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(54) Title: AN APPARATUS FOR USE IN BREAKING DOWN AN ANIMAL CARCASS

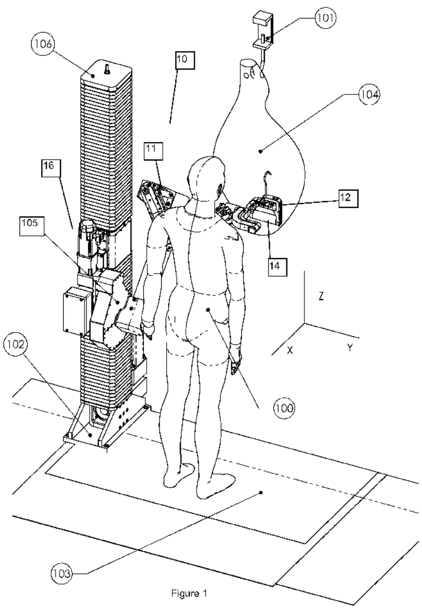

Figure 1

(57) Abstract: An apparatus for use in breaking down an animal carcass is described including: an arm; an end effector is mounted to the arm for effecting actions on the carcass; the end effector includes an input device for detecting input forces of a worker; a motive device is associated with the arm for driving the arm in response to the input forces to effectively amplify the input forces of the worker; and wherein the end effector is rotatable in at least one plane with respect to the arm.

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AN APPARATUS FOR USE IN BREAKING DOWN AN ANIMAL CARCASS

Technical Field

The present invention relates to an apparatus for use in breaking down an animal carcass. The invention has particular applicaiton in meat processing operations.

Background to the Invention

The carcasses of larger livestock such as beef or lamb are typically broken down into smaller, more manageable cuts of meat prior to sale. In order to break a carcass down into smaller cuts, it is typically hung from a rail at a convenient height and workers perform the manual task of breaking down the carcass. The workers make use of a knife which is held in the dominant hand, and also usually a hook which is held in the non-dominant hand. The hook used to grapple, hold, orient, pull, and tear the carcass as pieces of meat are separated from it. The hook is also often used to support, control, transport and even throw pieces of meat once separated from the carcass. Large forces are commonly exerted with the hook, and producing these large forces can lead to repetitive strain injury or other injury to the worker. Furthermore, the necessity to exert large forces can lead the worker to adopt body postures which are not optimal for ergonomic safety. Productivity, in speed of work and also in the quality and value of the cuts of meat produced, are also affected by the worker's ability to produce large pulling forces with the hook. Older workers or those who become less strong for any reason may find themselves unable to continue in their line of work because of the high physical demands or injury. It would be advantageous to improve upon techniques for breaking down carcasses.

Summary of the Invention

In a first aspect the present invention provides an apparatus for use in breaking down an animal carcass including: an arm; an end effector is mounted to the arm for effecting actions on the carcass; the end effector includes an input device for detecting input forces of a worker; a motive device is associated with the arm for driving the arm in response to the input forces to effectively amplify the input forces of the worker; and wherein the end effector is rotatable in at least one plane with respect to the arm.

The end effector may be rotatable in at least two planes with respect to the arm.

The end effector may be rotatable in three planes with respect to the arm.

The end effector may be fitted with a tool.

The tool may include any one of a hook, knife, or gripping device.

The end effector may include at least one rotational position sensor.

The end effector may include at least one load cell for detecting input forces of a user.

The end effector may include an arrangement of three load cells for detecting input forces of a user.

The end effector may be rotatable by way of at least one gimbal.

The end effector may be rotatable by way of an arrangement of three gimbals.

A rotational sensor may be associated with at least one of the gimbals.

The apparatus may further including a device for determining the total forces at a tool mounted to the end effector.

The forces of a user may be amplified by a factor in the range of 5 to 20 times.

The forces of a user may be amplified by a factor of about 10 times.

In a second aspect the present invention provides an apparatus for use in breaking down an animal carcass including: an arm; a motive device is associated with the arm for driving the arm in response to the input forces to effectively amplify the input forces of the worker.

In a third aspect the present invention provides an end effector including at least one gimbal.

Brief Description of the Drawings

An embodiment of the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 shows an apparatus for use in breaking down an animal carcass with a worker standing before a portion of a carcass;

Figure 2 is an exploded view of the apparatus of figure 1;

Figure 3 is an exploded view of the LZ tower of the apparatus of figure 1;

Figure 4 is an exploded view of the RY assembly of figure 1;

Figure 5 shows detail of additional components of the RY assembly of figure 1;

Figure 6a shows the LY linkage of figure 1;

Figure 6b is an exploded view of the LY linkage of figure 1; and

Figure 7 is an exploded view of the gimbal assembly of figure 1.

Detailed Description of the Preferred Embodiment

Referring to figure 1, an apparatus 10 for use in breaking down a carcass of an animal is shown including an arm 11. An end effector 12 is mounted to arm 11 for effecting actions on the carcass. The end effector 12 includes an input device in the form of handle 14 which detects input forces of a worker. A motive device in the form of robot 16 drives arm 11 to thereby effectively amplify the input forces of the worker. The combined force of the worker and the robot effect actions on the carcass as will be later described.

In this embodiment there are three axes of motion, which are denoted z, the vertical translational axis of motion; y, a horizontal translational axis of motion parallel to an overhead chain rail (not shown) along which carcasses or parts of carcasses 104 move along in a direction left/right for the worker 100 drawn in the figure; and x, a horizontal translational axis of motion perpendicular to the motion of the chain rail and forward/backward for the worker drawn in the figure. These axes of motion will be further detailed in subsequent figures and description.

In this embodiment the apparatus is described for a right-hand dominant worker, who would generally hold a knife in the right hand and use the left hand for a hook. In other embodiments the apparatus can be configured ambidextrously for a right and/or left handed worker.

The end effector is rotatable in three planes with respect to the arm by way of a gimbal assembly. Three unpowered (passive) axes of motion are allowed by the end effector 12, which are rotations allowed about axes passing through the worker's hand. The end effector 12 will be further detailed in subsequent figures and description.

Figure 1 shows the worker's work space on the plant floor. In this embodiment the base of the robot 102 is bolted securely to the floor 103. In other embodiments the base may instead be secured to the ceiling, to overhead support structure and/or to a translation stage which can move in the y direction. Numerous kinds of translation stage are known for this purpose. A translation stage can extend the volume that the worker can reach with the power-assisted hook, and in particular the translational stage can move along the chain rail to track the motion of the meat 104 and/or the worker along the chain rail. Such a translational stage is preferably powered.

