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(71) Applicant: **DYSON TECHNOLOGY LIMITED** [GB/GB]; Tetbury Hill, Malmesbury Wiltshire SN16 0RP (GB).

(72) Inventors: **SHAW, Andrew**; Dyson Technology Limited, Tetbury Hill, Malmesbury Wiltshire SN16 0RP (GB). **CLERC, Vincent**; Dyson Technology Limited, Tetbury Hill, Malmesbury Wiltshire SN16 0RP (GB).

(74) Agent: **MITCHELL, Joshua** et al.; Intellectual Property Department, Dyson Technology Limited, Tetbury Hill, Malmesbury Wiltshire SN16 0RP (GB).

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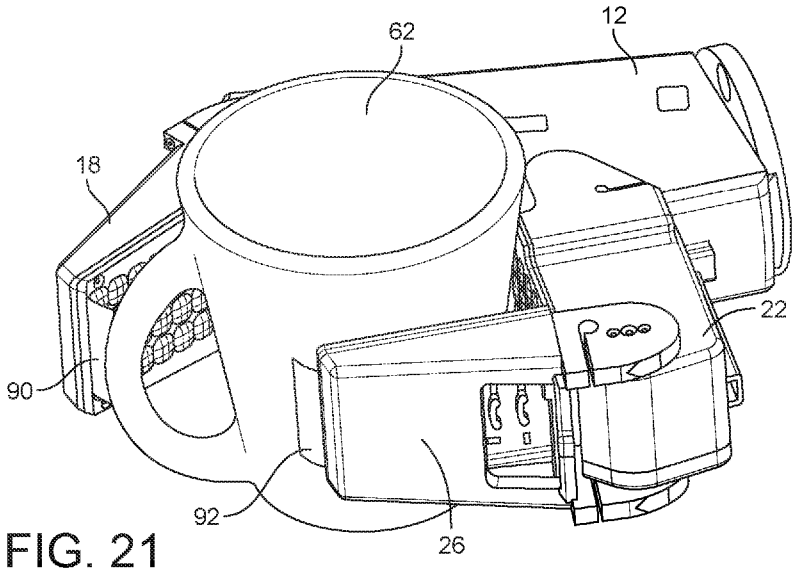

FIG. 21

(57) Abstract: A robot gripper comprising: a base section; a first finger comprising a first phalanx, which is connected to the base section by a joint, and a tip portion distal to the base section; a second finger comprising a first phalanx, which is connected to the base section by a joint, and a tip portion distal to the base section, wherein the first and second fingers are opposable to each other, the first finger comprising an inner surface that faces the second finger and the second finger comprising an inner surface that faces the first finger; wherein the tip portion of one of the fingers comprises a nail protrusion, the nail protrusion being deployable between a deployed configuration and an undeployed configuration.

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ROBOT HAND

TECHNICAL FIELD

The present invention relates to a robot hand. Aspects of the invention relate to a robot gripper and to a robot comprising a robot gripper.

BACKGROUND

Robot devices comprising robotic hands and gripper arrangements (which may also be referred to herein as robot or robotic grippers) are known in industries such as the manufacturing industry. It is often a key capability of such robot devices that they are able to manipulate a range of objects. However, known robotic grippers capable of manipulating objects and picking objects from flat surfaces tend to be complicated in their construction, in particular, where such grippers are designed to closely mimic the human hand.

It is an object of the present invention to provide a robot gripper that mitigates or substantially mitigates the above problems.

SUMMARY OF THE DISCLOSURE

According to an aspect of the present invention, there is provided a robot gripper comprising: a base section; a first finger comprising a first phalanx, which is connected to the base section by a joint, and a tip portion distal to the base section; a second finger comprising a first phalanx, which is connected to the base section by a joint, and a tip portion distal to the base section, wherein the first and second fingers are opposable to each other, the first finger comprising an inner surface that faces the second finger and the second finger comprising an inner surface that faces the first finger; wherein the tip portion of one of the fingers comprises a nail protrusion, the nail protrusion being deployable between a deployed configuration and an undeployed configuration.

The present invention provides a robot gripper in which at least one of the fingers comprises a nail protrusion that is deployable between deployed and undeployed configurations. The nail protrusion advantageously aids with the picking up and gripping of objects, especially small, flat objects on a surface.

The tip portion of the first finger may comprise a nail protrusion and the tip portion of the second finger may comprise a nail protrusion, each nail protrusion being deployable between a deployed configuration and an undeployed configuration, the nail protrusions of the first and second fingers being opposed to one other when in their deployed configurations. Preferably both fingers comprise nail features to aid in the gripping of objects. In such an arrangement both nails can engage on either side of the object.

In the undeployed configuration the nail protrusion may be flush with the inner surface of the finger or may be recessed within the finger. The nail protrusion may in some configurations be configured such that it sits flush with the surface of the finger or even recessed within the finger when in the undeployed configuration.

In the deployed configuration the nail protrusion may project further beyond the inner surface of the finger than in the undeployed configuration. In some configurations the fingernail protrusion may not sit flush or recessed with the finger in the undeployed configuration, in which case when the fingernail is deployed it is arranged to project further beyond the inner surface of the finger than in the undeployed configuration.

At least one of the fingers may comprise a first phalanx and a second phalanx and the tip portion may be integrated in the second phalanx. Where a finger comprises more than one phalanx the fingernail protrusion is advantageously located in the tip portion of the last phalanx.

The inner surface of the or each finger comprising a nail protrusion may be moveable between an undeformed configuration and a deformed configuration and may be configured such that moving the inner surface to the deformed position causes the nail protrusion to be deployed. Conveniently, a nail arrangement can be provided in which moving the inner surface of a finger exposes the nail protrusion. In one version of such a nail arrangement, the finger may be designed to deform to expose a nail protrusion when coming into contact with an object such that no mechanical parts are required.

The or each finger comprising a nail protrusion may comprise a cam mechanism configured to extend the nail protrusion of the or each finger when the robot gripper interacts with an object.

The cam mechanism may be located on the inner surface of the or each finger. The cam mechanism for the or each finger may be located in the base section of the robot gripper.

In an alternative configuration, the or each finger comprising a nail protrusion may comprise a groove within which the nail protrusion is arranged to move, the gripper comprising a linear actuator for each nail protrusion arranged to move each nail protrusion between the deployed and undeployed configurations.

The gripper may comprise further fingers opposing the first finger and each finger may comprise a nail protrusion.

The robot gripper may comprise: a base section; a first finger connected to the base section by a base section joint and comprising *n* phalanxes; a second finger connected to the base section by a base section joint and comprising *n+m* phalanxes, each phalanx of the second finger being connected to an adjacent phalanx by a phalanx joint and the first and second fingers being opposable to one other; wherein *n* and *m* are positive integers.

The robot gripper may be configured such that the fingers have an asymmetric arrangement. This arrangement advantageously provides the ability to grip objects and to manipulate them, e.g. by rolling an object between the two fingers). This arrangement also allows the gripper to be handed.

In one arrangement of a robot gripper the values of *n* and *m* may both be set to equal 1 such that the first finger comprises a first phalanx connected to the base section by a pivotable joint and the second finger comprises a first phalanx and a second phalanx, the second finger comprising pivotable joints between the base and first phalanx and between the first and second phalanxes. This arrangement conveniently provides for a robot gripper that is compact (it comprises three phalanxes in total) and which is capable of gripping and rolling objects.

The base section may comprise a surface extending between the base section joints, the distance between the base section joints being substantially the same length as the first phalanx of the second finger such that first and second fingers may be brought parallel to one another such that the first phalanx of the first finger is adjacent to the second phalanx of the second finger. The component parts of the robot gripper may conveniently

be dimensioned such that the two fingers can be brought together such that their tips meet. This enables the robot gripper to pick up objects more easily.

Each joint may be rotatable about an axis and the axes of all the joints within the robot gripper may be parallel to one another.

Each joint may comprise a motor. In this way the gripper may be fully actuated which allows full control of the fingers of the robot gripper. This aids the gripping positions that the robot gripper may take up.

The motors associated with the first phalanxes may be located within the base section. The motor associated with a second phalanx may be located within the finger. Where the motors are located within the finger, this provides a gripper in which all the control elements are integrated within the gripper itself which allows replacement grippers to be attached to a robot, e.g. via a wrist connection, with minimal difficulty.

The gripper may further comprise an arm section which is rotatably connected to the base via a wrist connection and each motor may be located within the wrist portion remote from the joints, each motor being connected to a joint by a tendon linkage. As an alternative to integrating the motors within the gripper, this arrangement provides a gripper in which the bulk of the gripper is reduced since there is no need to incorporate the motors therein.

Each finger may comprise a tip portion and the fingers may be configured to move between open configurations and a pinch configuration where the tip portions of each finger are in contact. The gripper may advantageously take up a range of open configurations which allows a number of different sizes of object to be gripped.

The first and second fingers may comprise a fingernail protrusion. The provision of a fingernail protrusion allows objects to be picked up more easily.

The gripper may comprises further fingers opposing the first finger, each further finger comprising $n + m$ phalanxes.

The robot gripper may comprise: a base section; a first finger comprising a proximal phalanx which is connected to the base section by a joint; a second finger comprising a proximal phalanx which is connected to the base section by a joint, the first and second fingers being opposable to each other; wherein the base section comprises a sucker arranged to allow the gripper to interact with objects by suction.

The robot gripper may be configured such that it advantageously comprises a sucker that allows the gripper, when it is already gripping a first object, to manipulate a second object (e.g. opening a door or drawer without needing to put down the first object).

The sucker may comprise a vacuum pump. The sucker may be associated with a vacuum pump which thereby allows a vacuum to be conveniently created and controlled. The vacuum pump may be located within the base section.

The sucker may be a passive sucker that is configured to be activated when the sucker is pushed against an object. As an alternative to a vacuum sucker, a passive sucker may be used which results in an arrangement with fewer parts compared to the vacuum option. Such a passive sucker arrangement would also save space as fewer components would need to be packed into the body of the gripper (or associated robot).

The base section may comprise a palm surface, a back surface and side surfaces, the sucker being located on one of the palm, back or side surfaces.

The robot gripper may comprise one or more suckers located on the same surface of the base section. Additional suckers may be provided to provide a better seal or to compensate if one sucker doesn't form a seal correctly (e.g. because of a surface feature on the second object).

The robot gripper may comprise one or more suckers located on different surfaces of the base section. Providing suckers on different surfaces of the base section allows greater flexibility and reduces the need to rotate or realign the gripper in order to use a sucker.

According to an aspect of the present invention there is provided a robot comprising a robot gripper according to the above aspect of the present invention.

Where the robot gripper is configured to comprise a sucker, the robot may comprise a robot body connected to the robot gripper wherein the sucker may comprise a vacuum pump located within the robot body.

Where the robot gripper is configured to comprise a sucker, according to an aspect of the present invention, there is provided a method of operating a robot gripper or a robot according to the above aspect of the present invention, comprising: manipulating the first and second finger to grip a first object; moving the gripper such that the sucker contacts a second object; forming a vacuum seal between the sucker and the second object; moving the gripper to manipulate the second object; breaking the vacuum seal with the second object; releasing the first object.

Where the second object is a drawer or door, the method may further comprise moving the robot gripper while the vacuum seal is in place in order to open the drawer or door.

Forming the vacuum seal may comprise moving the robot gripper such that the sucker is pushed against the second object.

Breaking the vacuum seal may comprise moving the robot gripper such that the sucker twists relative to the second object.

Forming the vacuum seal may comprise moving the robot gripper such that the sucker contacts the second object and activating a vacuum pump connected to the sucker.

It is noted that the order of the steps in the above method according to the present disclosure may be varied slightly depending on the particular implementation of the method, e.g. certain steps may occur together or in a different order to that shown above.

Within the scope of this application it is expressly intended that the various aspects, embodiments, examples and alternatives set out in the preceding paragraphs, in the claims and/or in the following description and drawings, and in particular the individual features thereof, may be taken independently or in any combination. That is, all embodiments and/or features of any embodiment can be combined in any way and/or combination, unless such features are incompatible. The applicant reserves the right to change any originally filed claim or file any new claim accordingly, including the right to

amend any originally filed claim to depend from and/or incorporate any feature of any other claim although not originally claimed in that manner.

