(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
23 November 2023 (23.11.2023)

WIPO | PCT

(10) International Publication Number
WO 2023/223215 A1

(51) International Patent Classification:
B25J 15/00 (2006.01) *B25J 15/02* (2006.01)
A61B 34/30 (2016.01)

(21) International Application Number:
PCT/IB2023/055047

(22) International Filing Date:
16 May 2023 (16.05.2023)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
63/342,363 16 May 2022 (16.05.2022) US

(71) Applicant: **LEM SURGICAL AG** [CH/CH]; Murtenstrasse 143a, 3008 Bern (CH).

(72) Inventors: **BAR, Yossi**; Hubeliweg 14, 3014 Muri bei Bern (CH). **KOMRON, Lior**; Blumlisalpstrasse 2, 3014 Muri bei Bern (CH).

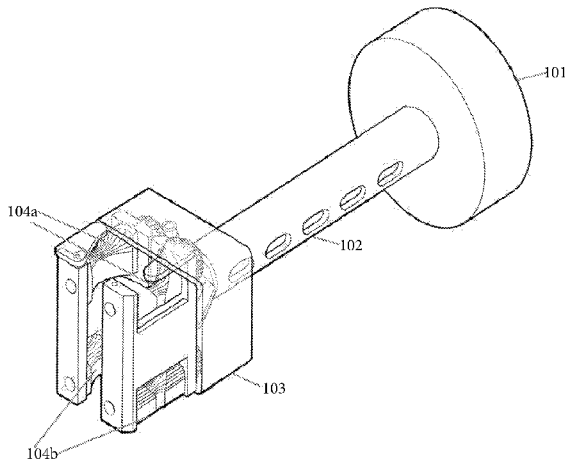
(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CV, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, MG, MK, MN, MU, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, CV, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SC, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, ME, MK, MT, NL, NO, PL, PT, RO, RS, SE,

WO 2023/223215 A1

(54) **Title:** TOOL GRIPPER WITH INTEGRATED CONCENTRIC SHUTTER

FIG. 1



(57) **Abstract:** A gripper for holding surgical tools is provided. The gripper incorporates a concentric and adjustable shutter mechanism that allows the gripper to hold tools of multiple different circumferences and tools that do not have perfectly circular circumferences. In the context of a centrally coordinated robotic system and, in particular, a surgical robotic system, the disclosed gripper allows the robotic system to deploy a large variety of surgical tools without regard to their circumference or precise circumferential dimensions. A robotic system using the inventive gripper is able to deploy a wide variety of tools while always keeping the tools centered in the work area due to the concentric shutter design.

[Continued on next page]

SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*
— *in black and white; the international application as filed contained color or greyscale and is available for download from PATENTSCOPE*

TOOL GRIPPER WITH INTEGRATED CONCENTRIC SHUTTER

PRIOR RELATED APPLICATIONS

This application claims the benefit of priority of prior-filed United States Provisional Patent Application 63/342,363 filed May 16, 2022.

FIELD OF THE INVENTION

The invention relates to a gripper with an integrated concentric shutter mechanism for holding tools of varying diameters. The invention further relates to a gripper that may open and close in a conventional manner but is able to grasp tools of varying diameters through the incorporation of a concentric shutter mechanisms that centers the tool in the gripper regardless of the tool's diameter. Specifically, it is generally desired for a gripper to hold a longitudinal tool around its circumference (for example, a screwdriver), but for the gripper to be able to accomplish this with respect to tools of multiple varying diameters so that a different gripper is not required to specifically match each tool. Moreover, not all tools have a perfect circular shape. Accordingly, the invention pertains to a gripper with an integrated shutter mechanism that can thus accommodate different tool diameters also without perfect circular shape. More particularly, in the context of robotic surgery, multiple robotic tools may be deployed on robotic arms and controlled by a single control unit and may be used in a centrally coordinated fashion to perform a robotic surgical procedure, with the relative movements of each robotic element being coordinated by the central control unit. The invention thus relates to the need of central control unit of the robotic system to always know where the center of a robotic tool is, regardless of its diameter - the flexible, concentric nature of the inventive gripper with integrated shutter allows for this functionality. While robotic systems can in theory be capable of using many tools of varying dimensions, they may be supplied by many different manufacturers and may have different characteristics and dimensions (e.g., circumference), creating a challenge for the robotic system. Most particularly, in the context of robotic surgery, numerous tools made by different manufacturers with different dimensions may be deployed by an end effector with the inventive

gripper with integrated concentric shutter and used without the need for changing end effectors according to the apparatus and methods provided by the present invention.

BACKGROUND OF THE INVENTION

Grippers are useful end-effectors that are used in wide variety of fields to hold and operate tools or other objects. Grippers are also well known in the robotics field and also particularly in the medical robotics field. In medical robotics, and in robotics generally, grippers are used to grip and hold various instruments for various applications.

Shutters, with varying designs, are also known in multiple fields. Some shutters are mainly used as gates or valves. Inherent in the design of some shutters as applicable to the present disclosure are their ability to open and close concentrically, thus always having a natural, consistent center regardless of the diameter of the shutter's opening.

It is very much required in the medical robotic field (but not exclusively in medical robotics), to be able to hold, grip maybe only partially grip random longitudinal tool from its side while keeping the tool concentric to the gripper and to the robotic arm. Meaning, the gripper is required to hold a random tool with random diameter and/or with a non-perfect circular shape but no matter the tool's diameter the gripped tool's center is always in the same location which is known to the robot controller. In this regard, the robot can hold any random tool and regardless of its different diameter its center is always in the same place which is known to the robotic controller. This is essential to the robotic system's ability to perform procedures accurately – if the robot does not know where the center of the robotic tool is, it cannot accurately guide the tool to the location of interest, or in the case of robotic surgery, to the anatomy of interest. This use case is best served by a gripper that can hold a tool concentrically, with a shutter being an excellent mechanism for accomplishing this goal. More over, a standard gripper may hold and firmly grip the tool, while this invention describes a gripper/shutter mechanism that allows to close the shutter around the tool and than open the shuuter in the exact required amount to facilitate the required margins for a certain amount of motion of the tool inside the shutter. The

current inventors are unaware of a gripper incorporating a concentric shutter being available in medical robotics, in robotics generally, or in any field for that matter.