Also shown in figure 1 is the attachment of RY assembly 105 to LZ tower 106, which will be described subsequently.

Figure 2 shows four major components of the apparatus. The LZ tower assembly 200 is bolted to the plant floor via base plate 201, or may be attached to a translatable carriage or rail. LZ tower assembly 200 preferably includes a gusset plate 202 which connects base plate 201 to a tower providing powered vertical motion, as will be further detailed in subsequent figures. RY assembly 203 is conveyed vertically by its attachment to LZ tower assembly 200; this attachment is shown disconnected in Figure 2. RY assembly 203 produces powered rotation about a y axis, as will be described further. LY assembly 204 is shown in the figure detached from arm 205 of RY assembly 203, to which it would normally be attached. LY assembly 204 provides translational motion along the y axis. Gimbal assembly 206 is shown detached from LY assembly 204, to which it would normally be attached. Gimbal assembly 206 allows rotation of a worker's hand and a hook assembly 207 about three rotation axes, with centre of rotation preferably located near the centre of the worker's hand. These axes of rotation are unpowered. Gimbal assembly 206 and hook assembly 207 will be further detailed in subsequent figures. LZ Tower assembly 200 is enclosed by bellows 208 which attaches to the top and bottom of travelling bellows sleeve 209, which will be shown in figure 4.

Figure 3 shows an exploded view of a preferred embodiment of the LZ tower 200. In this embodiment a main structural element is tower box beam 300 which is cut to allow attachment of a linear track 301. Within tower box beam 300, belt 302 is supported, at its lower end by toothed pulley 303 and at its upper end by idler pulley 304. Belt 302 carries more distal portions of the robot vertically (along the z axis) as will be described next. Belt 302 is driven via toothed pulley 303, which is rotated by gearbox 305 which is preferably a 5:1 reduction gearbox. Motor 306 drives the input of gearbox 305. Motor 306 is preferably a brushless DC servomotor. Brake 307 is attached to motor 306, preferably at the back as shown. Motor 306 is driven by a conventional motor amplifier or controller, under software control as will be described. To allow the conveyance of signal and power wires to distal parts of the robot, cable track 308 is attached at its lower end to cable funnel 309 which is attached to tower box beam 300. At its upper end, cable track 308 moves vertically with RY assembly, which is carried vertically by belt 302 as will be described next.

Figure 4 illustrates the RY assembly which provides powered rotation about the y axis. Travelling bellows sleeve 209 is attached to carriage plate 400, in turn attached to belt 302 and also to carriage plate extension 401 and neck 402. RY shaft housing 403 is also attached to neck 402, and within RY shaft housing 403 is a potentiometer 404 for measuring the rotation of RY tube 205 about the y axis. Attached to motor plate 405 is gearbox 406 which is preferably of a 28:1 reducing gear ratio. Gearbox 406 is driven by motor 407 and braked by brake 408, where motor 407 is preferably a brushless DC servomotor and brake 408 is mounted to the rear of motor 407. In this way motor 407 produces rotation of toothed pulley 409, which passes through motor plate 405, and drives belt 410. Belt 410 is housed within pulley guard 411, and drives RY output pulley in order to rotate arm 205, as will be further illustrated in the next figure.

Figure 5 shows RY output pulley 500 which is housed within pulley guard 411 and rotated by belt 410. RY output pulley 500 includes toothed section 501 which is preferably machined into its otherwise flat curved surface, and engages belt 410 so that rotation of toothed pulley 409 causes RY output pulley 500 to rotate at a reduced speed. RY output pulley 500 is attached via taper-lock bushing 502 to RY shaft 503, and then to tube-RY-shaft coupler 504. RY tube 505 is inserted and bolted into tube-RY-coupler 504. RY arm 205 provides rotation of the remaining distal parts of the robot about the y axis, and also provides translation of it along the x axis.

Figure 6a and 6b show LY assembly 204 in a perspective and in an exploded view, respectively. LY assembly 204 allows passive translational motion of the remaining distal parts of the robot along the y axis. LY assembly 204 is connected to RY tube 505 by RY-LY offset bracket 600. Tube links 601 and tie rods 602 form a pair of four-bar linkages, which are coupled by modified gears 603 which engage each other. Thus the motion of the two four-bar linkages keeps the two bearing ends 604 and 605 level with each other as the LY assembly 204 is lengthened and shortened by a worker's applied forces. Modified gears 603 are housed within gear housing 606, which also supports tie rods 602. Tube links 607 are housed within tube braces 608. The distal end of LY assembly 204 includes two-axis load cell 609 which is able to measure the forces applied to the end effector along the x and z axes. Two axis load cell 609 bears and measures its loads via gimbal connecting shaft 610, which supports the remaining distal parts of the robot, which will be described next. It is important to note that the forces measured by load cell 609 will be a combination of both the worker's input forces, and other forces experienced by the end effector, such as the weight of a portion of the carcass.

Figure 7 shows an end effector 12 being a combination of gimbal assembly 206 and detachable hook assembly 207 which inserts into it. Gimbal assembly 206 allows passive motion about three rotational axes, where the center of rotation of these allowed passive motions is located approximately at the center of the worker's hand as it grips handle 14. Gimbal connecting shaft 610 inserts into first gimbal link 700 which may rotate freely about gimbal connecting shaft 610. On this axis there is also a rotational position sensor in the form of a potentiometer (not shown) which is used to measure the angle of rotation of first gimbal link 700 with respect to load cell 609 base. This freedom of rotation is provided by a bearing within first gimbal link 700. Second gimbal link 701 is also rotatably attached to first gimbal link 700 by another bearing, and on this axis there is also potentiometer 702 which is used to measure the angle of rotation of second gimbal link 701 with respect to first gimbal link 700. Third gimbal link 703 is, similarly, rotatably attached to second gimbal link 701, and similarly incorporates potentiometer 704 to measure the relative angle. Third gimbal link 703 incorporates three axis load cell 705 which is preferably implemented as three consecutive flexures as shown in the figure, but may also be implemented in other ways. Gimbal grip 706 is attached to three axis load cell 705 such that a worker's manually applied forces on gimbal grip 706 will cause readings from three axis load cell 705. With knowledge of both the output of the angular positional information from the potentiometers, and the output of the three axis load cell, it is possible for the control system to calculate in which absolute direction the user is exerting a force and the amount of force exerted by the user. Using this information, the arm can be driven to amplify the forces exerted by the user.