BRIEF DESCRIPTION OF THE DRAWINGS

One or more embodiments of the disclosure will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 shows a perspective view of a robotic gripper according to an embodiment of the present invention;

Figure 2 shows a plan view of the robotic gripper of Figure 1 in an open configuration;

Figure 3 shows a plan view of the robotic gripper of Figure in a closed configuration;

Figure 4 shows a plan view of the robotic gripper of Figure 1 in a further open configuration;

Figure 5 shows a section through the robotic gripper of Figure 1;

Figure 6 shows a close up view of a tip portion of the fingers of the robotic gripper of Figure 1;

Figure 7 shows a side view of a variant design of a robotic gripper having a phalanx that is split into three sections;

Figure 8 shows a phalanx of the robotic gripper of Figure 7;

Figures 9 to 14 show the robotic gripper of Figure 1 in a variety of configurations and gripping different objects;

Figure 15 show a phalanx comprising a nail protrusion in an undeployed configuration for a finger of a robotic gripper according to an embodiment of the present invention;

Figure 16 shows the phalanx of Figure 15 in a deployed configuration;

Figure 17 shows a plan view of a robotic gripper having a nail protrusion according to an embodiment of the present invention;

Figure 18 shows the gripper of Figure 17 when the gripper is closed;

Figure 19 shows the gripper of Figure 17 while holding an object;

Figures 20 to 21 show the gripper of Figure 17 holding a further object;

Figure 22 shows a plan view of a robotic gripper having a nail protrusion according to an embodiment of the present invention;

Figure 23 shows a plan view of a robotic gripper having a passive sucker according to an embodiment of the present invention;

Figure 24 shows a plan view of a robotic gripper having a vacuum sucker according to an embodiment of the present invention;

Figure 25 shows a side view of the gripper of Figure 23 or 24;

Figure 26 shows a gripper according to Figure 23 or 24 interacting with a cupboard door;

Figure 27 is a flow chart showing how a gripper according to Figure 23 or 24 may be operated;

Figure 28 shows a robot comprising a robotic gripper according to an embodiment of the present invention.

DETAILED DESCRIPTION

General and specific embodiments of the disclosure will be described below with reference to the Figures. Like numerals have been used to denote like features within the figures.

Figure 1 shows a perspective view of a robot gripper 10 according to an embodiment of the present invention. The gripper 10 comprises a base section 12, a first finger 14 and a second finger 16.

The first finger 14 comprises a first, or proximal, phalanx 18 which is connected to the base section 12 by a joint 20. The second finger 14 comprises a first (proximal) phalanx 22 which is connected to the base section 12 by a (base) joint 24. The second finger 16 further comprises a second (distal) phalanx 26 which is connected to the adjacent proximal phalanx 22 by a (phalanx) joint 28. The first and second fingers (14, 16) are opposable to one another.

For the robot gripper 10 shown in Figure 1 there are an odd number of joints (in this case 3 joints) and an odd number of phalanxes. The presence of a hand having an uneven number of phalanxes in the opposable fingers results in a "handed" gripper 10 which enables the fingers of the gripper to perform gripping and pinching actions as well as more complicated actions such as rolling an object between the two opposable fingers.

In a more general form, a robot gripper in accordance with an embodiment of the invention comprises a first finger comprising n phalanxes and a second finger with $n+m$ phalanxes, where n and m are positive integers. In the example of Figure 1, n=1 and m=1, but it is to be appreciated that other arrangements are possible (e.g. where n=2 and m=1 the first finger would have two (proximal and distal) phalanxes and the second finger would have three (proximal, intermediate and distal) phalanxes). In this regard, the robot gripper is asymmetric.

As shown in Figure 1, the inner surfaces 30 of the fingers comprise a textured surface to aid gripping of objects. This surface could for example comprise a rubberised material. The robot gripper additionally comprises a wrist connection 32 to enable connection of the gripper 10 to a robot arm (not shown in Figure 1).

Figure 2 shows the gripper 10 of Figure 1 in a side view in an open "grip" configuration. In Figure 2 the gripper 10 is additionally shown connected via the wrist connection 32 to an arm 34, the arm 34 and connection 32 defining an axis 38.

The base section 12 comprises a "palm" portion 36, the palm portion including surface 40 of the base section 12 that extends between the first finger/base section joint 20 and the second finger/base section joint 24.

As can be seen from Figure 2 the surface 40 of the palm portion 26 defines a plane that is at an angle θ to the axis 38. In an embodiment, the angle θ is 15 degrees, or approximately 15 degrees, which allows the robot gripper to grab and pinch objects effectively.

Each joint (20 24, 28) is rotatable about an axis. As shown in Figure 2, the axes of each joint (20, 24, 28) are parallel to one another and perpendicular to the plane of the figure. Each joint comprises its own motor such that the robot gripper is fully actuated thereby aiding the gripping positions that the gripper can take up.

The motor for each joint may be directly associated with the joint (as shown in Figure 5 below). Such an arrangement would facilitate replacing the gripper that is connected to

the wrist connection with a replacement gripper (in the case of damage) or alternative robotic manipulators.

Alternatively, the motor for each joint may be located remote from the gripper 10 (e.g. within the arm 34) and may be connected to the joint via a suitable mechanical or hydraulic tendon system. This arrangement may enable a less bulky design for the gripper compared to directly locating the motors with each joint within the gripper.

The gripper may be rotatable about the wrist connection to enable the gripper to move between a first handed position and a second handed position.

Turning to Figure 3, the gripper of Figures 1 and 2 is shown in a closed configuration (a "pinch" configuration) in which the first and second fingers (14, 16) are arranged parallel to one another.

It is noted that the distance (labelled "a" in Figure 3) between proximal joints (20, 24) of the first and second fingers (14, 16) on the base section 12 is substantially the same length as the proximal phalanx 22 of the second finger 16 such that first and second fingers may be brought parallel to one another such that the proximal phalanx 18 of the first finger 14 is adjacent to the distal phalanx 26 of the second finger 16.

Additionally, the distance of the first phalanx 18 of the first finger 14 is substantially the same length (labelled "b" in Figure 3) as the distal phalanx 26 of the second finger 16. As a result, the tip portion 42 of the first finger 14 and the tip portion 44 of the second finger 16 come together.

Figure 4 shows the gripper 10 in a fully open configuration in which the surface 40 of the base section 12 and the surface 30 of the first finger 14 define a straight line. Additionally, the first and second phalanxes (22, 26) of the second finger 16 define a straight line. As shown in Figure 4 the first finger 14/base section 12 are at roughly 90 degrees to the second finger 16.

Figure 5 shows a cross section through a robot gripper 10 in which motors (46, 48, 50) and a control unit 52 are provided within the structure of the gripper 10. Each joint of the gripper comprises its own motor (joint 20 is actuated by motor 46; joint 24 is actuated by motor 48; joint 28 is actuated by motor 50). The control unit 52 is configured to send control signals to each of the motors to control operation of the gripper 10.

The gripper 10 comprises a metal, e.g. aluminium, frame within which the motors and control unit are mounted. The metal frame may be clad in any suitable material to form the gripper 10 (e.g. plastic outer body with rubber grips on the surfaces (30, 40)).

The motors (46, 48, 50) may be configured to measure the torque applied to a joint. Sensors may be disposed within the contact surfaces (30, 40) to detect where contact has been made with objects being manipulated by the gripper 10. The control unit 52 may determine the force applied to a gripped object from the torque and sensor data.

Figure 6 shows the tip portions (42, 44) of the fingers (14, 16) shown in Figures 3 and 5 (the "pinch" configuration) in more detail. It is noted that the phalanx 18 of the first finger 14 comprises a protrusion 54 (a "fingernail" protrusion) that is disposed on the inner surface of the phalanx 18 and which projects towards the other finger 16. Similarly, the distal phalanx 26 of the second finger 16 comprises a protrusion 56 that is disposed on the inner surface of the phalanx 26 and which projects towards the finger 14.

The two protrusions (54, 56) generally provide a pointed tip and thereby facilitate picking up objects from a flat surface. In particular, the provision of such fingernail protrusions allows low profile objects, e.g. coins, sheets of material, to be picked up more easily by the robot gripper that might otherwise be unable to gain sufficient purchase on such objects.

Figures 7 and 8 show a variant design of the gripper 10 in which the end phalanx 26 of the finger 16 is split into three sections – a central phalanx portion 26a and side portions (26b, 26c). The phalanx 26 comprises a base portion 58 that comprises the joint 28. The central portion 26a is fixed relative to the base portion 58. The side portions (26b, 26c) are sprung via spring members 60 such that they are biased towards the opposing finger 14.

It is noted that Figures 7 and 8 show the three prong variant design on the finger 16. The skilled person will appreciate that the three prong arrangement may instead be used on the phalanx 18 of the first finger 14. Alternatively both fingers 14,16 may incorporate the arrangement shown.

The sprung side portions (26b, 26c) facilitate gripping of objects.

Figure 9 shows a first perspective view of a gripper 10 according to Figures 1 to 6 gripping an object, a cup 62, with the finger 16 at the front of the image. Figure 10 shows the same interaction from above the gripper 10. Figure 11 shows a second perspective

view of the gripper with the finger 14 at the front of the image. It can be seen that the gripper 10 is in the general grip configuration shown in Figures 1 and 2.

Figure 12 shows a plan view of a gripper 10 according to Figures 1 to 6 gripping a further object, a pen 64. It can be seen that the gripper 10 is in the pinch configuration shown in Figures 3 and 5. Figure 13 shows a first perspective view of the gripper 10 with the finger 14 at the front of the image. Figure 14 shows a second perspective view of the gripper with the finger 16 at the front of the image. The robot gripper allows the second finger 16 to flex via the phalanx joint 28 such that the second phalanx 26 can roll the pen along the phalanx 18 of the first finger.

Figures 15 and 16 show a configuration for a phalanx 70 for a finger of a robot gripper comprising a nail protrusion that can deploy from an undeployed configuration (shown in Figure 15) to a deployed configuration (shown in Figure 16) according to an embodiment of the present invention. As described below, the nail protrusion arrangement shown in Figures 15 and 16 is a passive arrangement in which the nail moves from the undeployed to the deployed configurations on contact with an object. This contrasts with the active nail protrusion arrangements shown in Figures 17 to 22 in which a cam arrangement or linear actuator arrangement is used to deploy the nail protrusions.

Returning to Figures 15 and 16, the phalanx 70 comprises a base portion 72 within which a joint 74 is provided. It is noted that the phalanx 70 of Figures 15 and 16 may be incorporated into one or more fingers of a robot gripper. For example, the phalanx 70 may be incorporated into one or both of the phalanxes 18 or 26 described above.

The phalanx 70 comprises an inner surface 76 which, when the phalanx 70 is provided on a finger of a robot gripper, faces another finger on the gripper. The inner surface 76 comprises a deformable section 78. The deformable section 78 is provided distal to the joint 74.

The phalanx 70 further comprises a tip portion 80 which comprises a nail protrusion 82 which, when the phalanx 70 is provided on a finger of a robot gripper, projects towards another finger on the gripper.

In Figure 15 the phalanx 70 is in the undeployed configuration in which the nail protrusion 82 does not substantially project beyond the inner surface 76 of the phalanx.

In Figure 16 the phalanx is shown in the deployed configuration. The phalanx 70 may be deployed to the deployed configuration when the phalanx 70/gripper 10 comes into

contact with an object (not shown). As the object contacts the deformable section 78, the deformable section 78 is deflected into a cavity 84 within the body of the phalanx 70. The previous position of the inner surface of the deformable section 78 is shown in Figure 16 by the dotted line 86. It can be seen that in the deployed configuration the nail protrusion 82 now projects further beyond the inner surface of the section 78 and can be used to aid in picking up small objects (especially on a flat surface) and to improve grip.

The fingernail configuration shown in Figures 15 and 16 conveniently provides improved gripping ability without the need for further motors or other mechanical activation means since the fingernails are provided by the deformable section 78 of the finger.