Performance of a full range of spinal surgery procedures requires robotically coordinated movement of multiple robotic arms and, optionally, robotically coordinated navigation – a package of features that is not available today. For present purposes, a typical procedure may require the maneuvering of one or more end effectors deployed by robotic arms, the deployment of other instruments, placement of multiple passive or active markers on bone and/or on soft tissue, and one or more robotically controlled and maneuvered cameras that can be placed at varying distances and angulations from the surgical field, and one or more end effectors deployed by robotic arms. This complex dynamic is further complicated by the presence of numerous surgical tools and implants on the market made by multiple manufacturers, particularly in the spinal surgery market. A multi-arm robotically coordinated system that can accommodate many different tools without endless changes of end effectors is not available on the market today. There is a strong and long-felt need for such a system as it will enable the performance of a full range of spinal surgery procedures with robotically coordinated control and navigation at a level of accuracy not currently possible. The current inventive gripper with concentric shutter mechanism is a key component of such a system as it provides for accuracy (the robotic system "knows" where the center of the robotic tool is) and ease of use since an essentially unlimited tool set can be accommodated.

It is well understood in the areas of robotic surgery generally and spinal robotic surgery specifically that there are numerous manufacturers of tools and implants to be used in various surgical procedures. It is also the case that there are many companies that design and manufacture robotic systems to be used in surgical procedures. This creates a mismatch and/or a lack of synchronization between robotic systems and robotic tool sets. A robotic device and its specific software may not optimally fit with the tool set of a particular manufacturer that has designed tools for particular types of robotic surgical procedures, such as spinal surgical procedures. This mismatch can be true of end effectors, such as drilling tools, and also true of surgical tools, implants etc.

In this situation the robotic device and the robotic software of a company that develops a generic surgical robotic system, does not optimally fit any random implant and tools system that a certain hospital or surgeon might use. Moreover, there are dozens of implants systems in the market which continuously evolve and changes, so for the robotic companies it is practically impossible to fit their robotic systems to the huge number of tool variations in the marketplace. Additionally, the health regulatory agencies will usually require a business or QA agreement between the robotic system manufacturer and tool manufacturer in order to approve the use of the tools with the robot, which will complicate things significantly and eventually will delay advanced treatment to patients.

All of these barriers bring robotic companies to the situation in which they must be forced to form some kind of business relationship with one specific implant/tool company or to just settle on generic tool guidance for their robotic system. This creates a situation where the robot is designed without optimal fit to the full range of implants or tools that may be used with their robotic system (i.e. the surgeon can use the robotic system only for guidance and tool positioning, or at the top to drill a hole, but not to guide the tap or the screwdriver and implant). All of this of course results in less precise procedures (the robot is used for drilling but not for the screw insertion) that do not take advantage of the full capabilities of the robotic system and that do not benefit the patient or the surgeon.

There is thus a strong need for a robotic system that can deploy an essentially unlimited range of robotic tools with a generic gripper, and this is true for spinal surgery in particular. Such a gripper is provided in the context of the present invention. The gripper can open and close and grasp a tool like a conventional gripper but it also incorporates a concentric shutter so that a large range of tools with varying diameters can be accommodated.

SUMMARY OF THE INVENTION

Provided herein is a gripper with an integrated concentric shutter mechanism for grasping an essentially unlimited range of tools with varying random diameters. The novel gripper may open and close like a conventional gripper such that it can, for example, open and close its

"jaws" to hold a longitudinal tool around the tool's circumference. The inventive gripper also incorporates a concentric shutter mechanism that provides for a tool to be centered in the gripper regardless of its diameter or precise dimensions and also if the tool's circumference is not a perfect circle.. Centering of the tool is essential to the tool being deployed and operated accurately. This is particularly true of a tool deployed by a robotic system, or in a specific example, by a surgical robotic system. The robotic system may deploy the inventive grasper with an end effector, the location of which is known by the central control unit of the robotic system. The robotic system requires a method of deploying the working end of the tool accurately toward a target location or anatomy and if the tool is reliably and concentrically centered in the gripper, the tool can be targeted accurately based on the robotic system knowing the location of the end effector relative to the known location of the center of the tool.

The gripper with integrated concentric shutter mechanism of the present invention has several inherent advantages over the current state of the art, which does not provide an integrated device that can center a wide variety of tools concentrically. Namely, the inventive device may open and close like a conventional gripper – in other words, it can open and close its "jaws" to hold and release a wide variety of longitudinal tools around their circumference. For the inventive gripper to hold tools in this manner, the tools do not need to have perfectly circumferential dimensions, but the present inventors refer to the "circumference" of the tools for ease of understanding. Another key advantage is that the inventive device has a shutter mechanism. Thus, a tool or instrument can always be concentrically centered in an end effector and, in this way, a robotic system can always know where the center of a gripped tool is, regardless of the precise identity, design or dimensions of the tool. Also advantageously, the integrated shutter mechanism creates a perfect circle around the gripped tool, even if the tool's dimensions are not perfectly circumferential. Accordingly, the tool can be rotated about its own longitudinal axis which may be important for many applications, including robotic surgical applications. The presently available gripper, however, has a smooth and consistent circumferential surface in contact with the tool that allows for easy motorized rotation. Finally, The ability to add to the basic shutter design, also the additional gripper design ("jaws" that open and close), the inventive device is relatively simple in external design and may thus be

cleaned and sterilized easily – a key feature for end effector compatibility in the surgical robotics context.