Figure 7 also illustrates detachable hook assembly 207, which engages with gimbal assembly 206. Cylindrical insert 707 engages with gimbal grip 706, while gimbal latch pins 708 engage with holes in latch plate 709. Spring 710 causes latch plate 709 to engage with grooves in gimbal latch pins 708, preventing detachable hook assembly 207 from disengaging with gimbal assembly 206. Latch lever 711 allows a worker, by deflecting the latch lever, to disengage detachable hook assembly 207 from gimbal assembly 206. Detachable hook assembly 207 also carries meat hook 712, which the worker may use in the ways a meat hook is conventionally used.

The movements of the robot are coordinated by a control system (not shown) in the form of a computer which is configured with suitable software to sample the outputs of the various sensors on the robot, and control movements by controlling the various motors or other motive devices on the robot.

To use the apparatus, worker grips the handle 14 and power is supplied to the robot 16 and its control system. The worker manipulates the hook by way of grasping the handle 14 in their left hand and moves the hook in a similar fashion as they would in a traditional manual operation, holding a boning knife in their right hand to cut the carcass in combination with pulling sections to be removed from the carcass with the hook. The three load sensors in the gimbal assembly detect the forces applied to the handle by the worker in the x, y and z axes. The output of the sensors is relayed to the control system of the robot along with the output of the potentiometers in the gibla mechanism. The robot processes these signals and then drives the motors of the robot to provide an amplification of the workers input forces by a factor of 10. Thus, if the worker pulls down on the handle with a force of 10 N, then the robot motors will provide an additional pull force to the carcass of 90 N in the direction the worker is pulling.

Load sensor 609 provides the robot with feedback information of total forces at the end effector, being a combination of the worker's forces and the additional forces applied by the robot. This allows the control system to distinguish between forces applied by the user, and the forces applied by way of the object being manipulated, in this case, a carcass. When a portion of the carcass is cut away, it typically swings downwards and the hook rotates about the gimbal assembly. The robot arm is able to distinguish this from a force applied by a user, and supports the weight of the cut away portion of meat, preventing it from falling to the floor. The worker removes the cut away portion from the hook and resumes breaking down the remainder of the carcass until the entire carcass has been processed. Another carcass then travels along the overhead rail to the workers station for subsequent processing.

In the embodiment described above the end effector included a hook for manipulating the carcass. Similarly, in other embodiments the end effector may be provided with a knife or meat gripping device.

In the embodiment described above the movement along the y axis was not amplified and thus was entirely passive. In other embodiments, movement in the y axis may be powered.

In the embodiment described above, the amount of amplification was of the order of 10 times. In other embodiments, the amplification of the users force may lie in a range of 5 to 20 times. In some embodiments, the degree of amplification may be variable or may be selectable by the user.

It can be seen that embodiments of the invention provide for amplification of the actions of a worker to assist in breaking down of a meat carcass. Thus, the worker need only exert smaller forces than is traditional. This reduces the risk of injury to a worker, and enables workers with less strength than was traditionally required to successfully break down a meat carcass. Further, because the end effector allows rotational freedom, the user may manipulate the handle in a similar manner as they would usually do to effect a manual operation. In this way, the apparatus is ergonomically designed to amplify normal movements of a user.

Any reference to prior art contained herein is not to be taken as an admission that the information is common general knowledge, unless otherwise indicated.

Finally, it is to be appreciated that various alterations or additions may be made to the parts previously described without departing from the spirit or ambit of the present invention.

CLAIMS:

1. An apparatus for use in breaking down an animal carcass including:
an arm;
an end effector is mounted to the arm for effecting actions on the carcass;
the end effector includes an input device for detecting input forces of a worker;
a motive device is associated with the arm for driving the arm in response to the input forces to effectively amplify the input forces of the worker; and
wherein the end effector is rotatable in at least one plane with respect to the arm.
2. An apparatus according to claim 1 wherein the end effector is rotatable in at least two planes with respect to the arm.
3. An apparatus according to claim 1 wherein the end effector is rotatable in three planes with respect to the arm.
4. An apparatus according to any preceding claim wherein the end effector is fitted with a tool.
5. An apparatus according to claim 4 wherein the tool includes any one of a hook, knife, or gripping device.
6. An apparatus according to any preceding claim wherein the end effector includes at least one rotational position sensor.
7. An apparatus according to any preceding claim wherein the end effector includes at least one load cell for detecting input forces of a user.
8. An apparatus according to any preceding claim wherein the end effector includes an arrangement of three load cells for detecting input forces of a user.
9. An apparatus according to any preceding claim wherein the end effector is rotatable by way of at least one gimbal.
10. An apparatus according to any preceding claim wherein the end effector is rotatable by way of an arrangement of three gimbals.
11. An apparatus according to either of claim 9 or claim 10 wherein a rotational sensor is associated with at least one of the gimbals.
12. An apparatus according to any preceding claim further including a device for determining the total forces at a tool mounted to the end effector.
13. An apparatus according to any preceding claim wherein the forces of a user are amplified by a factor in the range of 5 to 20 times.
14. An apparatus according to claim 13 wherein the forces of a user are amplified by a factor of about 10 times.