Figures 17 to 21 show a further configuration for a finger of a robot gripper comprising a nail protrusion that can deploy from an undeployed configuration to a deployed configuration according to an embodiment of the present invention. As described below, the nail protrusion arrangement shown in Figures 17 to 21 is an "active" arrangement in which the nail moves from the undeployed to the deployed configurations in response to movement of a cam arrangement that is linked to the nail protrusion. This contrasts with the passive nail protrusion arrangements shown in Figures 15 and 16 above in which contact with an object is used to deform the finger to deploy a fingernail protrusion.

For ease of reference the nail protrusion arrangement according to Figures 17 to 21 are shown incorporated into the robot gripper 10 of Figures 1 to 14. It is however noted that the nail protrusion arrangement could be incorporated into any suitable robot gripper. It is further noted that both fingers (14, 16) in Figures 17 to 21 are shown to comprise a nail protrusion arrangement but the skilled person will appreciate that the arrangement may only be present on one or other of the fingers.

As shown in Figure 17, finger 14 comprises a nail protrusion 90 within the tip portion 42 of the phalanx 18. The nail protrusion 90 is connected to a cam arrangement 94. The cam arrangement is mounted on a pivot 96.

Also shown in Figure 17 is a further nail protrusion 92 within the tip portion 44 of phalanx 26 of finger 16. Nail protrusion 92 is connected to cam arrangement 98 which is mounted on pivot 100.

Nail protrusion 90 and cam arrangement 94 are shown in a deployed configuration and it can be seen that the inner surface 102 of the cam (the "object contacting" side) is substantially flush with the inner surface 30 of the phalanx 18. In the deployed

configuration, the nail protrusion 90 projects beyond the inner surface 30 of the phalanx 18.

Nail protrusion 92 and cam arrangement 98 are shown in an undeployed configuration. In this configuration the nail protrusion does not substantially project beyond the inner surface 30 of the phalanx 26 (and may be completely recessed within the body of the phalanx 26). Inner surface 104 of cam arrangement 98 is raised above the inner surface 30 of the phalanx 26.

The cam arrangements 94 and 98 may be biased towards the undeployed configuration about their respective pivots (96, 100), the cam arrangements (94, 98) being configured to move to their respective deployed configurations upon contact of an object with the cam arrangements. [Note: cam arrangement 94 is shown in the deployed configuration in Figure 17 but for clarity the object in contact with the cam arrangement is not shown.]

As shown in Figure 18, the cam arrangements 94 and 98 may be activated by each other, thereby deploying the nail protrusions 90 and 92, when the fingers 14 and 16 are brought into the “pinch” configuration shown in Figure 18 (and Figure 3).

As shown in Figure 19, the cam arrangements (94, 98) have been activated, thereby deploying the nail protrusions 90, 92, as the fingers 14, 16 grip the object (pen) 62.

Figures 20 and 21 show respectively a plan and perspective view of the nail protrusion arrangement of Figures 17 and 18 while the gripper 10 is holding a larger object, cup 62.

Figure 22 shows a further “active” nail protrusion arrangement in accordance with an embodiment of the present invention in which a linear actuator is used to deploy the finger protrusions.

For ease of reference the nail protrusion arrangement according to Figure 22 is shown incorporated into the robot gripper 10 of Figures 1 to 14. It is however noted that the nail protrusion arrangement could be incorporated into any suitable robot gripper. It is further noted that both fingers (14, 16) in Figure 22 are shown to comprise a nail protrusion arrangement but the skilled person will appreciate that the arrangement may only be present on one or other of the fingers.

In Figure 22, phalanx 18 of finger 14 comprises a groove 106 within the body of the phalanx. A nail protrusion 108 is located within the groove 106 and may moved between an undeployed configuration in which the nail protrusion 108 is recessed within the

groove 106 and a deployed configuration in which the nail protrusion 108 projects beyond the inner surface 30 of the phalanx 18. The nail protrusion 108 is deployed by a linear actuator 110 located within the phalanx 18. The linear actuator 110 may in turn be controlled by control signals received from a control unit (e.g. control unit 52 shown in Figure 5).

Finger 16 shown in Figure 22 shows a corresponding nail protrusion 112 within a groove 114 within the phalanx 26. Linear actuator 116 is configured to deploy the nail protrusion 112 between deployed and undeployed configurations.

Figures 23 to 26 show a gripper comprising a sucker according to an embodiment of the present invention. For ease of reference the sucker according to Figures 23 to 26 is shown incorporated into the robot gripper 10 of Figures 1 to 14. It is however noted that a sucker could be incorporated into any suitable robot gripper.

Figure 23 shows the gripper 10 described above in relation to Figures 1 to 14. Additionally, the base section 12 comprises a sucker 120 mounted thereon. As previously described the base section 12 comprises a palm portion 36. Additionally, it is noted that the base section comprises side surfaces 122 and 124 (surface 122 is shown in Figure 23 and both surfaces 122, 124 are shown in Figure 25) and a back surface 126. As shown in Figure 23 the sucker 120 is mounted on the back surface 126 of the base section 12.

Although a single sucker 120 is shown in Figures 23 to 26 it is to be appreciated by the skilled person that multiple suckers may be mounted on the gripper. Furthermore, a sucker or suckers may be provided on other surfaces of the gripper 10, e.g. the side surfaces 122, 124.

The sucker 120 shown in Figure 23 is a passive sucker that is activated when the sucker is pushed against an object. Figure 24 shows an example of a vacuum sucker 128 which is connected to a vacuum pump 130 by a conduit 132. It is noted that the vacuum pump may be located within the robot gripper 10 or remote from the gripper 10 (e.g. within a robot arm 34 as shown in Figure 2 or at any suitable location within a robot comprising a robot gripper as shown in Figure 24).

The sucker 120, 128 according to an embodiment of the present invention may be used, as shown in Figure 26, to interact with an object, such as a door 134, when the gripper 10 is gripping an item (such as the cup 62 shown in Figure 26). In this manner the

gripper 10 may complete tasks, such as putting an item into a cupboard, in a single sequence (e.g. grip item, engage sucker with door 134, open door, place item into cupboard) instead of having to put the item down in order to use the gripper fingers 14, 16 to open the door.

Figure 27 is a flow chart of a method of using the gripper 10 shown in Figures 23 to 26. In step 200 the first and second fingers (14, 16) are manipulated to grip a first object. Once the first object has been grasped by the gripper 10, the gripper is moved, in step 202, such that the sucker contacts a second object.

In step 204 a vacuum seal is formed between the sucker (120, 128) and the second object. The vacuum seal may be formed by pressuring the sucker against the second object (in the case of a passive sucker) or by using a vacuum pump 130 to form a vacuum between the sucker and the second object.

In step 206 the gripper 10 may be moved in order to manipulate the second object. For example, if the second object is a drawer or cupboard door then the gripper may be moved in order to open or close the drawer/door.

In step 208 the vacuum seal is broken. This may be achieved either by turning off the vacuum pump or by controlling the gripper to twist relative to the second object (or a combination of both).

In step 210 the first object may be placed and then released.

Figure 28 shows a robot 140 comprising an arm 24 and a robot gripper 10 according to any of the above Figures 1 to 26.

Many modifications may be made to the above examples without departing from the scope of the present disclosure as defined in the accompanying claims.

CLAIMS

1. A robot gripper comprising:

a base section;

a first finger comprising a first phalanx, which is connected to the base section by a joint, and a tip portion distal to the base section;

a second finger comprising a first phalanx, which is connected to the base section by a joint, and a tip portion distal to the base section,

wherein the first and second fingers are opposable to each other, the first finger comprising an inner surface that faces the second finger and the second finger comprising an inner surface that faces the first finger;

wherein the tip portion of one of the fingers comprises a nail protrusion, the nail protrusion being deployable between a deployed configuration and an undeployed configuration.

2. A robot gripper as claimed in Claim 1, wherein the tip portion of the first finger comprises a nail protrusion and the tip portion of the second finger comprises a nail protrusion, each nail protrusion being deployable between a deployed configuration and an undeployed configuration, the nail protrusions of the first and second fingers being opposed to one other when in their deployed configurations.

3. A robot gripper as claimed in Claim 1 or Claim 2, wherein in the undeployed configuration the nail protrusion is either flush with the inner surface of the finger or is recessed within the finger.

4. A robot gripper as claimed in claims 1 and 2, wherein in the deployed configuration the nail protrusion projects further beyond the inner surface of the finger than in the undeployed configuration.

5. A robot gripper as claimed in any one of Claims 1 to 3, wherein at least one of the fingers comprises a first phalanx and a second phalanx and the tip portion is integrated in the second phalanx.

6. A robot gripper as claimed in any preceding claim, wherein the inner surface of the or each finger comprising a nail protrusion is moveable between an undeformed configuration and a deformed configuration and is configured such that moving the inner surface to the deformed position causes the nail protrusion to be deployed.

7. A robot gripper as claimed in any preceding claim, wherein the or each finger comprising a nail protrusion comprises a cam mechanism configured to extend the nail protrusion of the or each finger when the robot gripper interacts with an object.

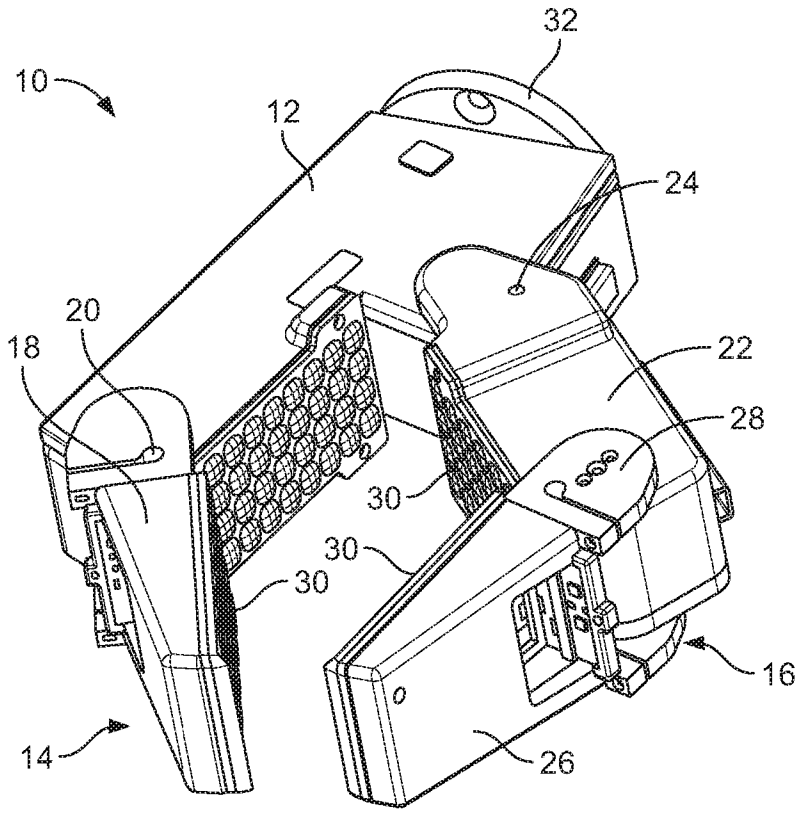
8. A robot gripper as claimed in Claim 7, wherein the cam mechanism is located on the inner surface of the or each finger.

9. A robot gripper as claimed in Claim 7, wherein the cam mechanism for the or each finger is located in the base section of the robot gripper.

10. A robot gripper as claimed in any one of Claims 1 to 5, wherein the or each finger comprising a nail protrusion comprises a groove within which the nail protrusion is arranged to move, the gripper comprising a linear actuator for each nail protrusion arranged to move each nail protrusion between the deployed and undeployed configurations.

11. A robot gripper as claimed in any preceding claim, wherein the gripper comprises further fingers opposing the first finger and each finger comprises a nail protrusion.

