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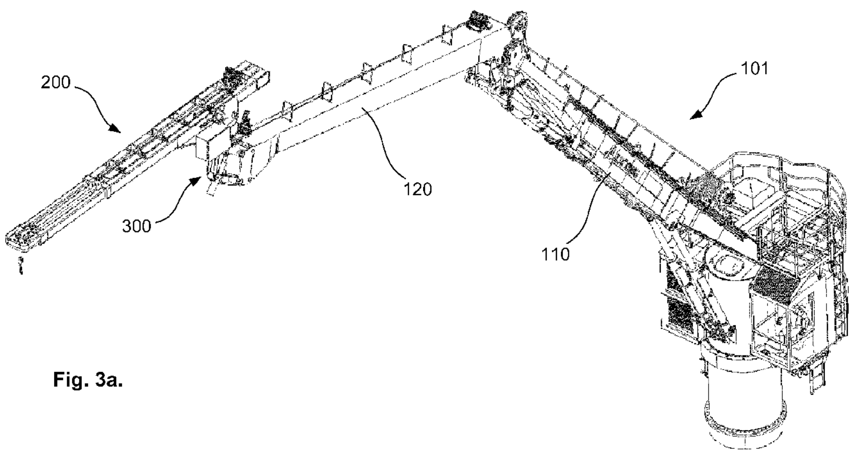

Fig. 3a.

(57) Abstract: 3D motion-compensated lifting assembly (200) for a crane (101) arranged on a vessel, barge or seagoing craft, the crane including a lower arm (110) and upper elbow arm (120), where the 3D motion-compensated lifting assembly (200) includes: - a connection assembly (300) adapted for arrangement to a distal end of the elbow arm (120), wherein the connection assembly (300) exhibits a rotational interface (331), - a telescopic boom (400) arranged to the rotational interface (331) of the connection assembly (300), and - a winch (500) with active heave compensation arranged to the telescopic boom (400).

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3D motion-compensated lifting assembly for cranes

The present invention is related to a 3D motion-compensated lifting assembly for cranes, according to the preamble of claim 1.

The present invention is especially related to a 3D motion-compensated lifting assembly for offshore cranes, designed to be arranged to a tip of the crane. Especially the present invention is designed to accommodate the installation and maintenance of offshore structures and being arranged to standard cranes, especially knuckle jib deck cranes, on a vessel, barge or seagoing craft performing such operations.

Background

In connection with crane operations in maritime/offshore environments, i.e. cranes arranged on maritime vessel, barges or other seagoing crafts, there is a need for compensation of the movements of the vessel, barge or craft, as otherwise the crane will follow the movements of the vessel, barge or craft, and accordingly result in inaccurate controlling of the load and accordingly an unsecure lifting operations.

There have been several attempts on solving this problem in prior art.

From US4021019 (British Columbia Research Counell) it is known a crane for ships having a telescopic boom pivotally mounted for achieving heave compensation.

US2009232625 A1 (Benjamin M. Almeda) describes a crane with heave compensation which is achieved by controlling of a winch.

In US8235231 B2 (Liebherr-Werk Nenzing GmbH) is disclosed a further example of a crane being controlled by active heave compensation.

US7044314 B2 (Virginia Tech Intellectual Properties) is generally related to a control system and method for controlling dynamical systems and especially a control system for reducing cargo pendulation in cranes on vessels.

The prior art solutions have drawbacks by that they only try to solve the problem by compensating for movement in one direction, and mainly as active heave compensation (Y-direction). In maritime/offshore lifting operations, movements in the other directions (X- and Z-directions) will also affect the load in lifting operations. Accordingly, prior art fails to solve the problems of maritime/offshore lifting operations.

There have been made some attempts to provide a 3D-solution where the crane is arranged on a movable platform, something which will result in that the entire crane will move and affect the entire vessel with moment of inertia. This solution is however is also expensive.

Accordingly there is a need for a fully (3D) motion-compensated lifting assembly for offshore/maritime cranes.

Object

The main object of the present invention is to provide a 3D motion-compensated lifting assembly for a crane partly or entirely solving the drawbacks of prior art.

It is further an object of the present invention to provide a 3D motion-compensated lifting assembly for a crane that provides a fully motion-compensation in all three directions, Z, X and Y.

A further object of the present invention is to provide a 3D motion-compensated lifting assembly for a crane which can be used for both existing maritime/offshore cranes and new maritime/offshore cranes.