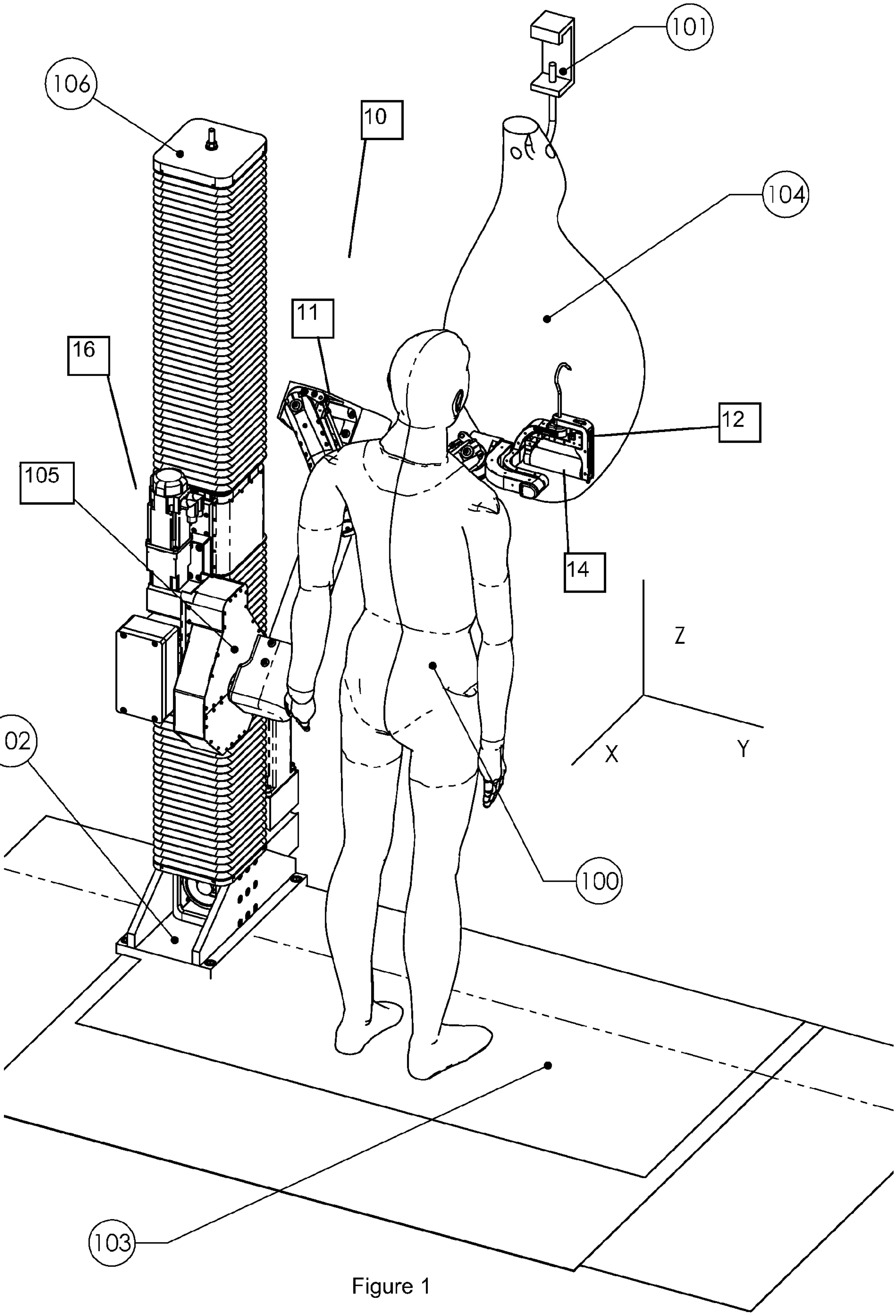

Figure 1

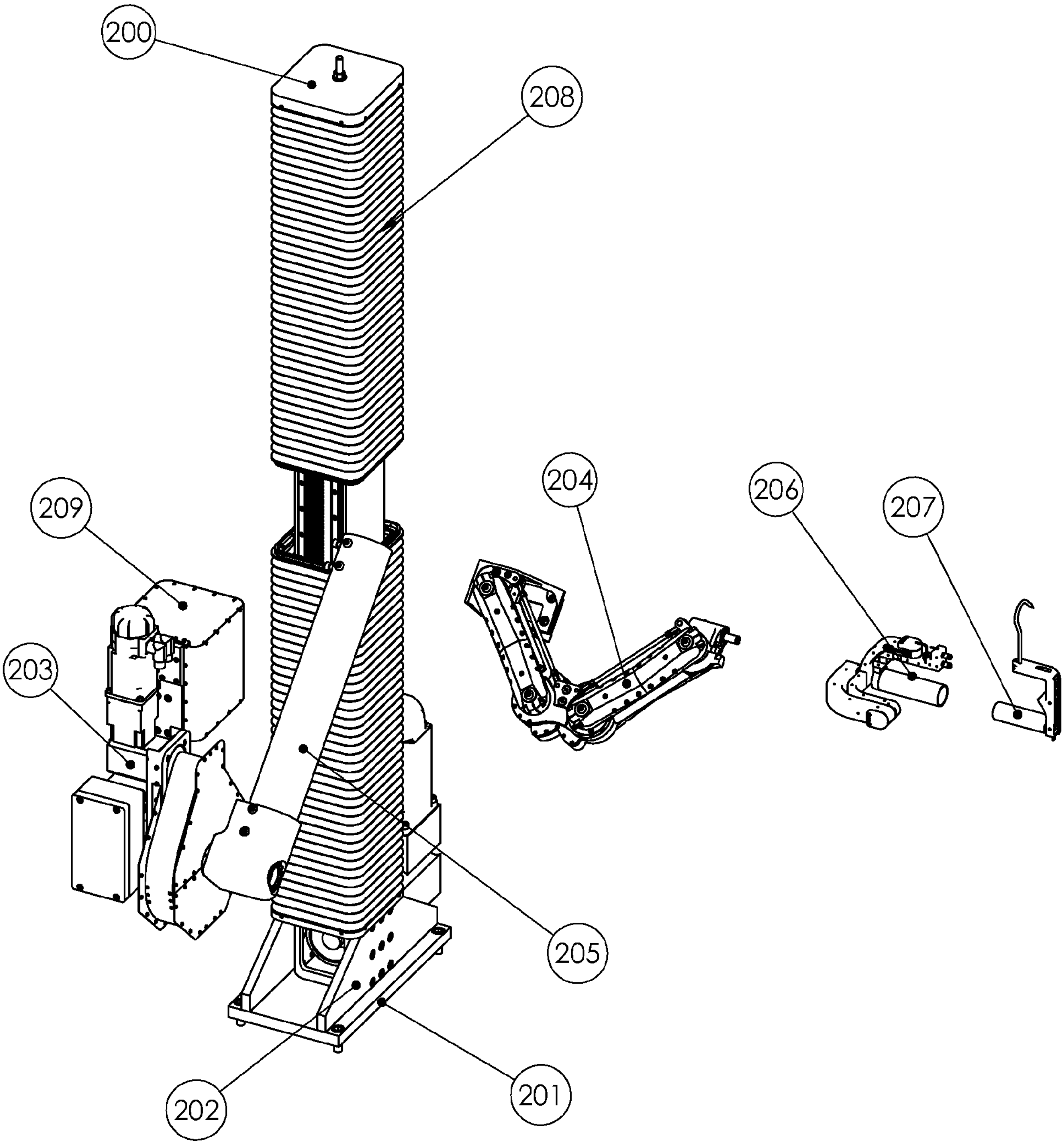

Figure 2

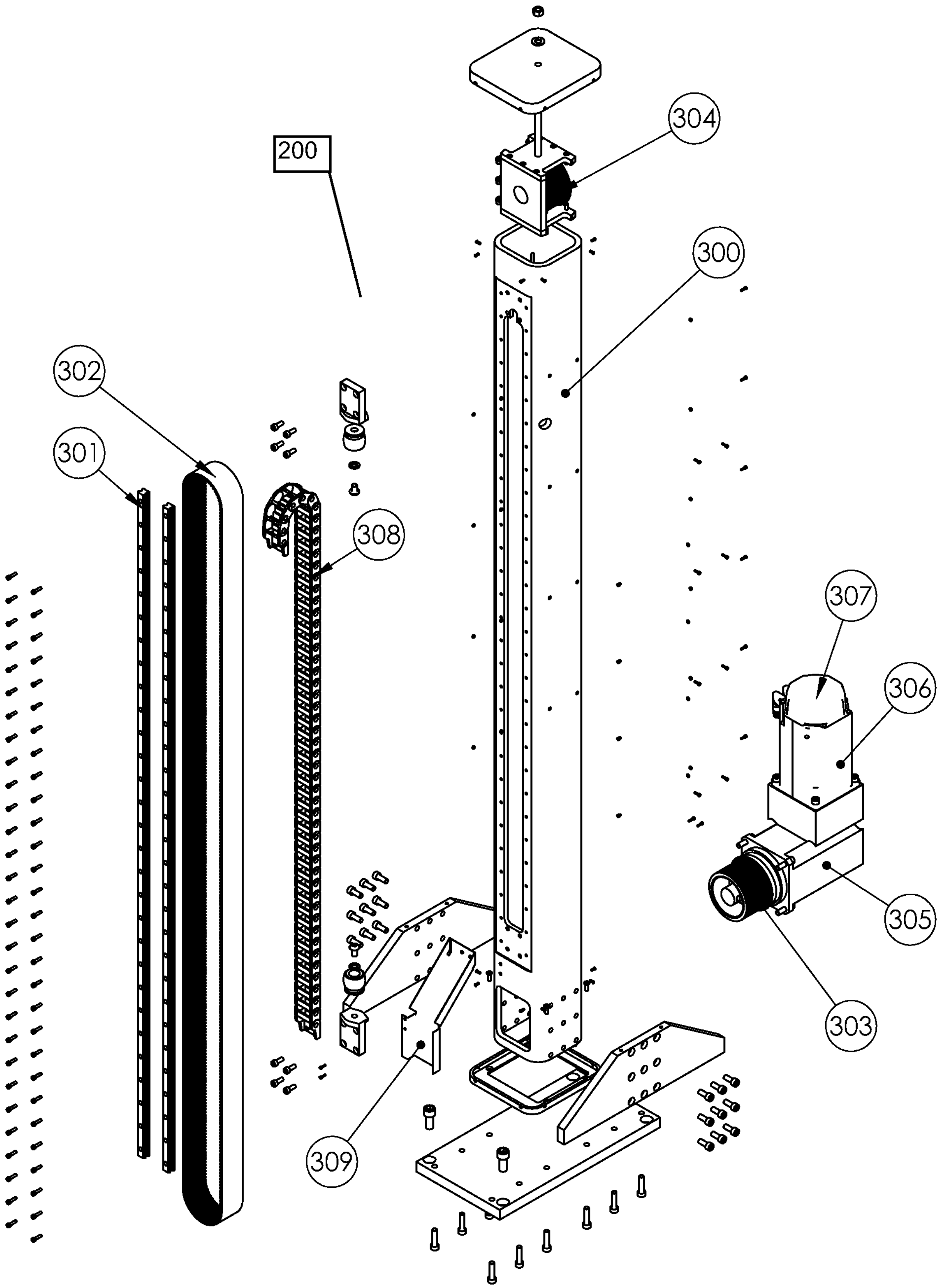

Figure 3

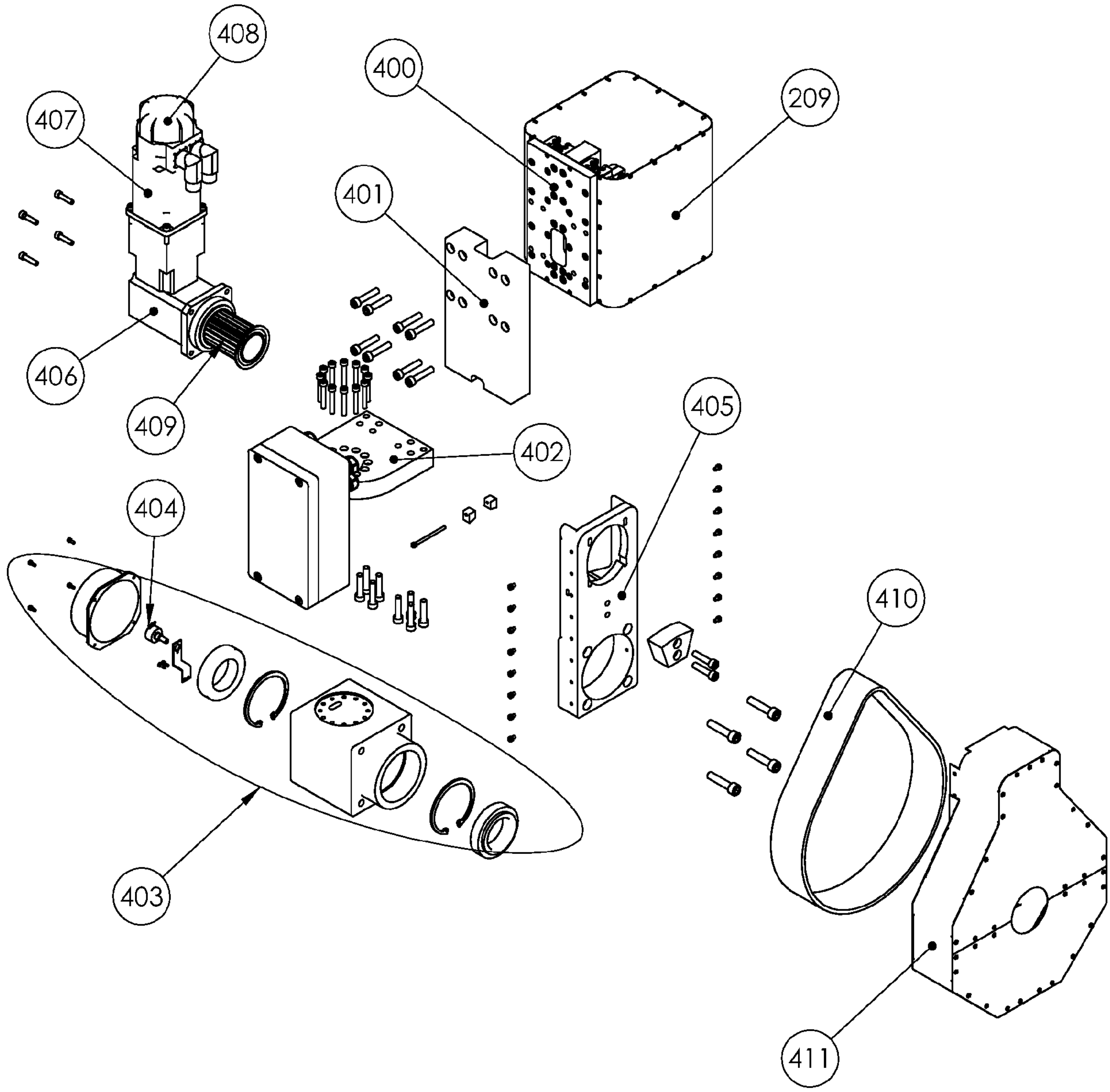

Figure 4

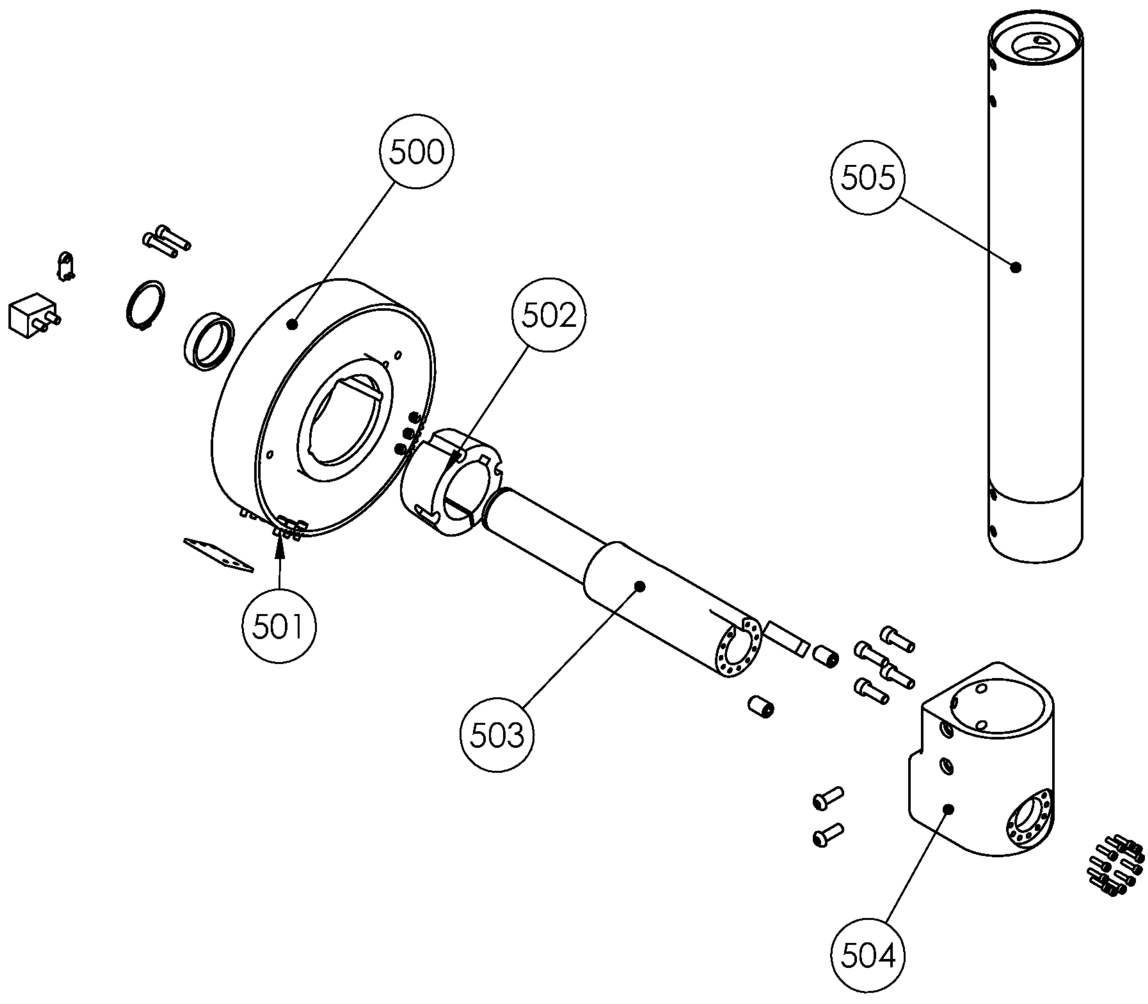

Figure 5

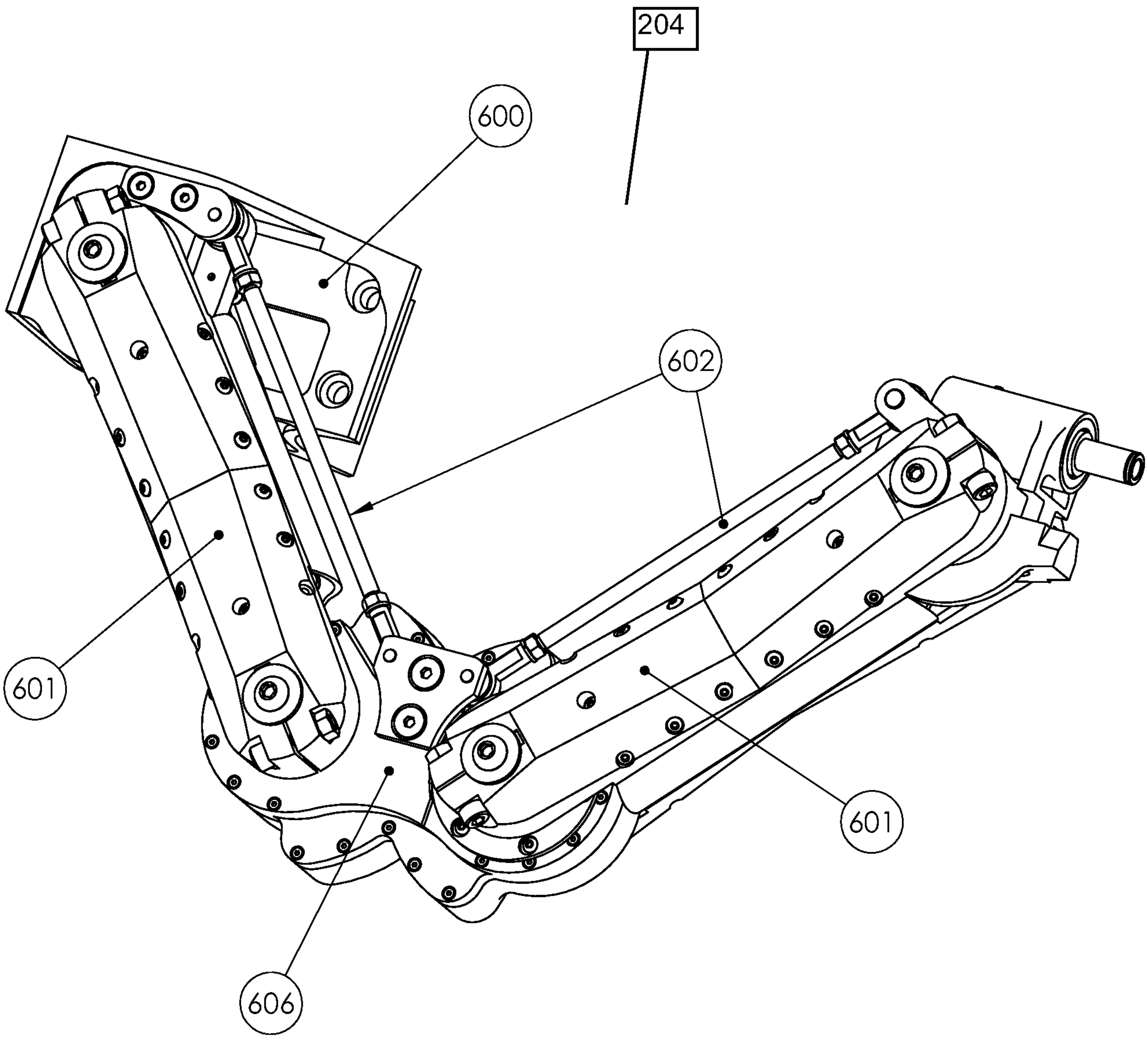

Figure 6A

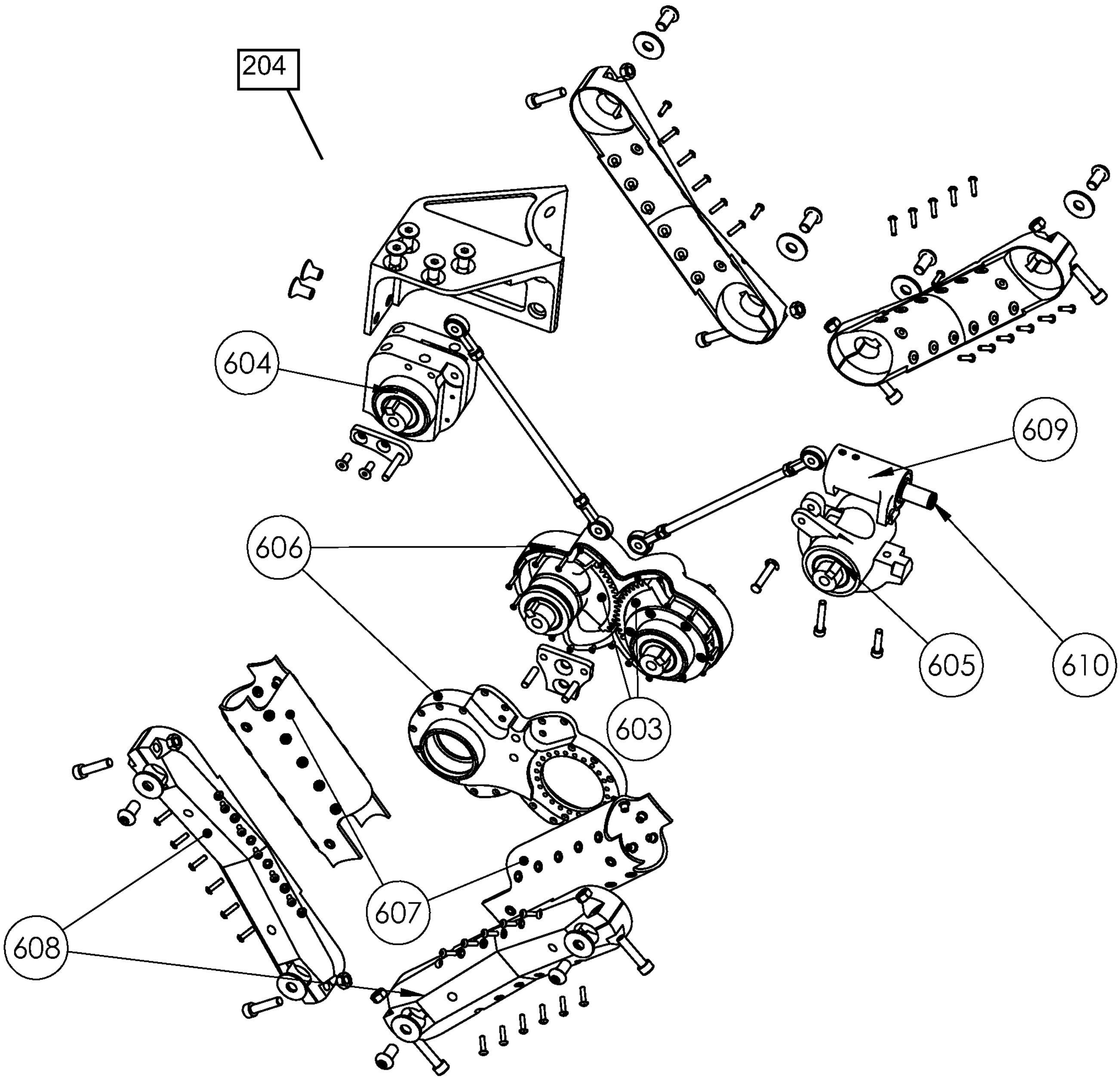

Figure 6B

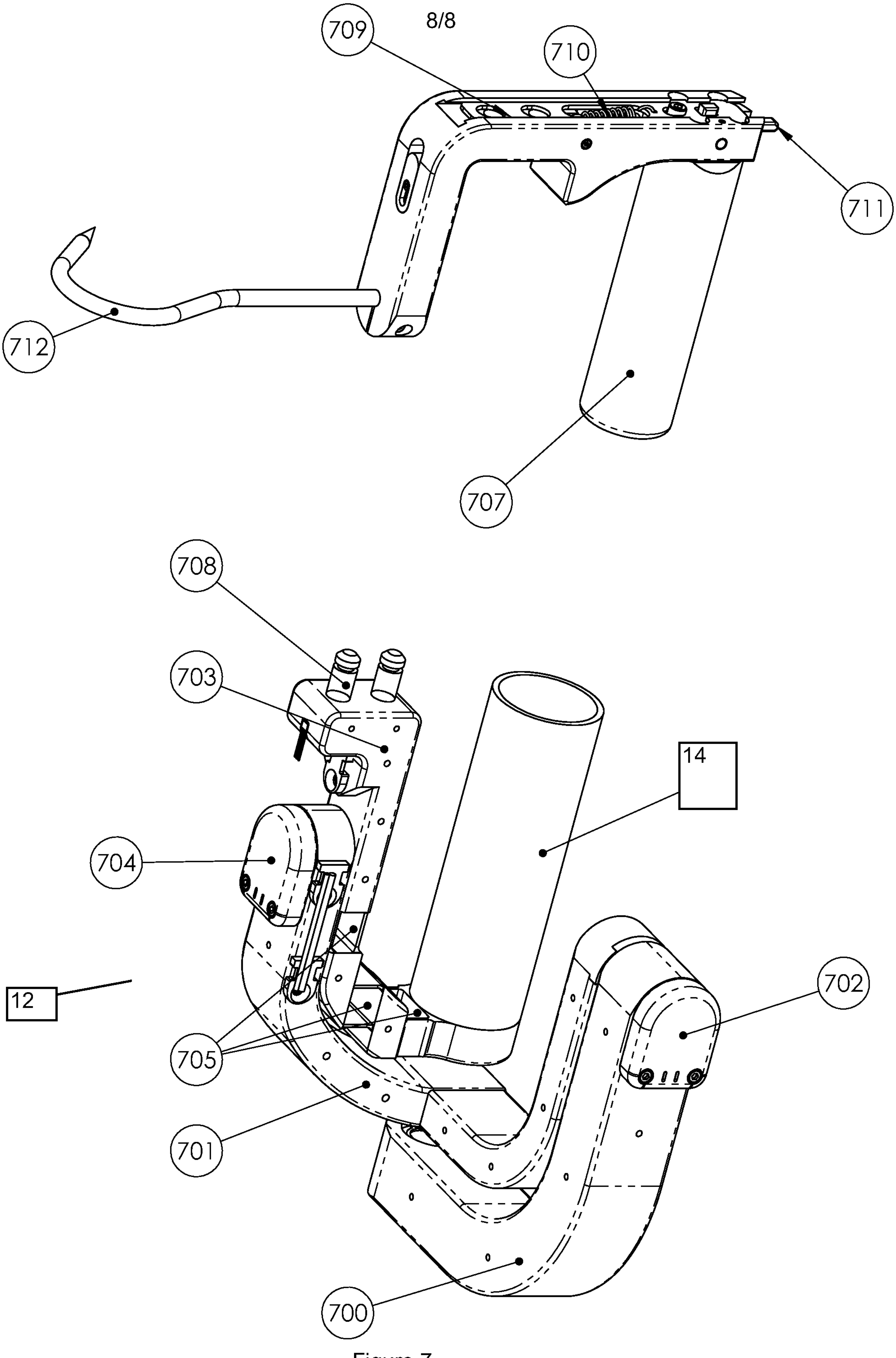

Figure 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2009/001164

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.

A22C 17/00 (2006.01) *A22B 5/00* (2006.01)