12. A robot comprising a robot gripper according to any one of Claims 1 to 11.


32
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22
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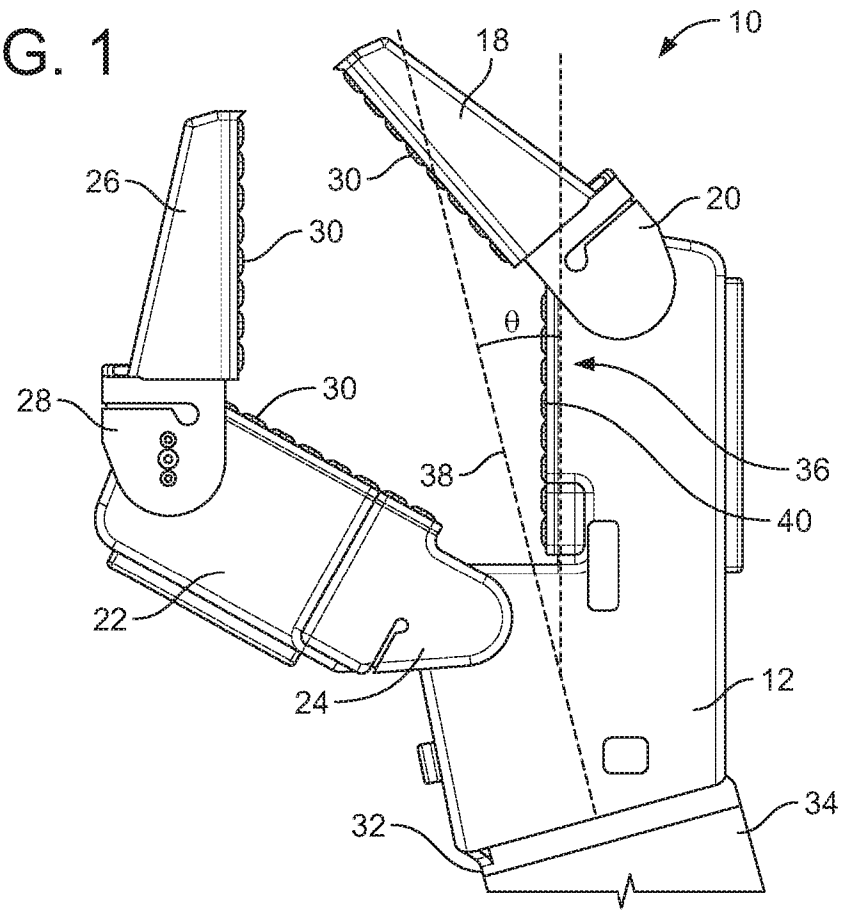
16
14
26

FIG. 1


10
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26
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38
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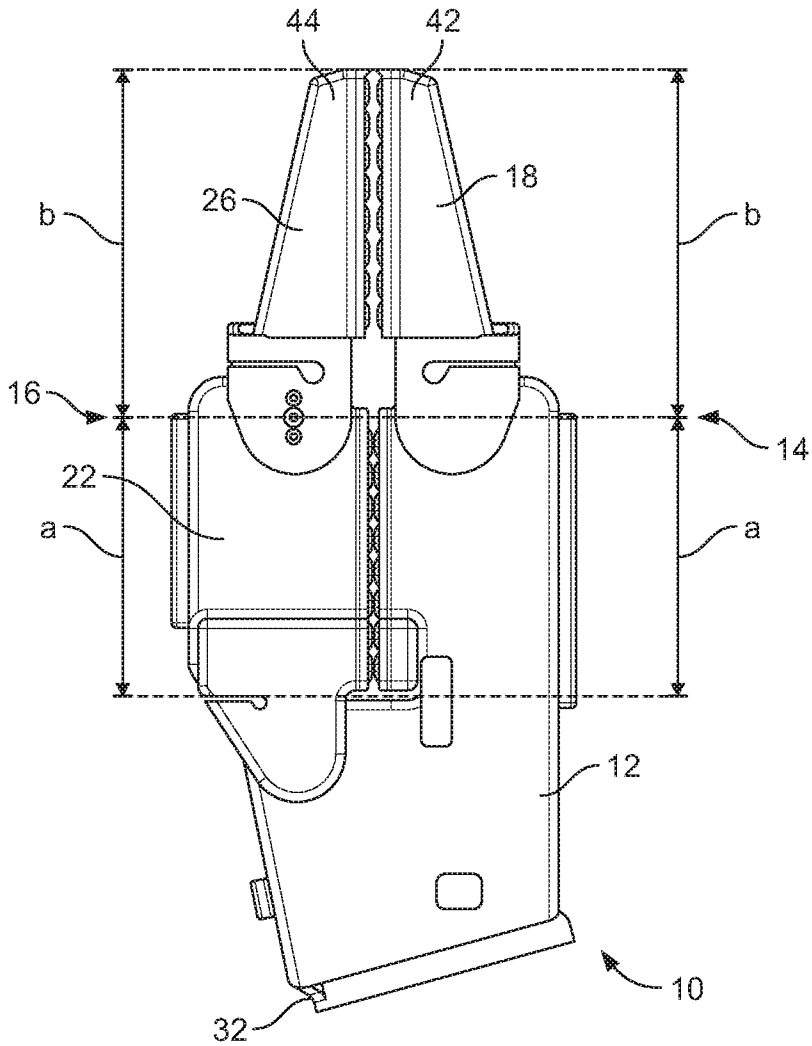
34

FIG. 2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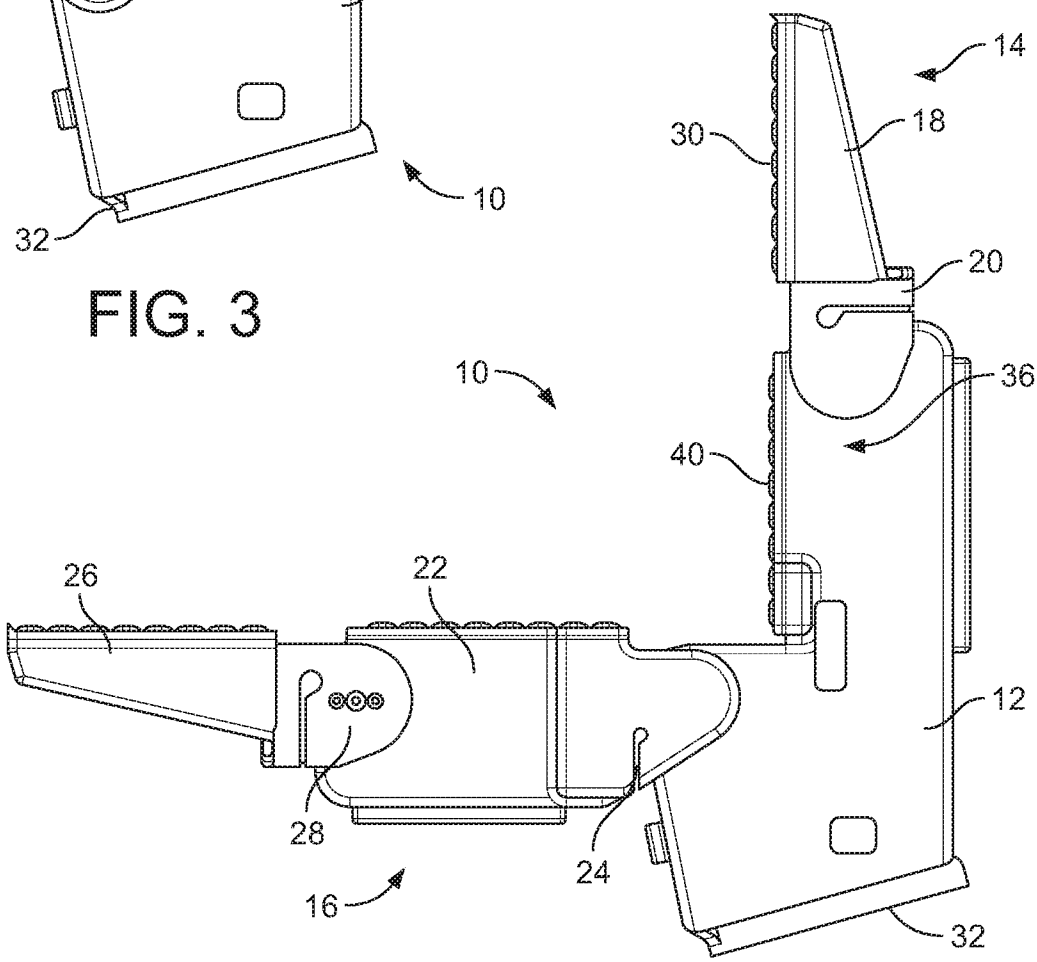
42
18
26
b
b
16
14
22
a
a
12
10
32

FIG. 3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30
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36
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32