An object of the present invention is to provide a 3D motion-compensated lifting assembly including all features necessary for achieving full 3D motion-compensation, i.e. the assembly being self-supplied.

It is further an object of the present invention to provide a 3D motion-compensated lifting assembly for a crane which provide efficient and accurate offshore load handling.

An object of the present invention is to provide a 3D motion-compensated lifting assembly for a crane which provides the crane with good operation capabilities under rough operation conditions, especially low pendulum height under offshore lifting operations.

It is further an object of the present invention to provide a 3D motion-compensated lifting assembly capable of compensating in all three directions Z, X and Y for movements of a vessel, barge or seagoing craft the crane is arranged on.

Another object of the present invention is to provide a 3D motion-compensated lifting assembly reducing the energy consumption, compared to prior art solutions.

Further objects of the present invention will appear when considering the following description, claims and drawings.

The invention

A 3D motion-compensated lifting assembly for a crane is described in claim 1. Preferable features of the 3D motion-compensated lifting assembly are described in the dependent claims.

The present invention is based on a prior art (standard) crane, e.g. cranes known as a knuckle jib deck cranes, i.e. a crane having a lower arm and an elbow arm arranged at distal end of the lower arm, and provides a 3D motion-compensated lifting assembly to be arranged to a distal end of the elbow arm, providing a reliable, long time operation and stowing in a tough and corrosive offshore marine environment.

In general, a crane with the 3D motion-compensated lifting assembly according to the present invention will be designed with major structural and mechanical overcapacity for offshore structures operation on open deck of offshore vessels and for safe stowing on aft deck of such vessels. Offshore structure is according to the present invention an offshore structure which is floating or fixed to seabed, floating being shipshape, propelled or moored. A typical example is an offshore wind turbine which in the following description will be used as an example of an offshore structure.

A crane with the 3D motion-compensated lifting assembly according to the present invention will be designed with a general crane dynamic factor allowing for offshore structure operations in accordance with current regulations.

The 3D motion-compensated lifting assembly according to the present invention provides compensation of movement in all three directions Z, X and Y, caused by the movement of the vessel in roll, pitch, yaw, heave, surge and sway.

The 3D motion-compensated lifting assembly according to the present invention includes a connection assembly which is designed for arrangement to the distal end of the elbow arm of the crane.

The connection assembly is further preferably provided with a movable (tiltable) interface in vertical direction in relation to the elbow arm.

The 3D motion-compensated lifting assembly according to the present invention further includes a telescopic boom which is arranged to the connection assembly. The connection assembly is further arranged with a rotational interface enabling rotation of the telescopic boom in relation to the elbow arm.

According to a second embodiment, the telescopic boom may further be arranged movably (tiltable) in the vertical direction in relation to the connection assembly. This features is an optional feature. Accordingly, the telescopic boom can be fixed or movable (tiltable) arranged to the connection assembly.

The 3D motion-compensated lifting assembly according to the present invention is further provided with a winch with full AHC (active heave compensation) compensation to pay out and reel in load wire via a guide sheave arranged at front end of the telescopic boom and the winch being arranged at rear end of the telescopic boom.

The 3D motion-compensated lifting assembly according to the present invention will among others be controlled based on input from a motion reference unit (MRU) or similar, informing about the movements of the vessel, barge or craft the crane is arranged on, hereinafter referred to as vessel.

Based on information about movements of the vessel, the 3D motion-compensated lifting assembly according to the present invention is arranged for compensation of the movements experienced by the crane and accordingly the load being handled by the crane in the dimensions Z, X and Y by:

- Extending and retracting the telescopic boom enable compensation in the Z-direction in the reference frame of the crane (caused by sway, roll and yaw motions of the vessel),
- Rotation of the telescopic boom enable compensation in the X-direction in the reference frame of the crane (caused by surge, yaw and pitch motions of the vessel),

- Controlling the winch enable compensation in the Y-direction in the reference frame of the crane (caused by heave, roll and pitch motions of the vessel).

Accordingly, the 3D motion-compensated lifting assembly according to the present invention provides fully motion-compensation in all three directions Z, X and Y direction, in the reference frame of the crane, in relation to the movements of the vessel.

The 3D motion-compensated lifting assembly according to the present invention further provides, by that the telescopic boom is movable (tiltable) in vertical direction in relation to the elbow arm, that compensation in the Z-direction (by extending and retracting the telescopic boom horizontally) is effective within different angle positions of the elbow arm.