The inventive gripper with integrated concentric shutter mechanism is composed of three main parts. A compartment houses the electronic parts, such as a motor and controller. In the context of a robotic surgical application, this compartment would be non-sterile and will be covered by a sterile cover. Needless to mention that this compartment can of course be designed to be completely sealed and by that being sterilized but this would result in more costly design and manufacturing. The suggested design offers a simple and cost effective unit. Next, a shaft for motion transfer from the motor to the gripper is provided. The shaft would typically be sterile in the robotic surgery context (e.g. autoclave sterile). Finally, the gripper unit itself is provided and would of course be sterile in the robotic surgical context. The concentric shutter incorporated into the gripper unit comprises two opposing pairs of curved cylinders that, when deployed in combination, create a circular engagement point for grasping tools of varying diameters and dimensions.

BRIEF DESCRIPTION OF THE DRAWINGS

- Figure 1 shows a tool gripper with integrated concentric shutter according to an embodiment of the present invention.

- Figure 2 shows two alternate views of the inventive device holding a tool according to an embodiment of the present invention.

- Figure 3 shows two alternate views of the rotating cylinder portions of the inventive device that allow the device to concentrically adjust to tools of varying diameters, according to an embodiment of the present invention.

- Figure 4 shows two alternate side partially transparent views of the inventive device holding a tool, according to an embodiment of the present invention.

- Figure 5 shows a top partially transparent view of the gripper element of the inventive device holding a tool according to an embodiment of the present invention.

- Figure 6 shows a side close up partially transparent view of the gripper element and rotating cylinders according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

With reference now to the figures and several representative embodiments of the invention, the following detailed description is provided.

In one embodiment of the invention shown in Figure 1, a tool gripper with integrated concentric shutter has three main components. A non-sterile compartment 101 houses the electronic parts, such as a motor and a controller. This non-sterile compartment 101 is designed to sit outside the sterile field during surgery. The non-sterile compartment is configured to be detachable from the rest of the device at the point where, the next component of the device, a sterile shaft 102, fits into the non-sterile compartment 101. The sterile shaft 102 is designed to transfer motion form the motor of the non-sterile compartment to the next component of the device, the gripper mechanism 103. The gripper mechanism has two main components and corresponding functions. The gripper itself opens and closes like a standard gripper or grasper. Contained within the two gripper elements are opposing pairs of concentric shutters 104a, 104b that can rotate to form a concentric larger or smaller opening to accommodate tools of varying sizes and/or diameters.

The gripper jaws open and close through the action of horizontal motion along the horizontal sterile shaft that is translated to lever elements on the gripper mechanism element. One of skill in the art will understand that this is but one modality for translating the energy generated by the motor to the jaws of the gripper and that other similar possibilities exist. The gripper element itself houses a vertical shaft that can engage in rotational motion from energy also provided by the motor in the non-sterile compartment. The rotational motion of this horizontal shaft in turn engages gears that, in turn, rotate the pairs of concentric shutter elements

inward or outward to make the concentric opening in the gripper mechanism larger or smaller to accommodate tools of different sizes.

In another embodiment of the invention shown in two alternate views in Figure 2a and 2b, a tool gripper with integrated concentric shutter is shown holding a tool. Both of figure 2a and 2b show the tool 201 being grasped by the apparatus with the gripper jaws 202 closed and the concentric shutter pairs 203 having been rotated to form a concentric opening that matches the diameter of the tool. Figure 2a highlights limiting edges 204 at the far left end of the gripper element that serve as stoppers for the tool so that the tool cannot slip out of the gripper horizontally. Figure 2b shows a partially transparent view of the sterile shaft so as to reveal the rotation shaft 205 and its method of engagement with the gripper mechanism through lever elements 206.

In another embodiment of the invention shown in Figures 3a and 3b, partially transparent top views of the gripper mechanism show the lever elements 301 that cause the gripper jaws 302 to open and close by translating the linear motion from the sterile shaft 303, along with the gears 304 that are engaged by the vertical shaft 305 of the gripper mechanism to cause rotating cylinders 306 to turn inward or outward to cause the concentric shutter to form a larger or smaller opening.

In additional embodiments of the invention shown in Figures 4a and 4b, partially transparent side views of a tool gripper with integrated concentric shutter are shown. Figure 4a shows the device grasping a larger tool 401 and Figure 4b shows the device grasping a comparatively smaller tool 402. Both figures show elements of the gripper and shutter mechanisms. In Figure 4a, the pairs of concentric shutter elements are rotated outward to accommodate the larger diameter of the tool, whereas in Figure 4b, the pairs of concentric shutter elements are rotated inward so that the device can grasp a comparatively narrower-diameter tool.

Similarly, Figure 5 shows a close-up view of just the gripper element of an embodiment of the inventive device grasping a small-diameter tool 501. In Figure 5 it can be seen that the

pairs of concentric shutter elements 502 are rotated almost completely inward to form a small diameter concentric opening to hold the small-diameter tool.

Figure 6 displays a close-up, partially cut-away view of the grasper end of an embodiment of the present invention. A vertical shaft 601 of the gripper element is shown, configured to translate rotational motion to gears 602 that then function to rotate pairs of concentric shutter elements 603 inward or outward to form smaller or larger concentric openings in the gripper.

One of skill in the art will realize that several variations on the disclosed embodiments are possible while staying within the bounds of the current invention. Solely by way of example, different variations in the precise dimensions and contours of the gripper and integrated shutter can be used without departing from the invention. As another example, further opposing pairs of curved cylinders could be integrated into an embodiment of the inventive gripper to accommodate larger and/or longer tools. As a further example, the motorized component and control functions of the inventive gripper could be operationally integrated with the control functions of a surgical robotic system or they could operate independently. The embodiments provided are representative in nature.