FIG. 4

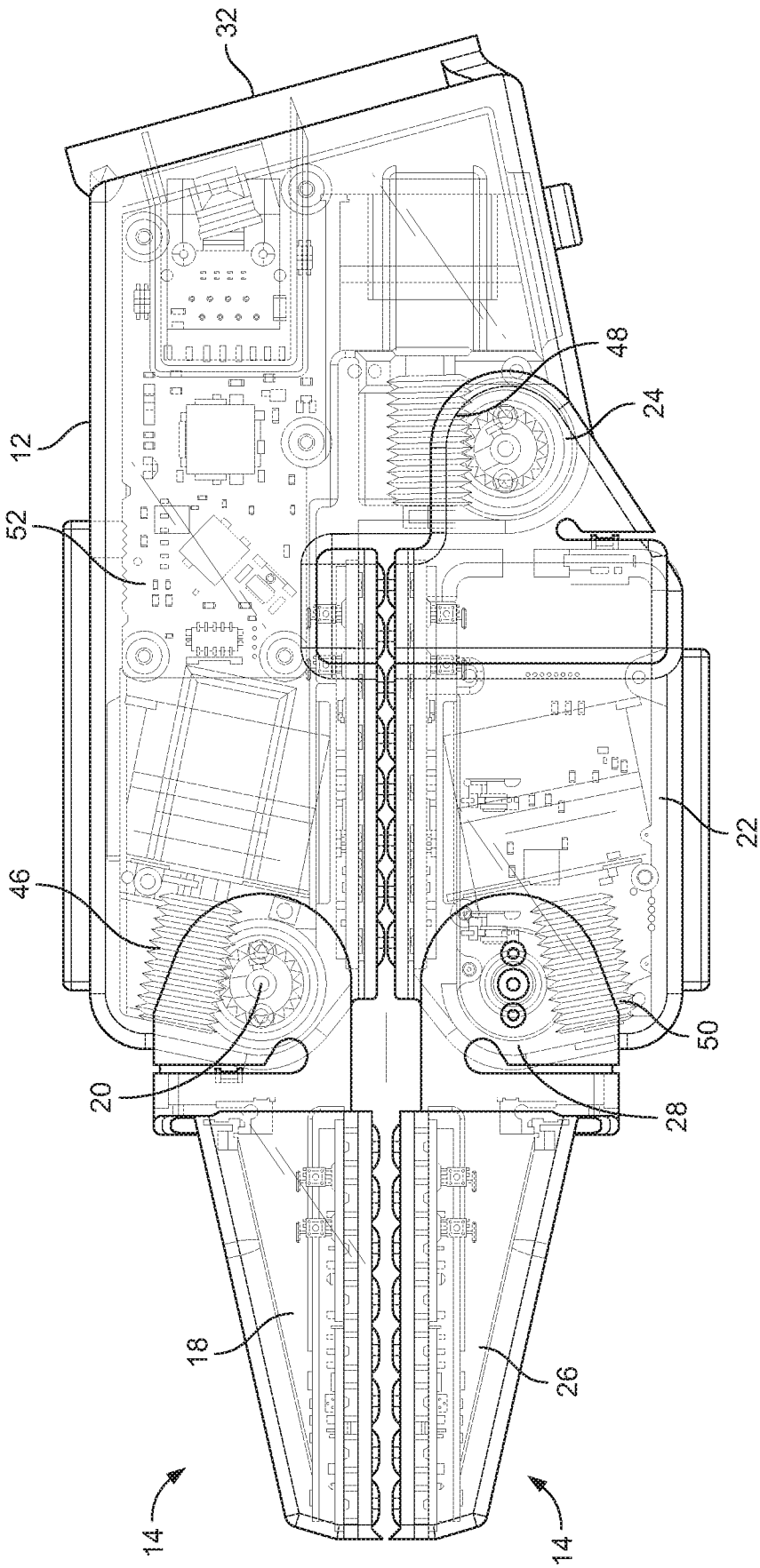

FIG. 5

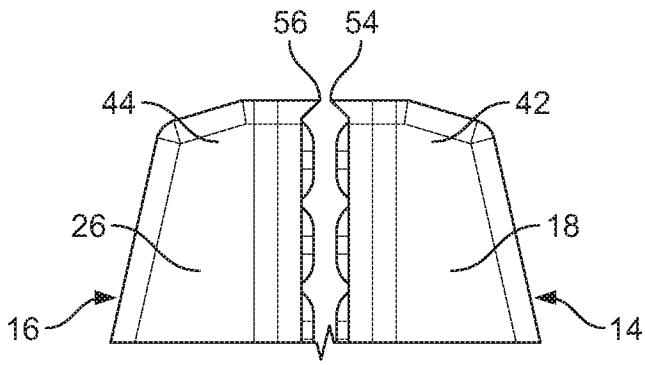

FIG. 6

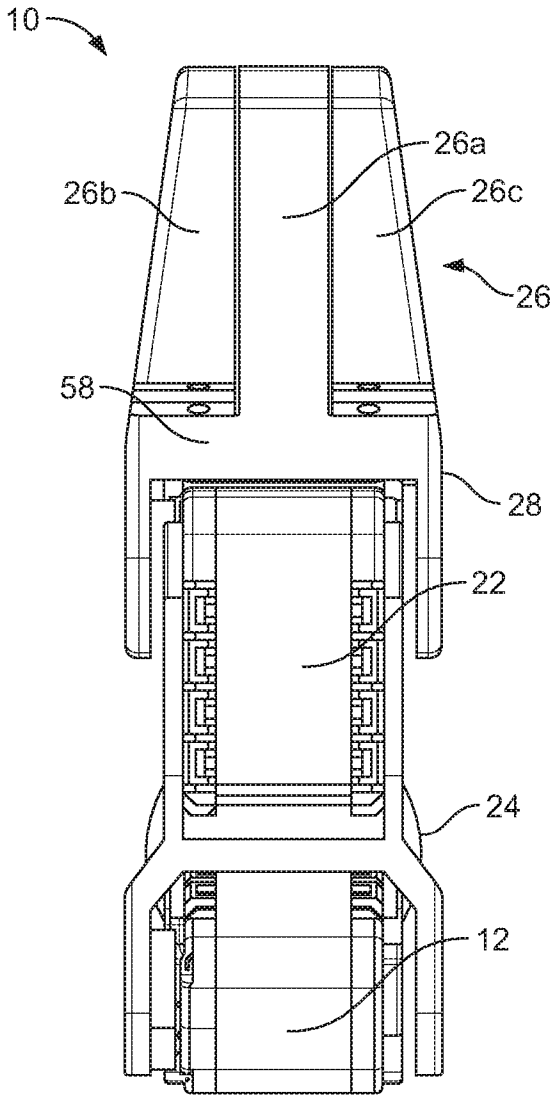

FIG. 7

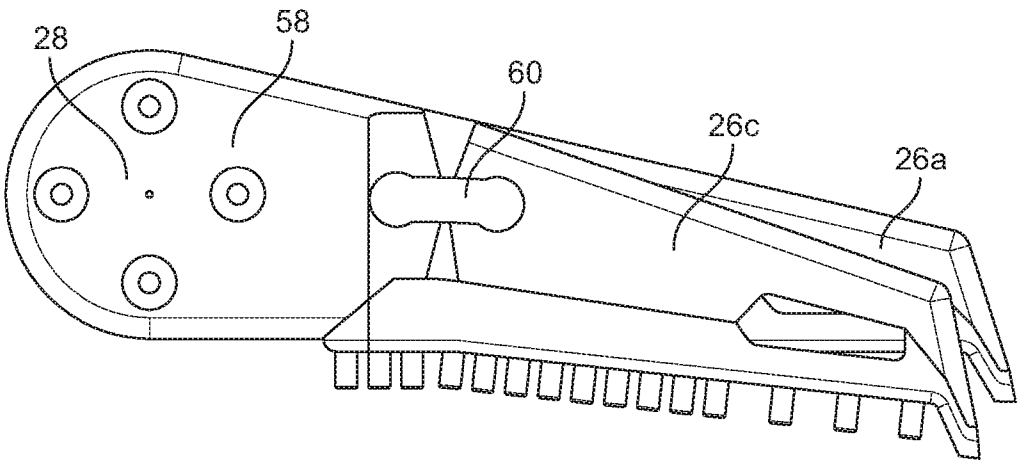

FIG. 8

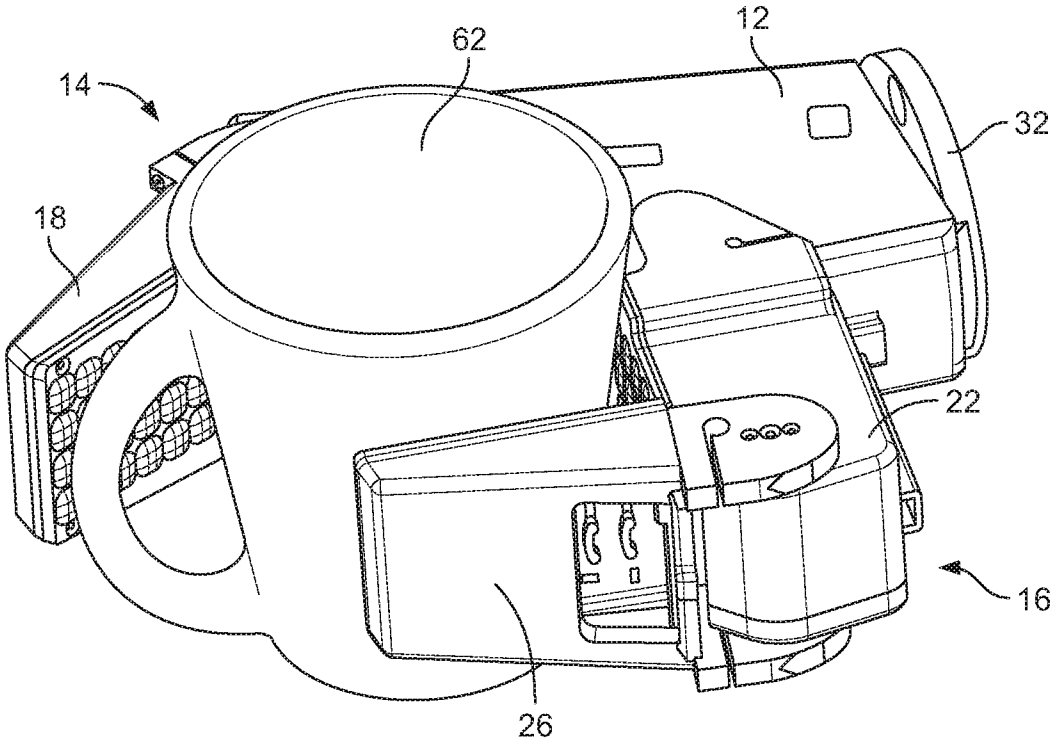

FIG. 9

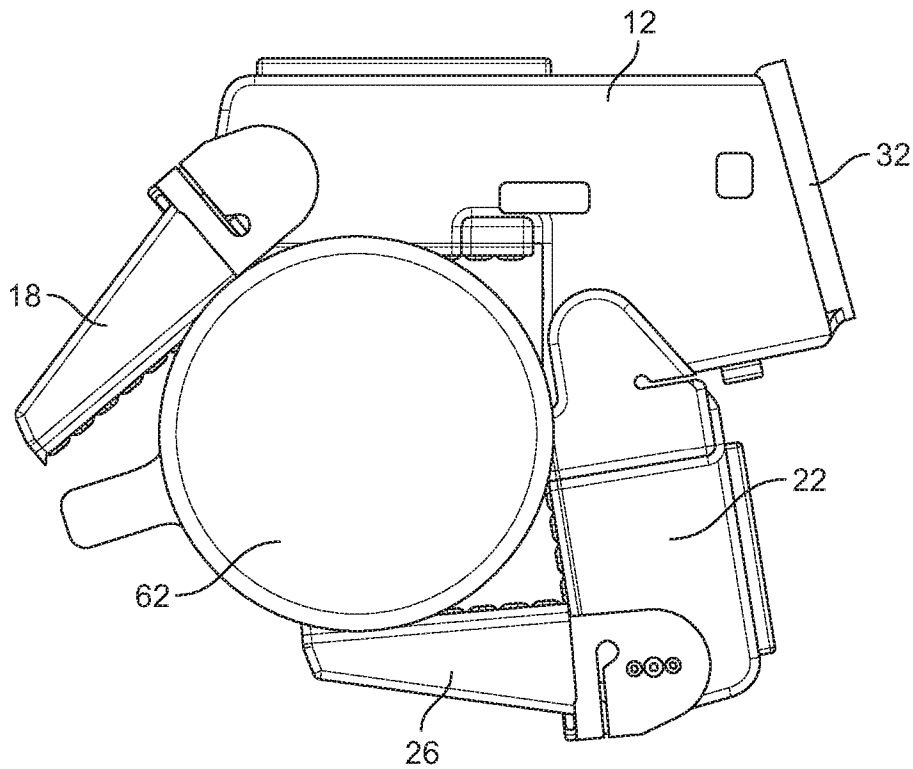

FIG. 10

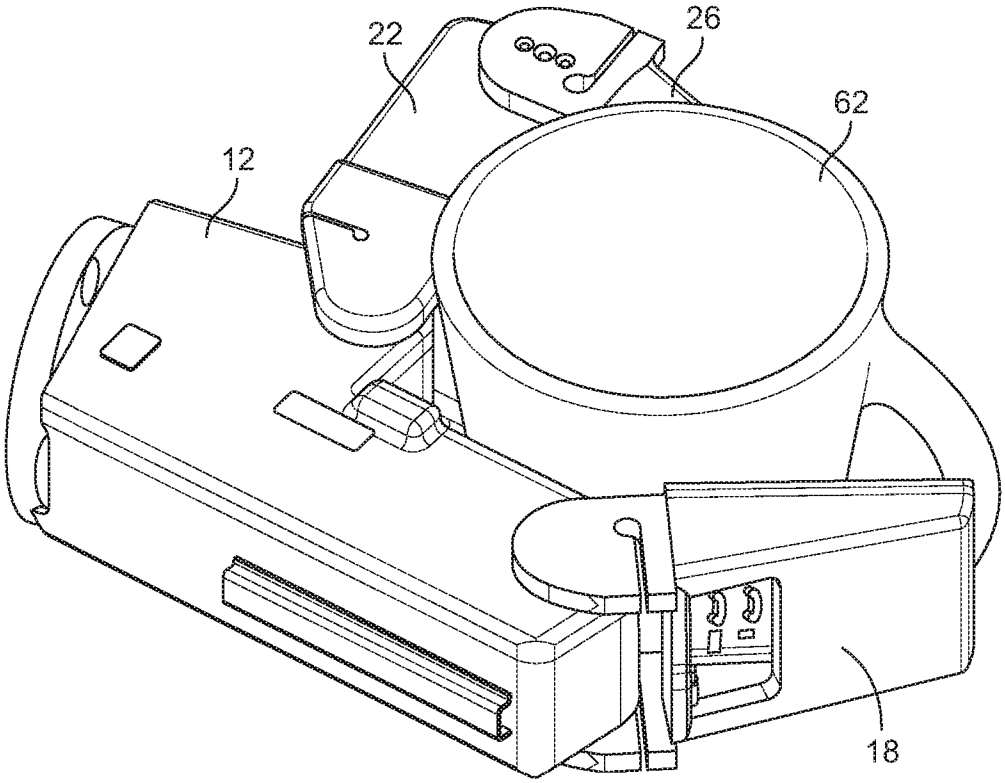

FIG. 11

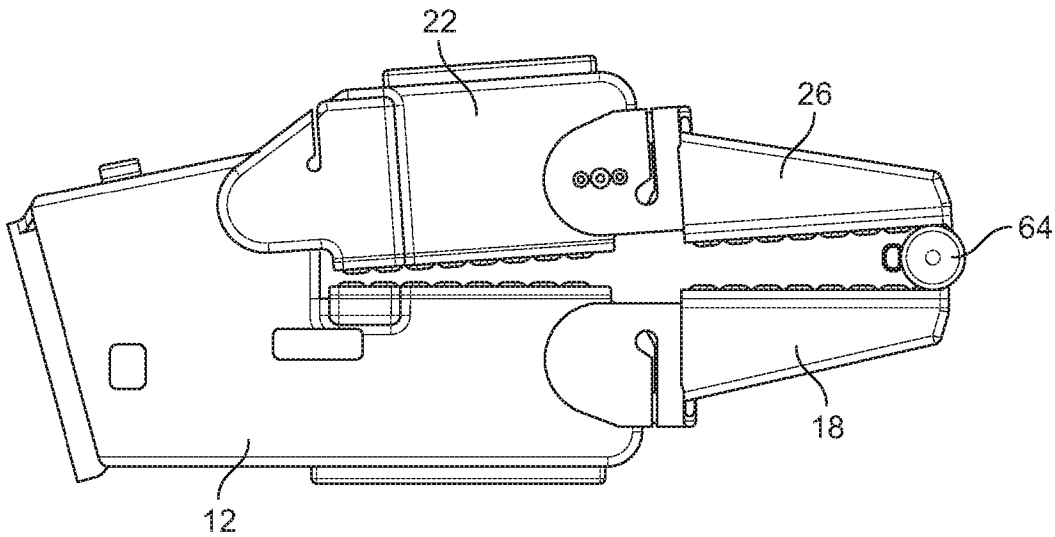

FIG. 12