Further, by arranging a position reference sensor on an offshore structure and a position reference sensor receiver on the crane/3D motion-compensated lifting assembly the controlling of the 3D motion-compensated lifting assembly can be further enhanced.

Accordingly, the present invention provides a crane with a 3D motion-compensated lifting assembly according to the present invention which is designed for efficient and accurate offshore structure /wind turbine load handling of general cargo and offshore structure/wind turbine cargo at specified load curves.

Further, a crane with a 3D motion-compensated lifting assembly according to the present invention provides a crane being able to launch and retrieve loads at an offshore structure/wind turbine platform, with practical no relative heave motion on the load relative the offshore structure/wind turbine platform.

A crane with the 3D motion-compensated lifting assembly according to the present invention will have the flexibility/ability to operate in wave heights up to Hs 2.5 m or higher resulting in that the operation can continue even if the weather window deteriorate under a operation. The present invention is adaptable to any maximum wave height required for a given application, by engineering appropriate distance and speed capacity of the compensation in X, Y and Z directions.

Accordingly, the present invention provides a 3D motion-compensated lifting assembly which enables the lifting hook to be “locked” in relation to the offshore structure/wind turbine platform and by means of controlling the 3D motion-compensated lifting assembly compensate for motions of the vessel and keep the load steady.

Further, by the present invention is achieved a 3D motion-compensated lifting assembly which increases vessel operability, is more cost-effective in relation to prior art, and can be used in harsher weather conditions compared to prior art solutions.

Further, by the 3D motion-compensated lifting assembly according to the present invention both existing (standard) cranes and new cranes in the offshore wind industry and the oil and gas markets can be 3D motion compensated in a simple manner by arranging it to the tip of the crane.

Further, the 3D motion-compensated lifting assembly according to the present invention can be used by cranes not provided with a winch arrangement to enable winch features.

Further, the 3D-motion-compensated lifting assembly can be arranged to the crane so that it can operate above the horizontal plane of the crane tip or arranged to the crane so that it can operate under the horizontal plane of the crane tip.

Further preferable features and advantageous details of the present invention will appear from the following example description.

Example

The present invention will below be described in further detail with references to the attached drawing, where:

Figure 1 is a principle drawing of a crane of prior art,

Figures 2a-c show principle drawings of a 3D motion-compensated lifting assembly according to the present invention,

Figures 3a-c show principle drawings of a 3D motion-compensated lifting assembly according to the present invention arranged to a standard offshore crane,

Figure 4 is a block diagram of a control system for controlling the 3D motion-compensated lifting assembly according to the present invention, and

Figure 5 is a principle drawing of a modification of the 3D motion-compensated lifting assembly according to the present invention.

Reference is now made to Figure 1 which is a principle drawing of an offshore crane 101, in the form of a knuckle jib deck crane, according to prior art. The crane 101 has a base structure 102 formed by a base platform 103 mounted on the upper end of a rotatable pedestal 104 arranged to a corresponding structure on a vessel (not shown) or similar. The pedestal 104 allows the crane 101 to be rotated about the pedestal 104 by a rotational drive system, which is well known in prior art and needs no further description herein.

The crane 101 further includes a lower arm 110 having a lower end pivotally mounted on the pedestal 104. The arm 110 can be raised and lowered by actuation of hydraulic cylinders 112 having their lower ends arranged to the pedestal 104 and their upper ends arranged to an intermediate location along the length of the arm 110.

The crane 101 also includes an upper elbow arm 120 having a lower end arranged to the upper end portion of the lower arm 110. The upper elbow arm 120 is pivotally connected relative to the lower arm 110 by hydraulic cylinders 121 having lower end portions pivotally arranged to an intermediate location along the lower arm 120 and upper end portions pivotally arranged an intermediate location along the length of the upper elbow arm 120.

Operation of the hydraulic cylinders 112 and 121 enables the crane 101 to be raised and lowered as well as to be extended and retracted.

The crane 101 further includes a main load winch 130 mounted on the lower end portion of arm 110 or the base 103 to pay out or reel in a main load wire 131 which is wound about a spool 132. A hook 133 is attached to the distal end of the wire 131. Between the spool 132 and hook 133, the wire 131 extends over a guide sheave 134 mounted on the distal end of arm 110, a further guide sheave 135 mounted on the lower or proximal end of elbow arm 120, and a distal sheave 136 mounted on the distal end portion of the elbow arm 120.