WHAT IS CLAIMED IS:

1. A gripper for holding tools comprising:

a compartment housing a motor;

a shaft with a proximal end and a distal end, mechanically connected at its proximal end to the compartment;

a gripper mechanism comprising two opposing gripper elements, mechanically connected to the distal end of the shaft; and

at least two pairs of concentric shutter elements integral with the gripper mechanism configured to rotate selectively inward or outward to vary the circumference of an opening in the gripper mechanism;

wherein the shaft is configured to transfer motion from the motor to the gripper mechanism and the concentric shutter elements.

2. The gripper for holding tools of claim 1, wherein the shaft is configured to transfer horizontal motion generated by the motor along the length of the shaft from its proximal end to its distal end in order to selectively open and close the gripper elements.

3. The gripper for holding tools of claim 1, wherein the shaft is configured to transfer rotational motion generated by the motor to engage and selectively rotate inward or outward the concentric shutter elements.

4. The gripper for holding tools of claim 1, wherein the shaft is configured to transfer horizontal motion generated by the motor along the length of the shaft from its proximal end to its distal end in order to selectively open and close the gripper elements and wherein the shaft is further configured to transfer rotational motion generated by the motor to engage and selectively rotate inward or outward the concentric shutter elements.

5. The gripper for holding tools of claim 3, further comprising a vertical shaft housing gears engaged to the concentric shutter elements, wherein the rotational motion causes rotation of the gears that, in turn, causes the concentric shutter elements to selectively rotate inward or outward.

6. The gripper for holding tools of claim 1, wherein the circumference of the opening in the gripper mechanism is varied to match the circumference of a tool being held by the gripper mechanism.

7. The gripper for holding tools of claim 6, wherein the tool is circumferentially centered in the gripper mechanism.

8. The gripper for holding tools of claim 7, wherein the tool has a non-constant circumferential radius but is still circumferentially centered in the gripper mechanism.

9. The gripper for holding tools of claim 1, wherein the shaft is selectively detachable from the compartment housing the motor.

10. The gripper for holding tools of any of claims 6 through 9, wherein the tool can be rotated while being held by the gripper mechanism.

11. The gripper for holding tools of any of the preceding claims, wherein the gripper for holding tools is an end effector of a robotic system.

12. The gripper for holding tools of claim 11, wherein the robotic system is a surgical robotic system.

13. The gripper for holding tools of claim 12, wherein the compartment housing the motor is configured to be positioned in the non-sterile field during a surgical procedure.

14. The gripper for holding tools of claim 12, wherein the shaft and gripper mechanism are configured to be positioned in the sterile field during a surgical procedure.

15. The gripper for holding tools of claim 14, wherein the shaft and gripper mechanism are configured to be sterilizable after being detached from the compartment housing the motor.