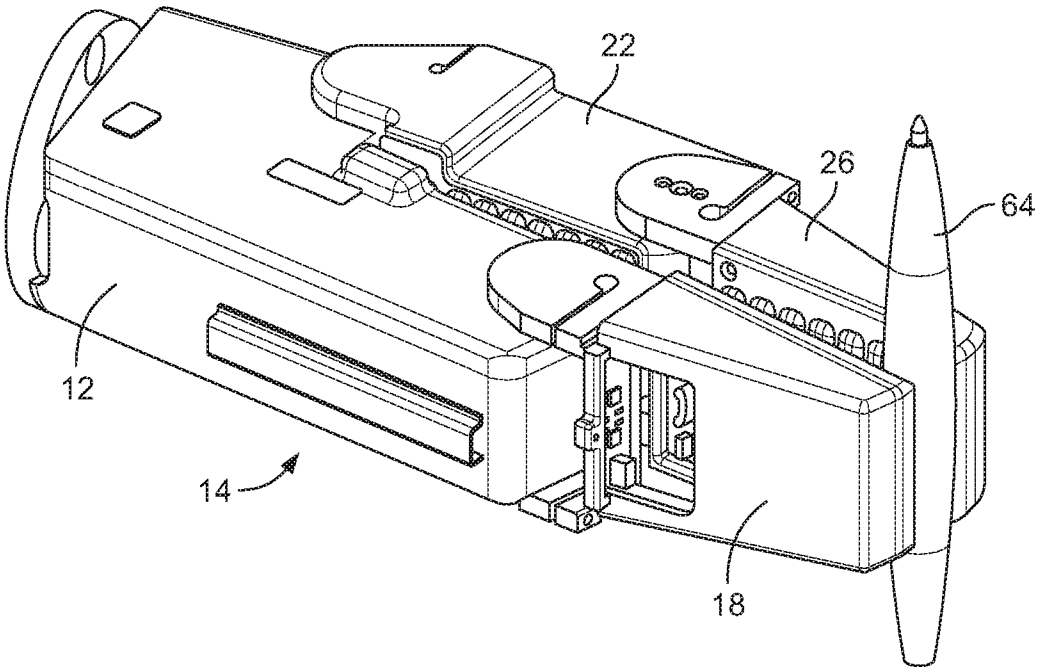

FIG. 13

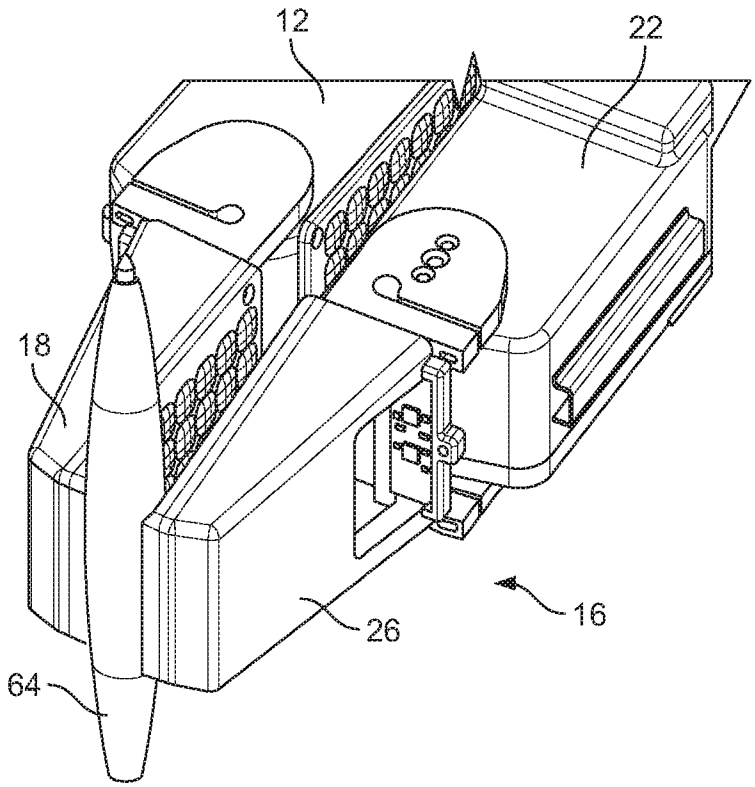

FIG. 14

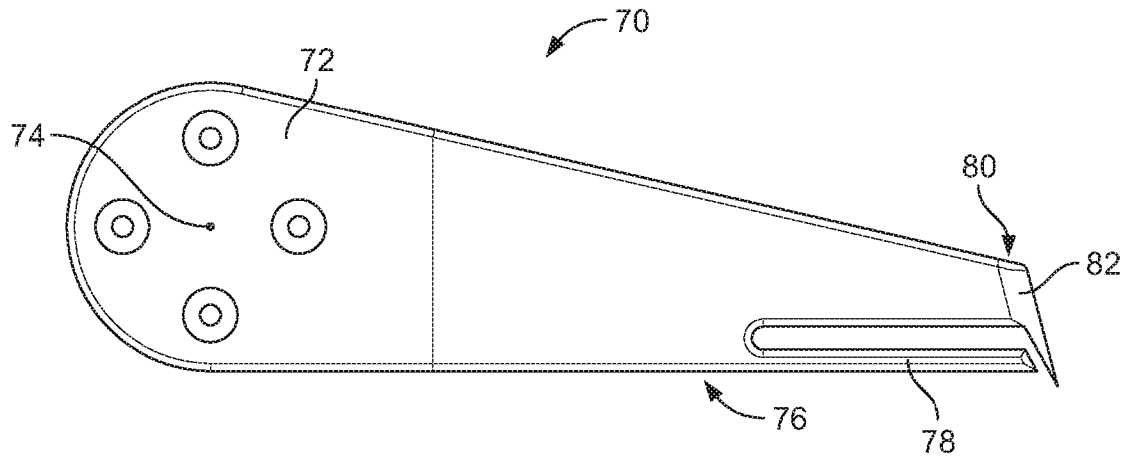

FIG. 15

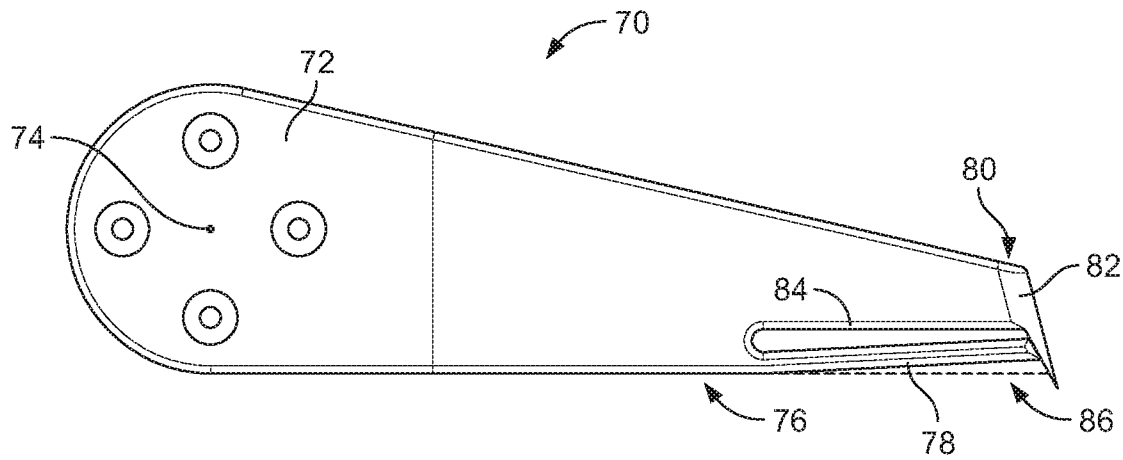

FIG. 16

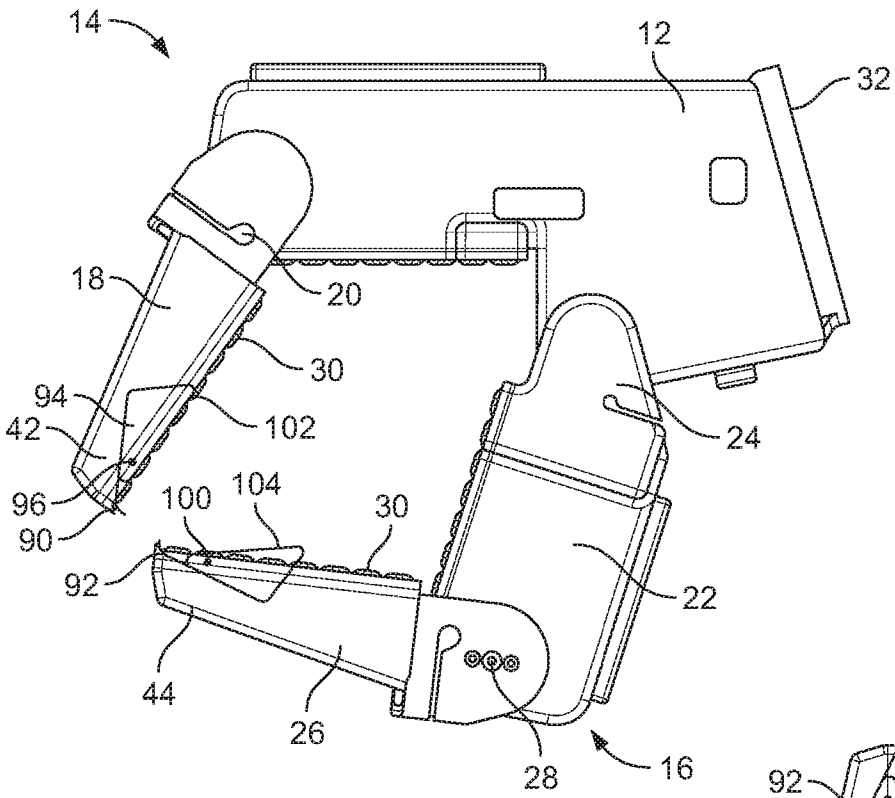
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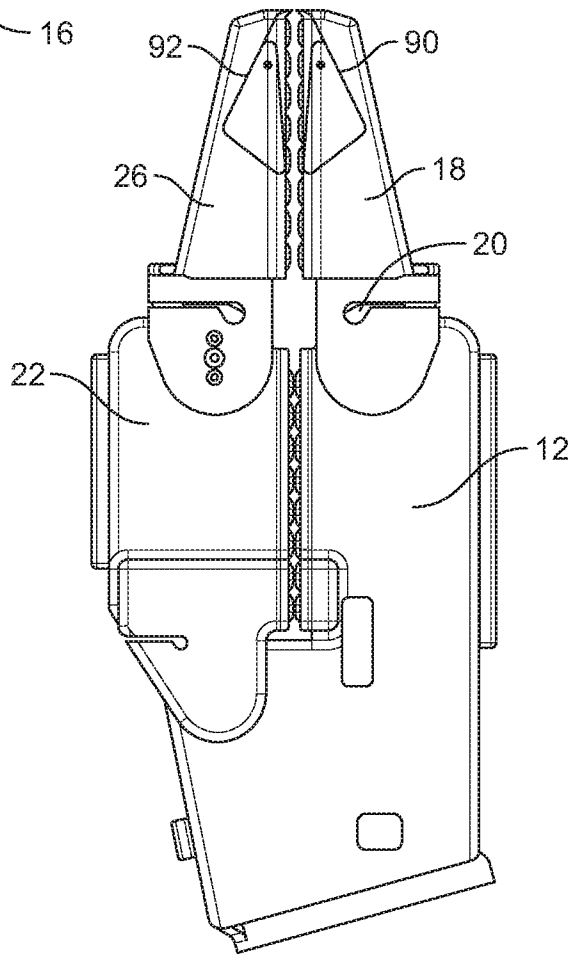
FIG. 17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22
12