Even if the winch 130 is active heave compensated this will not provide a fully 3D motion-compensated solution.

Reference is now made to Figures 2a-c showing principle drawings of a 3D motion-compensated lifting assembly 200 for a crane 101 according to the present invention.

The 3D motion-compensated lifting assembly 200 includes three main components in the form of a connection assembly 300, a telescopic boom 400 arranged to the connection assembly 300, and winch 500 arranged to the telescopic boom 400.

The connection assembly 300 is formed by an arm connection device 310 adapted for arrangement to the distal end of the elbow arm 120, replacing the distal sheave 136 in Figure 1. The connection assembly 300 further includes a boom connection device 320 for arrangement to the telescopic boom 400. The boom connection device 320 is pivotably arranged to the telescoping boom 400 via ears 321 arranged at lower side of the telescopic boom 400. The connection assembly further includes an intermediate connection device 330 connecting the arm connection device 310 and boom connection device 320. The intermediate connection device 330 is arranged with a rotational interface 331 between the boom connection device 320 and the arm connection device 310 so that the telescopic boom 400 can be rotated in relation to the elbow arm 120. The rotational interface 331 can be achieved as shown in the example by a slewing ring 332 with at least one slewing gear drive 333 or at least one linear actuator 334 (as shown in Figure 2c), such as a hydraulic cylinder, providing a rotational movement of respective parts in relation to each other.

According to a second embodiment, the telescopic boom 400 may further be arranged movable (tiltable) in vertical direction in relation to the boom connection device 320 by at least one linear actuator 322, such as a hydraulic cylinder, having upper end portions pivotally arranged to an intermediate location 323 along the telescopic boom 400 and lower end portions pivotally arranged an intermediate location along the length of the intermediate connection device 330. It should be mentioned that this feature is optional, and even if this feature is shown in the drawings, this feature is not necessary for the invention to work as intended/described. Accordingly, the telescopic boom 400 can be fixed or arranged movable (tiltable) to the boom connection assembly 300.

The arm connection device 310 is further arranged movable in relation to the intermediate connection device 330 by that the arm connection device 310 at upper side thereof is pinned to lower side of the intermediate connection device 330, and the lower side of the arm connection device 310 is arranged to the other side (preferably positioned some closer to the rotational interface 331) of the intermediate connection device 330 by means of two links 311 and 312, and wherein at least one linear actuator 313, such as a hydraulic cylinder, with is lower end portions pivotally arranged to the link 311 and the upper end portions of the linear actuator 313 is arranged to the pinned connection between the upper side of the arm connection device 310 and the lower side of the intermediate connection device 330.

In this way the telescopic boom 400 and intermediate connection device 330 are movable (tiltable) in relation to the arm connection device 310.

The telescopic boom 400 is formed by two parallel telescopic beams 401 and 402 with a given distance between them and fixed to each other at both ends, where each telescopic beam 401, 402 are formed by an outer hollow beam 401a and 402a, respectively, and an inner hollow beam 401b, 402b, respectively, arranged movable in the outer hollow beam 401a, 402a, respectively, wherein the inner hollow beams 401b, 402b are arranged to each other at the free end by a holder device 403 for a guide sheave 404. It is further arranged a linear actuator 405, such as a hydraulic cylinder, arranged between the rear end of the telescopic boom 400 and the holder device 403, thus extending between the outer hollow beams 401a, 402a for extending and retracting the telescopic boom 400, i.e. moving the inner hollow beams 401b, 402b and thus moving the guide sheave 404 in longitudinal direction of the telescopic boom 400.

To the upper part of the telescopic boom 400, at the rear end thereof, the mentioned winch 500 is arranged to pay out or reel in a load wire 501 which is wound about a spool 502. A hook 503 is attached to the distal end of the wire 501. Between the spool 502 and hook 503, the wire 501 extends over the guide sheave 404 mounted on the distal end of telescopic boom 400. It is further preferably arranged guide elements 406 at upper side of the telescopic boom 400 guiding the wire 501 from the winch 500 and to the guide sheave 404. The winch 500 is preferably a winch with full AHC (active heave compensation).

Further, the 3D motion-compensated lifting assembly 200 is preferably provided with a power and control unit 600, e.g. hydraulic reservoir, valves, hydraulic lines and hydraulic pump(s) for supplying and controlling the hydraulic cylinders with hydraulic fluid. In connection with the power source 600 can further be arranged a control unit for controlling each of the hydraulic cylinders and the winch 500. The power and control unit 600 will be provided with an interface (wireless or wired) to a crane control system 700, further described below.