FIG. 1

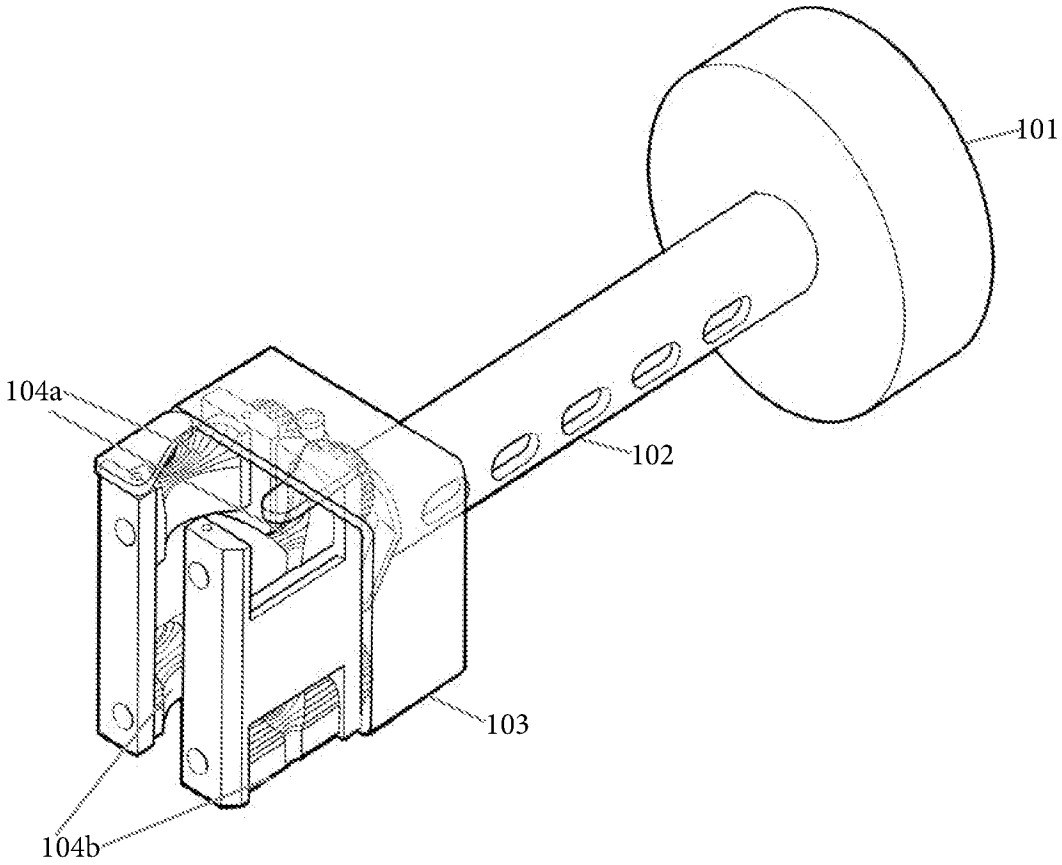


FIG. 2a

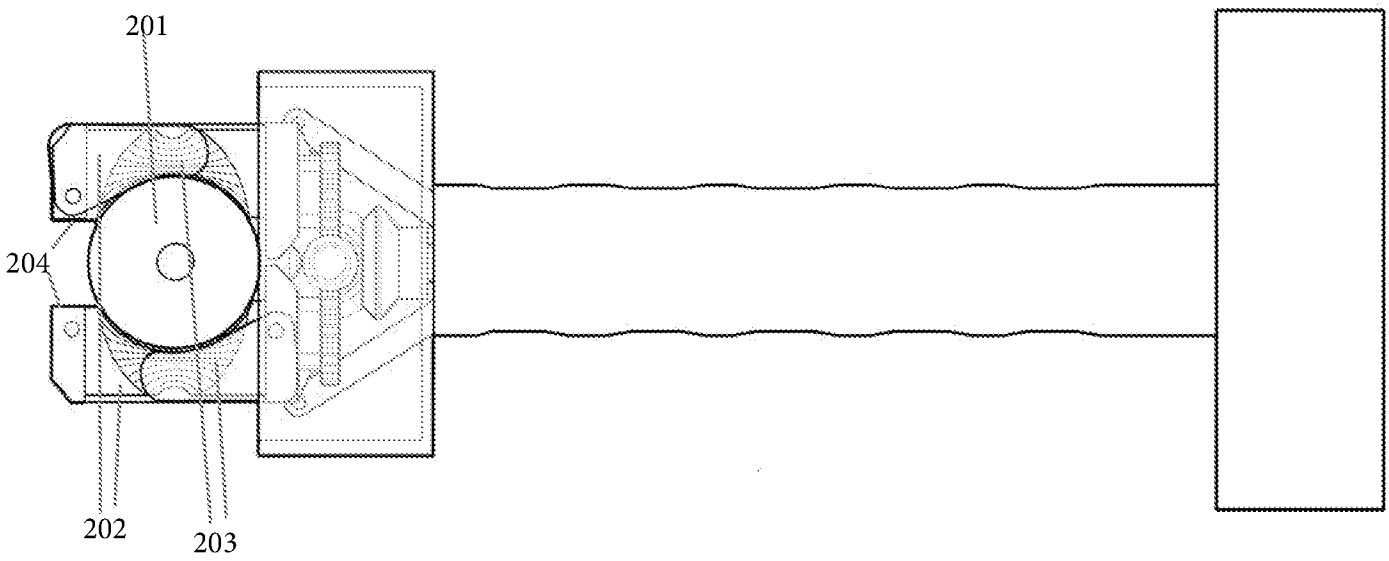


FIG. 2b

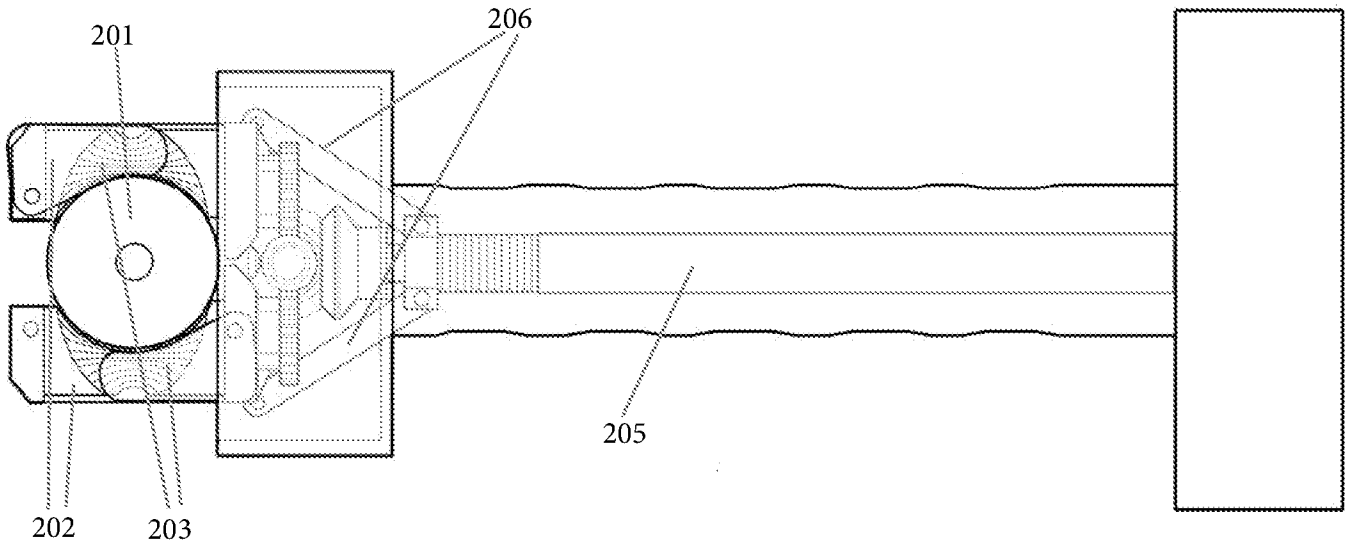


FIG. 3a

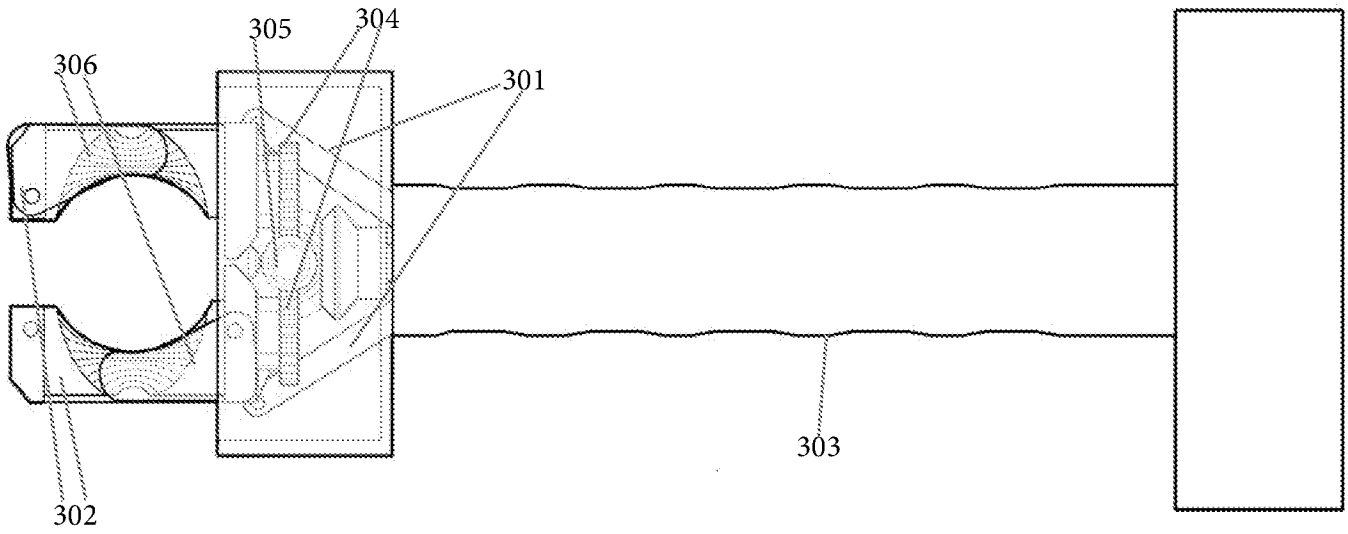


FIG. 3b

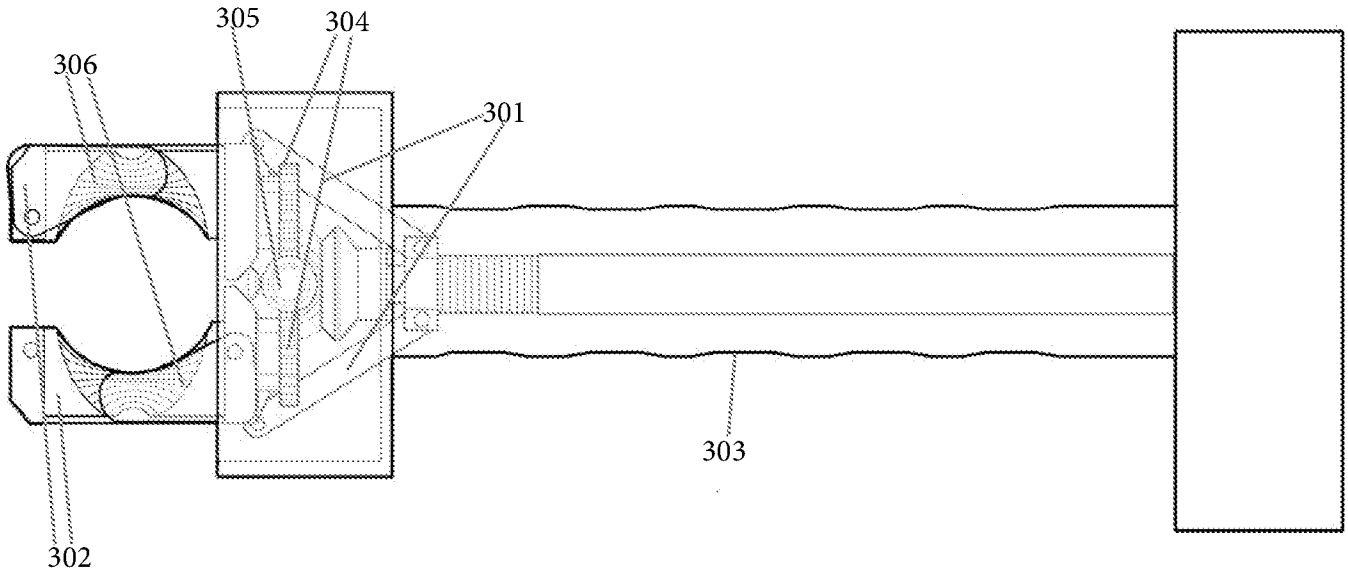


FIG. 4a

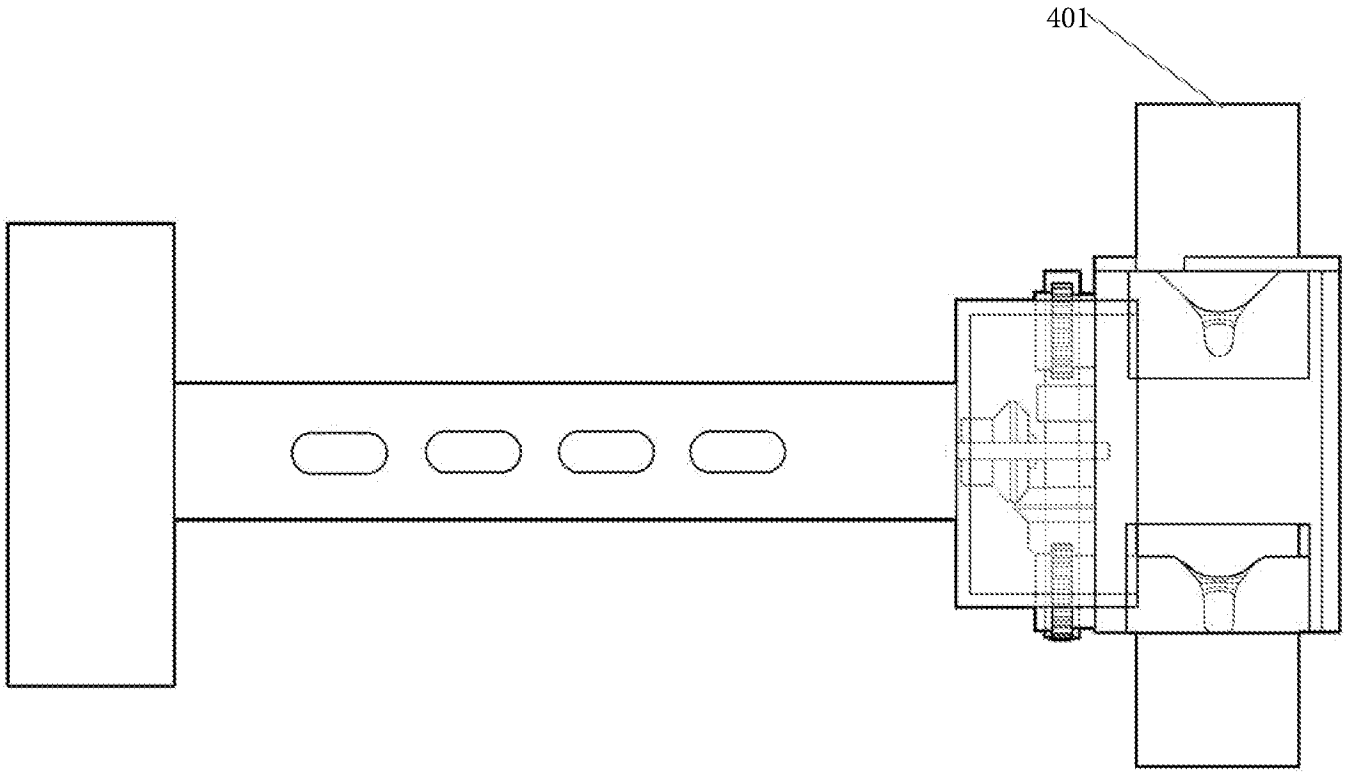


FIG. 4b

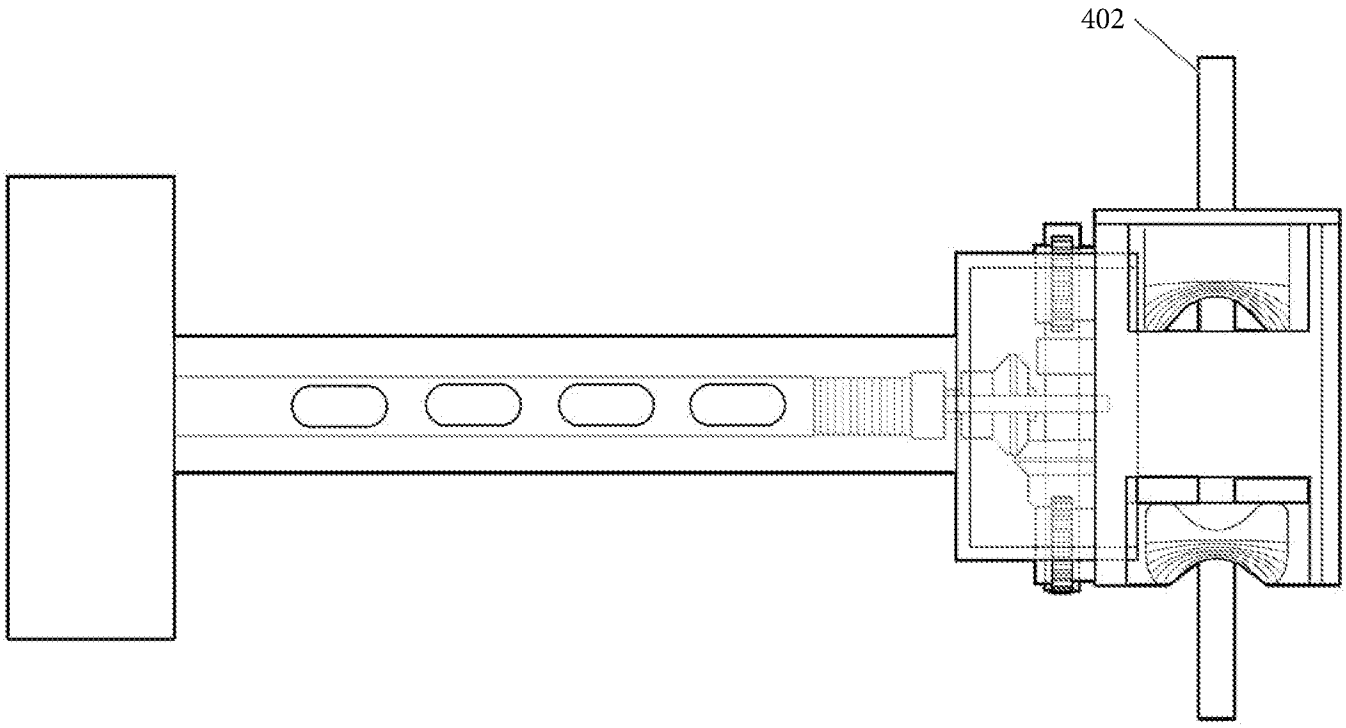