FIG. 18

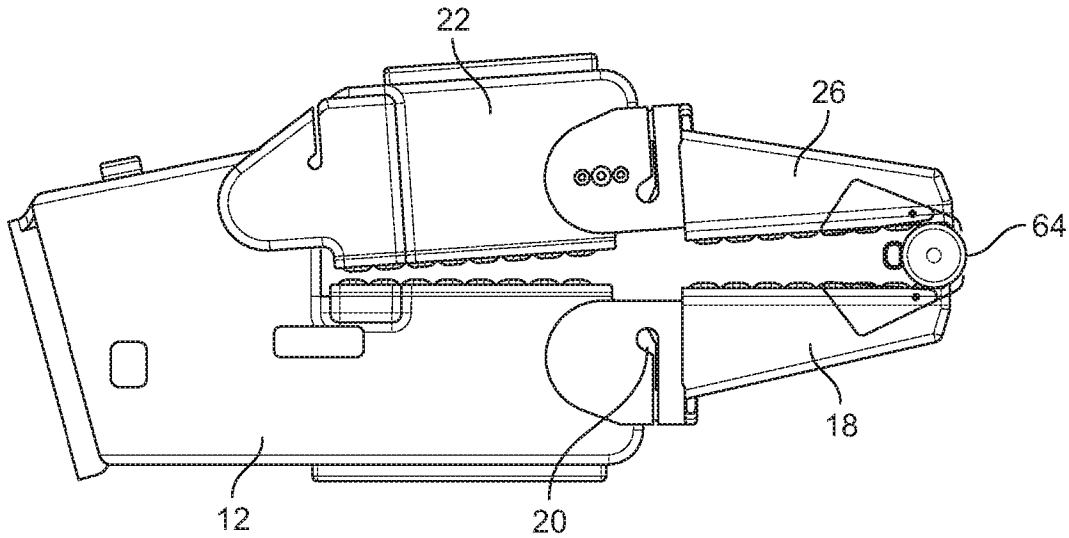


FIG. 19

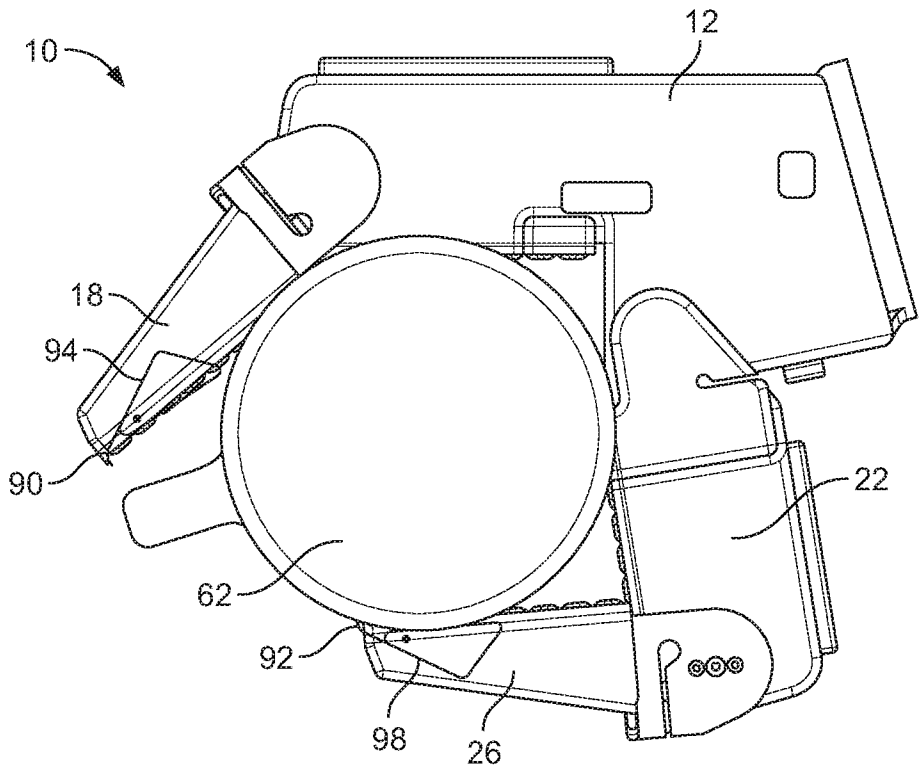
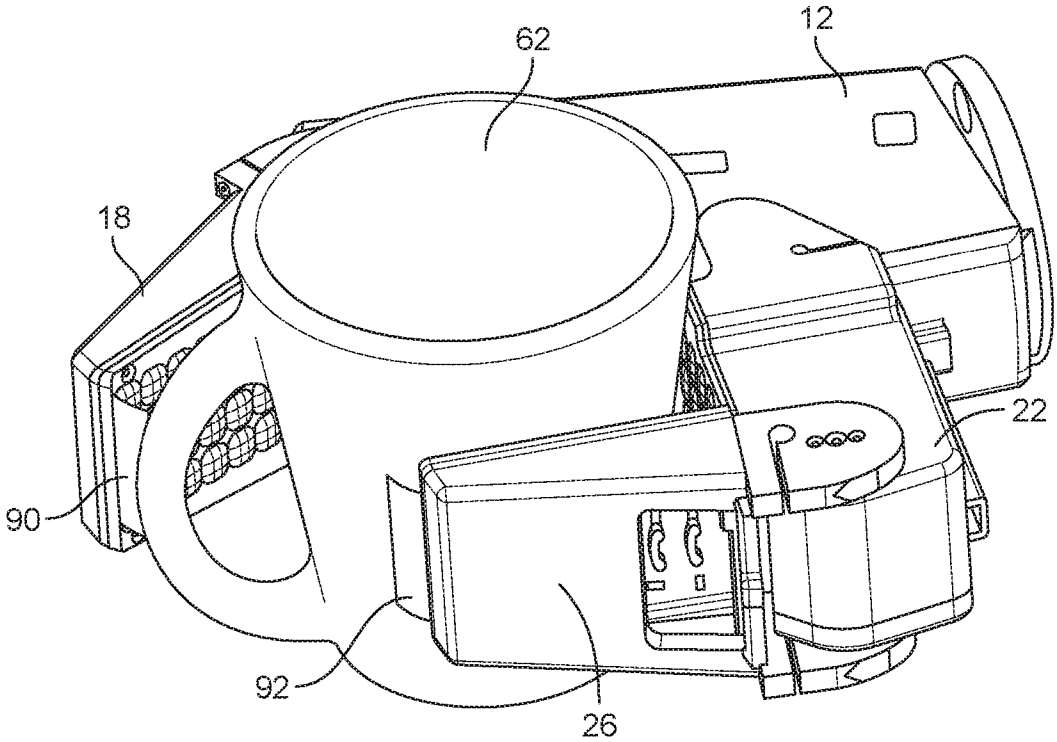


FIG. 20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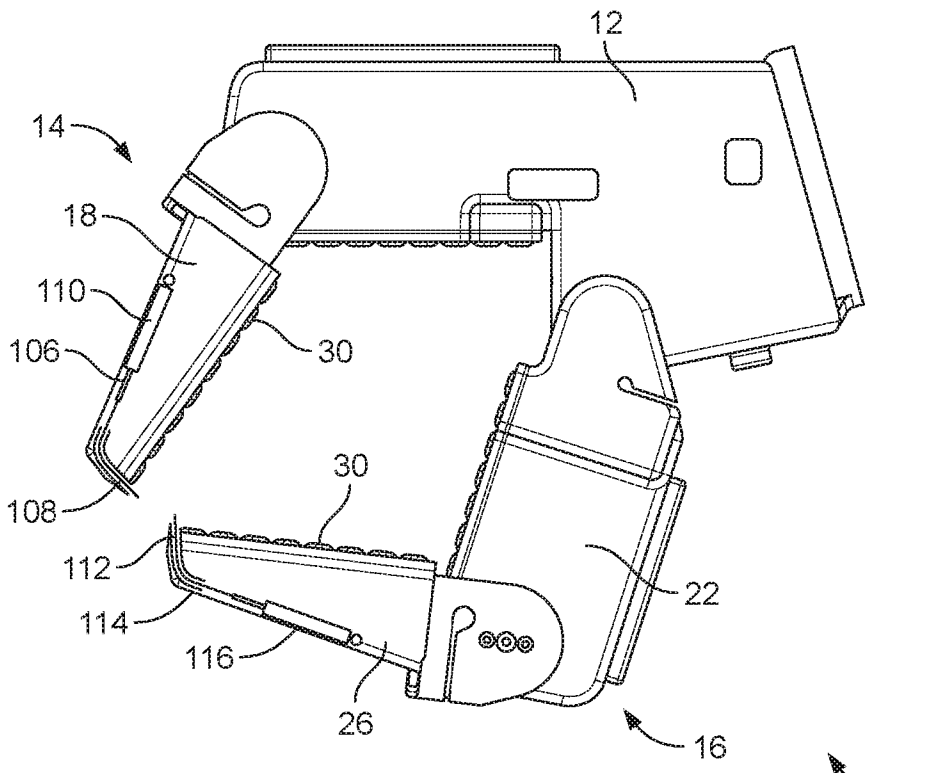
22
90
92
26

FIG. 21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14
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110
106
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108
112
114
116
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16
10