Accordingly, seen in the reference frame of the crane 101, the telescopic boom 400 can be extended and retracted for compensating for movement of the distal end of the crane elbow arm 120 in the Z direction, in the reference frame of the crane 101 (caused by sway, roll and yaw motions of the vessel, barge or craft).

Further, the rotation of the telescopic boom 400 in relation to the arm connection 310 can be used for compensating for movement of the distal end of the crane elbow arm 120 in the X direction, in the reference frame of the crane 101 (caused by surge, yaw and pitch motions of the vessel, barge or craft).

Further, the winch 500 with full AHC (active heave compensation) can be used for compensating for movement of the distal end of the crane elbow arm 120 in the Y direction, in the reference frame of the crane 101 (caused by heave, roll and pitch motions of the vessel, barge or craft).

Accordingly, by the 3D motion-compensated lifting assembly 200 according to the present invention the crane is fully compensated in all 3 directions, Z, X and Y direction.

In Figures 3a-c the above described 3D motion-compensated lifting assembly 200 is shown arranged to a crane 101. Accordingly, with the present invention in the form of the novel 3D motion-compensated lifting assembly 200, the 3D motion-compensated lifting assembly 200 is provided with a winch 500, resulting in that the main winch 130, wire 131 and guide sheaves 134-133 are not requested for the crane 101, as the functionality of these are already present in the 3D motion-compensated lifting assembly 200. However in most cases, the owner will usually like to have both these possibilities.

Further, the elbow arm 120 will preferably have an interface to combine either 3D motion-compensated lifting assembly 200 or a complete derrick head with two guide sheaves 134-135, so that if the 3D motion-compensated lifting assembly 200 needs maintenance the 3D motion-compensated lifting assembly 200 can easily be removed and the derrick head replaced. The derrick head will typically be connected by a single wire to an AHC controlled winch placed on the top of the elbow boom or as shown in Figure 1 a winch 130 arranged the base of the crane 101.

Figure 3a shows the 3D motion-compensated lifting assembly 200 arranged to the crane 101 and where the 3D motion-compensated lifting assembly 200 (and crane 101) is in working position and ready to handle a load.

In Figure 3b it is shown a situation where the crane 101 with the 3D motion-compensated lifting assembly 200 is set in a stowed position, showing that the crane 101 with a 3D motion-compensated lifting assembly 200 will take minimum space on a deck of a vessel. Due to the properties and movability of the 3D motion-compensated lifting assembly 200 this will not require more space on the vessel than a crane 101 without such a lifting assembly 200.In

In Figure 3c it is shown a typical area of use of the present invention, where the crane 101 with the 3D motion-compensated lifting assembly 200 is arranged on a vessel 800 and performing a lifting operation in relation to an offshore structure in the form of a wind turbine platform 811 of a wind turbine 810 (only parts of the wind turbine is shown).

It should further be noted that the 3D motion-compensated lifting assembly 200 will extend the lifting range of the crane 101 in the horizontal direction, as can be seen in e.g. Figure 3c.

It should further be mentioned that the arm connection device 310 is preferably adapted such that the 3D motion-compensated lifting assembly 200 can be arranged both as shown in the Figures, accordingly operating in a plane above the distal end of the elbow arm 120, and turned upside down so that the 3D motion-compensated lifting assembly 200 operates in a plane below the distal end of the elbow arm 120.

Reference is now made to Figure 4 showing a block diagram of a crane control system for controlling the crane 101.

By arranging a position reference sensor on a wind turbine platform 811 a crane operation is to be performed in relation to, and a position reference sensor receiver on the crane 101/lifting assembly 200, a more rapid lifting operation can be achieved, but this is not necessary for the present invention to be used.

The vessel, barge or seagoing craft movements are typically measured by a MRU (motion reference unit) providing information about the vessel, barge or seagoing craft movements in sway, surge, heave, yaw, pitch and roll for the reference frame of the vessel, barge or seagoing craft.

By a crane control system the measured movements of the vessel, craft or barge are transformed into the reference frame of the crane 101 and the necessary compensation to counteract these movements are calculated. This results in settings for the power and control unit 600 for the 3D motion-compensated lifting assembly 200 which by controlling the winch 500 achieves heave compensation, controlling the rotation of the telescopic boom 400 achieves compensation for movements affecting the crane 101 in X-direction, and by controlling the extension and retraction of the telescopic boom 400 achieves compensation for movements affecting the crane 101 in Z-direction.