FIG. 5

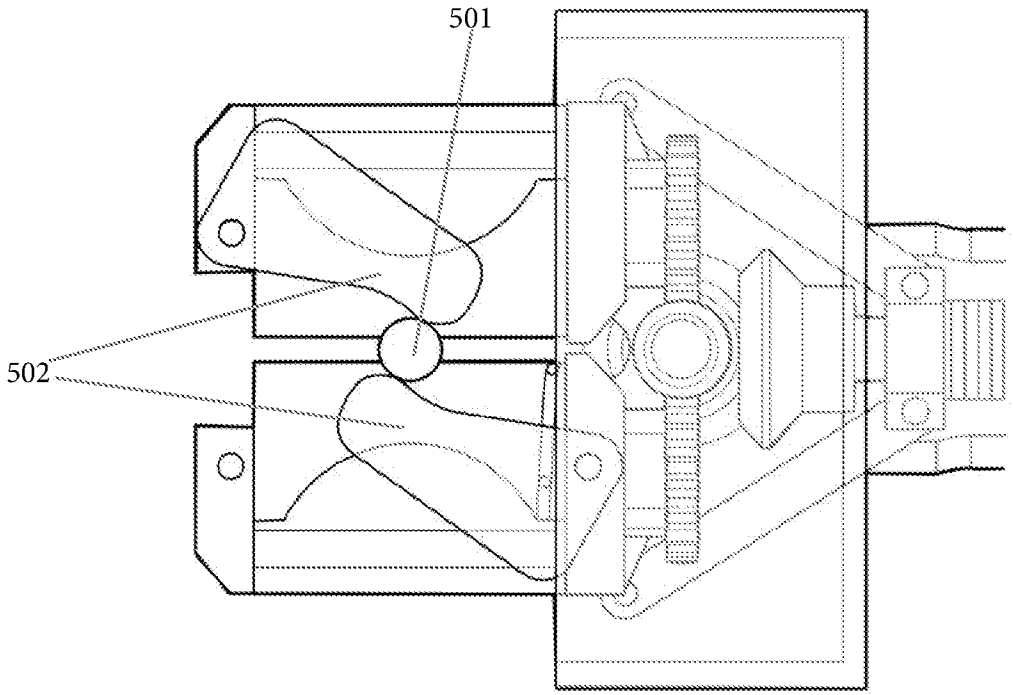
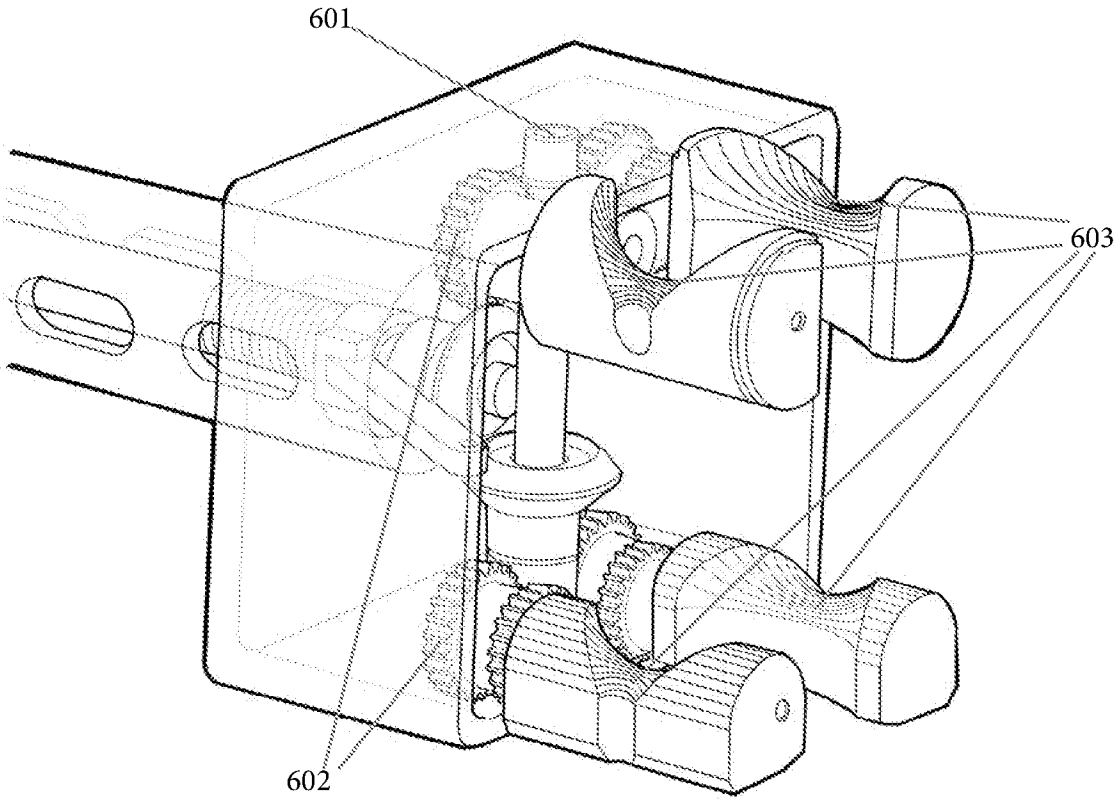


FIG. 6



INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2023/055047

A. CLASSIFICATION OF SUBJECT MATTER
INV. B25J15/00 A61B34/30 B25J15/02
ADD.

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)
B25J A61B

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2018 030179 A (DENSO CORP) 1 March 2018 (2018-03-01) figures 1-27	1-15
A	US 2009/163929 A1 (YEUNG BENNY HON BUN [CA] ET AL) 25 June 2009 (2009-06-25) figures 1-30	1-15

☐ 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
14 September 2023	25/09/2023

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Champion, Jérôme

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2023/055047

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 2018030179 A	01-03-2018	DE 102017214332 A1	22-02-2018
		JP 6648653 B2	14-02-2020
		JP 2018030179 A	01-03-2018
		NL 2019386 A	01-03-2018
US 2009163929 A1	25-06-2009	US 2009163929 A1	25-06-2009
		US 2014018821 A1	16-01-2014