FIG. 22

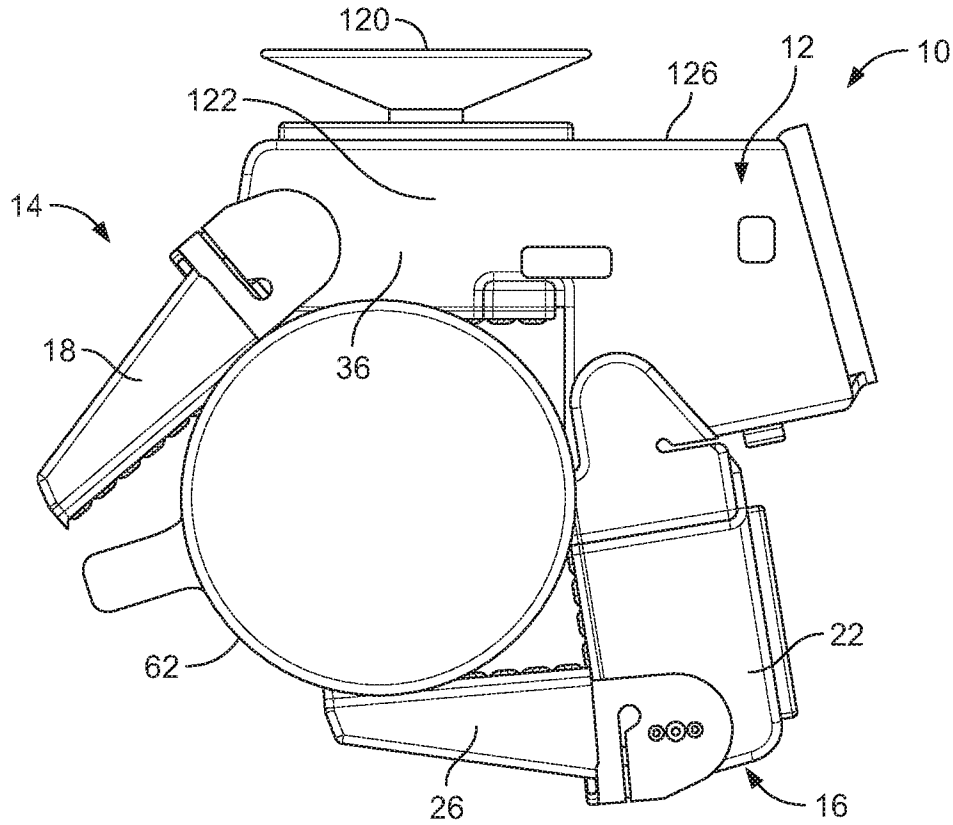
120
122
126
12
10
14
18
36
22
62
26
16

FIG. 23

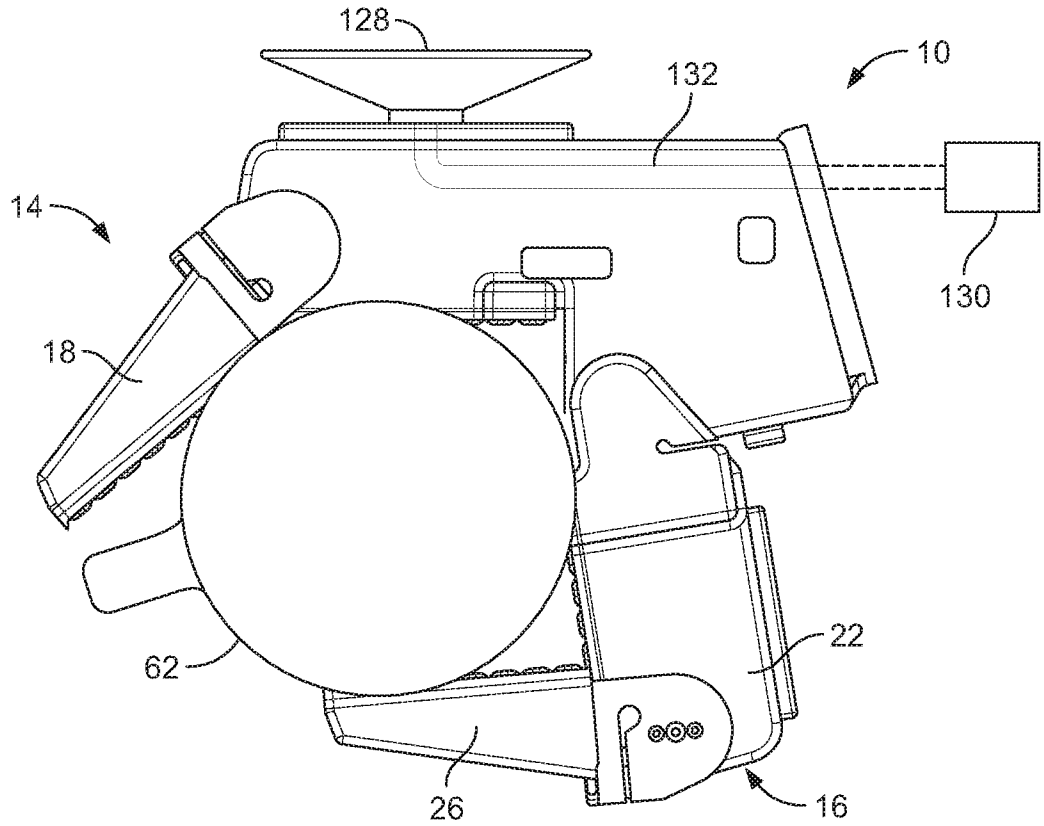
128
132
10
14
130
18
22
62
26
16

FIG. 24

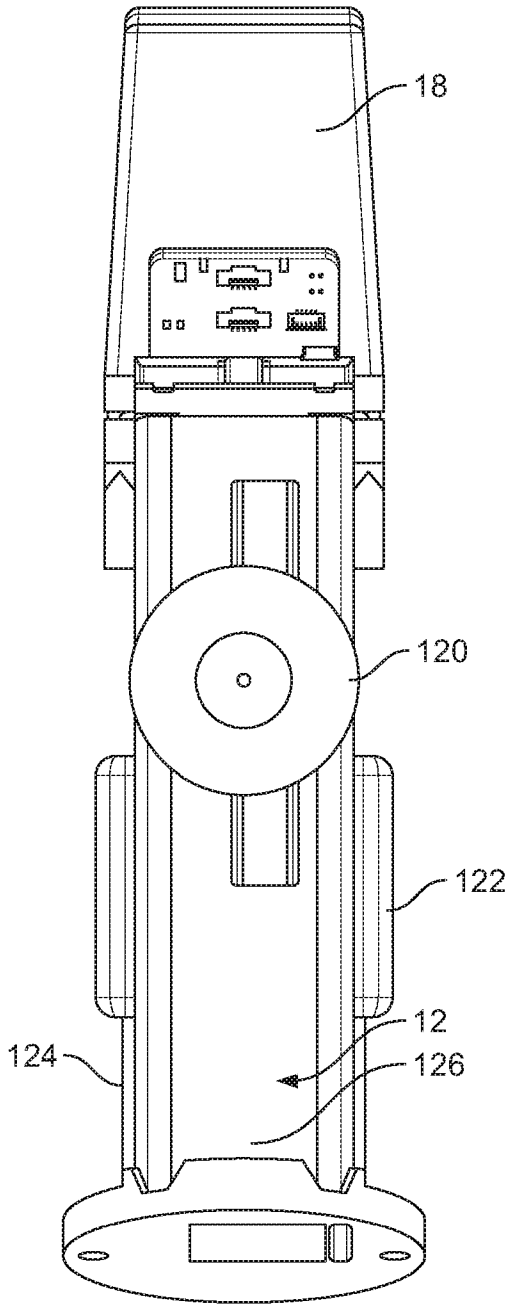

FIG. 25

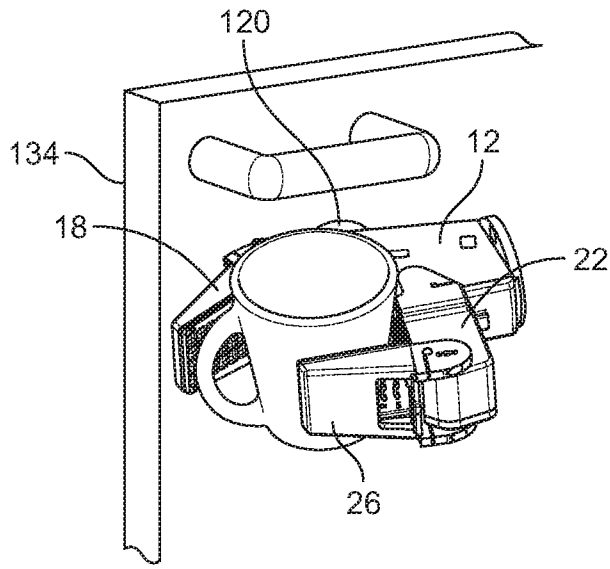

FIG. 26

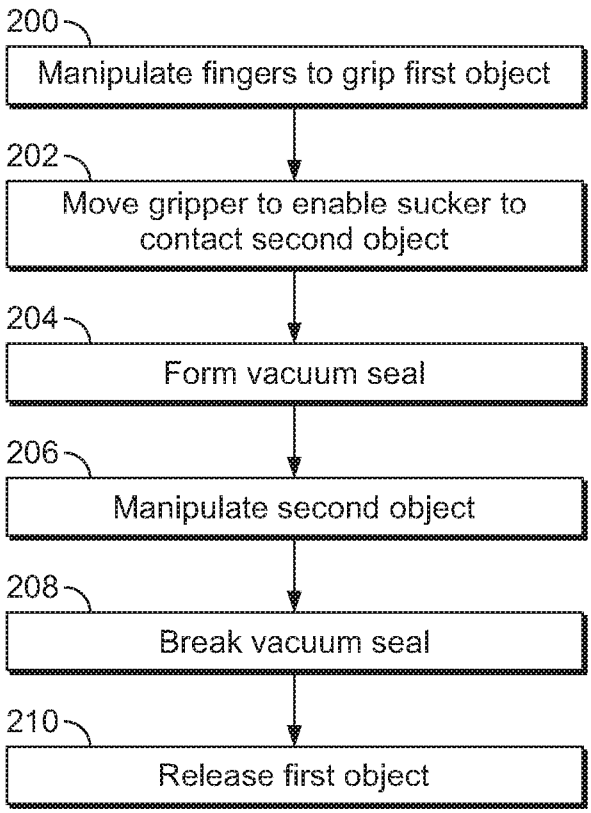
200
Manipulate fingers to grip first object
202
Move gripper to enable sucker to contact second object
204
Form vacuum seal
206
Manipulate second object
208
Break vacuum seal
210
Release first object

FIG. 27

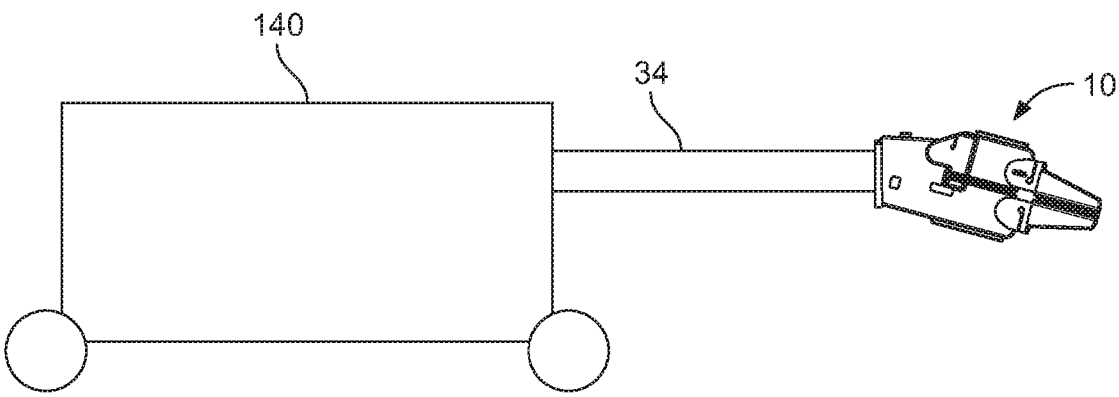
140
34
10

FIG. 28

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2021/050464

A. CLASSIFICATION OF SUBJECT MATTER
INV. B25J15/00 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

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, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 10 556 338 B1 (MARCHESE ANDREW D [US] ET AL) 11 February 2020 (2020-02-11) figures 1,2,11,12	1-4,10, 12
X	US 2017/282379 A1 (NAKAYAMA KAZUTAKA [JP]) 5 October 2017 (2017-10-05) figures 1-5	1,2,4-6, 12
X	WO 2017/121681 A1 (KUKA ROBOTER GMBH [DE]) 20 July 2017 (2017-07-20) figures 1-22	1,2,4, 7-9,12
X	US 2016/089793 A1 (TRUEBENBACH ERIC L [US]) 31 March 2016 (2016-03-31) paragraph [0055]; figure 10	1-3,5, 11,12

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"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
16 June 2021	28/06/2021

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

1

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2021/050464

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP S64 71684 A (TEIJIN SEIKI CO LTD) 16 March 1989 (1989-03-16) figures 4-6	1-4,10, 12
X	JP H03 43182 A (FUJITSU LTD) 25 February 1991 (1991-02-25) figures 1-8	1,2,4,6
X	JP 2010 253571 A (IHI CORP) 11 November 2010 (2010-11-11) figures 3-7	1,2,4, 7-9,12
X	US 2019/126493 A1 (JONAS JUDE ROYSTON [US] ET AL) 2 May 2019 (2019-05-02) figures 1-10	1-4,7,12

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/GB2021/050464

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		JP H0343182 A	25-02-1991
JP 2010253571 A	11-11-2010	NONE	
US 2019126493 A1	02-05-2019	DE 112018005221 T5	18-06-2020
		GB 2581098 A	05-08-2020
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