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)

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)
EPODOC, WPI: (i) IPC A22B 5/-, A22B 7/-, A22C 7/-, A22C 18/- & keywords (carcass, force, amplify) and like terms; (ii) (A22B/- or A22C/-) and B25J/-

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	WO 2000/018548 A1 (THE NEW ZEALAND MEAT PRODUCERS BOARD) 6 April 2000	
X	Entire document, especially page 1 lines 25-26, page 3 lines 25-29	1-5, 7, 8, 13, 14
Y	Page 3 line 20-page 4 line 11	1-14
	US 5116180 A (FUNG et al) 26 May 1992	
Y	Entire document, especially column 5 lines 12-14, column 7 lines 29-34, column 10 lines 52-55	1-14
	US 6623348 B1 (O'NEILL) 23 September 2003	
Y	Entire document, especially column 10 line 32-column 11 line 6, column 11 lines 41-44	1-14

[X] Further documents are listed in the continuation of Box C [X] 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
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- "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
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- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
6 October 2009	14 OCT 2009

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INTERNATIONAL SEARCH REPORT	International application No. PCT/AU2009/001164

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	GB 2110428 A (OSEL OFFSHORE SYSTEMS ENGINEERING LIMITED) 15 June 1983 Entire document, especially page 2 lines 81-107	1-14
Y	JP 2004-321032 A (MAEKAWA SEISAKUSHO KK et al) 18 November 2004 English abstract retrieved from EPODOC database Abstract	12
A	UA 31401 U (HZHYTSKYI LVIV NAT ACADEMY OF [UA]) 10 April 2008 English abstract retrieved from EPODOC database Abstract	
	Note: Claims 6, 9-11 each lack an inventive step when WO 2000/018548 and US 5116180 are combined together; Claim 12 lacks an inventive step when WO 2000/018548 is combined with US 5116180; Claim 12 also lacks an inventive step when WO 2000/018548 is combined with JP 2004-321032; Claims 1-14 each lack an inventive step when US 5116180, US 6623348 and GB 2110428 are combined together; Claims 1-14 each also lack an inventive step when US 5116180, US 6623348 and WO 2000/018548 are combined together	

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member	
WO	2000/018548	NONE	
US	5116180	EP	0353841
US	6623348	NONE	
GB	2110428	NONE	
JP	2004-321032	NONE	
UA	31401	NONE	

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

END OF ANNEX