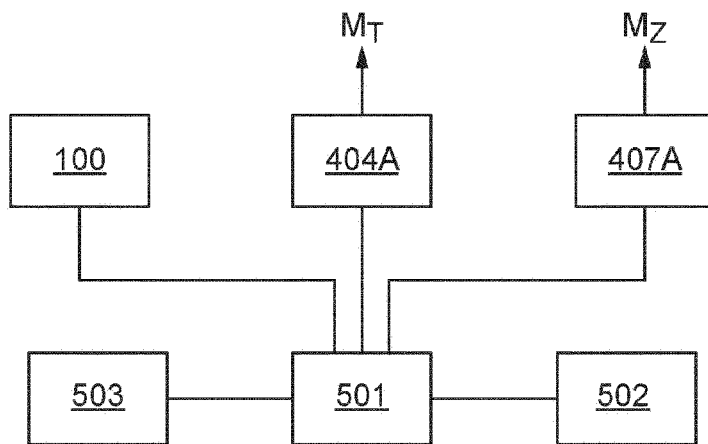


Fig. 6a

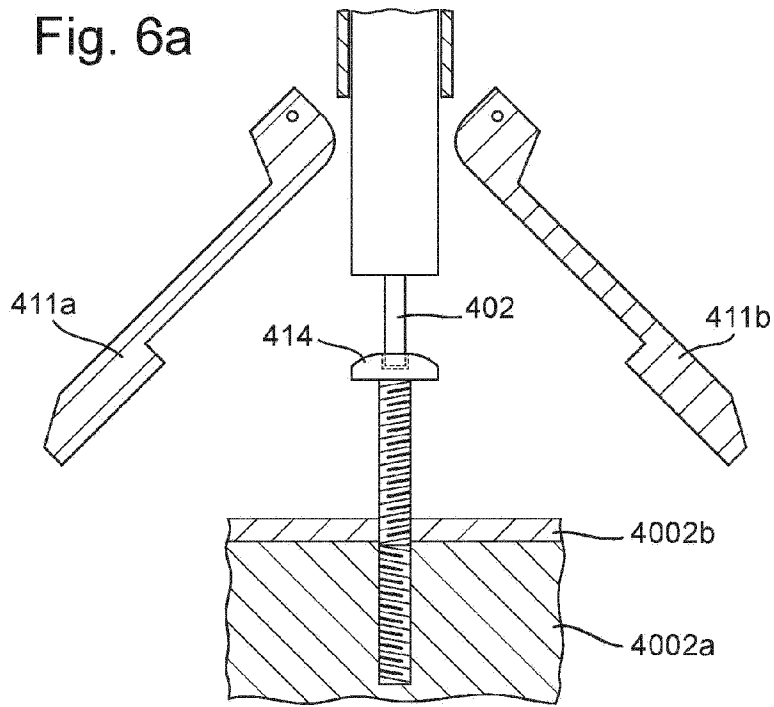


Fig. 6b

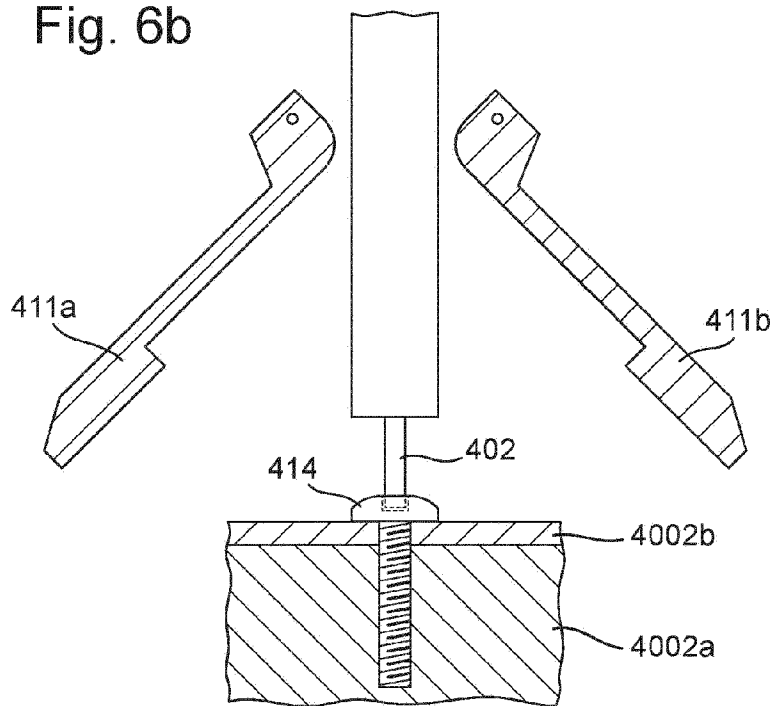


Fig. 7