By using the position reference sensor, the crane can be operated in normal operation to the crane tip is positioned in the vicinity of the area where the load is, whereupon the load is picked up and the compensation system activated. The present invention will then hold the load stable in relation to the vessel, barge or craft.

The use of the present invention can further be improved by arranging a proximity sensor on the structure of the wind turbine 810 or similar a crane operation is to be performed in relation to, for preventing the 3D motion-compensated lifting assembly 200 for colliding with the structure. The control system can, based on information from the proximity sensor be arranged to control the 3D motion-compensated lifting assembly 200 to a safe position at danger for collision.

Modifications

The present invention can be modified by providing the telescopic boom 400 with a vertical telescopic boom 900 hinged at lower side of the telescopic boom 400, at rear side thereof, and provided with an eye 901 at the distal end, through which the wire 501 runs. In this way the vertical telescopic boom 900 will be able to compensate for pendulation, and extend and retract with the wire being reeled in or out, as shown in Figure 5 (In Figure 5 details of the 3D motion-compensated lifting assembly 200 is omitted for simplification of the modification principle). When the wire 501 is reeled out the vertical telescopic boom 900 will extend and when the wire is reeled in the vertical telescopic boom 900 will retract, accordingly, adapting to the length of the wire 501 and provide a self-adjusting compensation means for pendulation.

Further modifications within the scope of the claims will be apparent for a skilled person considering the description and drawings.

Claims

1. 3D motion-compensated lifting assembly (200) for a crane (101) arranged on a vessel, barge or seagoing craft, the crane (101) including a lower arm (110) and upper elbow arm (120), **characterized in** that the 3D motion-compensated lifting assembly (200) includes:

- a connection assembly (300) adapted for arrangement to a distal end of the elbow arm (120), wherein the connection assembly (300) exhibits a rotational interface (331),

- a telescopic boom (400) arranged to the rotational interface (331) of the connection assembly (300), and

- a winch (500) with active heave compensation arranged to the telescopic boom (400),

wherein the rotational interface (331) enable motion-compensation in X-direction in reference frame of the crane (101), retraction and extension of the telescopic boom (400) enable motion-compensation in Z-direction in reference frame of the crane (101), and the winch (500) with active heave compensation enable motion compensation in Y-direction in reference frame of the crane (101) in relation to movements of the vessel, barge or seagoing craft.

2. 3D motion-compensated lifting assembly (200) according to claim 1, **characterized in** that the connection assembly (300) is arranged tiltable in vertical direction in relation to the elbow arm (120).

3. 3D motion-compensated lifting assembly (200) according to claim 1, **characterized in** that the telescopic boom (400) is arranged tiltable in vertical direction in relation to the connection assembly (300).

4. 3D motion-compensated lifting assembly (200) according to claims 1-3, **characterized in** that the connection assembly (300) includes an arm connection device (310) for arrangement to elbow arm (120).

5. 3D motion-compensated lifting assembly (200) according to claims 1-4, **characterized in** that the connection assembly (300) includes an intermediate connection device (330) tiltable arranged to the arm connection device (310) in the vertical direction, wherein the intermediate connection device (330) exhibit the rotational interface (331).

6. 3D motion-compensated lifting assembly (200) according to claims 1-5, **characterized in** that the connection assembly (300) includes a boom connection device (320) rotatably arranged to the intermediate connection device (330).

7. 3D motion-compensated lifting assembly (200) according to claims 1-5, **characterized in** that the telescopic boom (400) is tiltable arranged to the intermediate connection device (330) by at least one linear actuator (322).

8. 3D motion-compensated lifting assembly (200) according to claims 1-5, **characterized in** that the intermediate connection device (330) is arranged tiltable to the arm connection device (310) by two links (311, 312), wherein a linear actuator (313) is arranged to the link (311).

9. 3D motion-compensated lifting assembly (200) according to claim 1, **characterized in** that the telescopic boom (400) is extendable and retractable by at least one linear actuator (405) and that the winch (500) is arranged at a rear end of the telescopic boom (400), at upper side thereof, and that a holder device (403) is arranged at distal end of the telescopic boom (400) holding a guide sheave (404).

10. 3D motion-compensated lifting assembly (200) according to claims 1-9, **characterized in** that the 3D motion-compensated lifting assembly (200) is self-supplied by that a power and control unit (600) is arranged to the connection assembly (300).

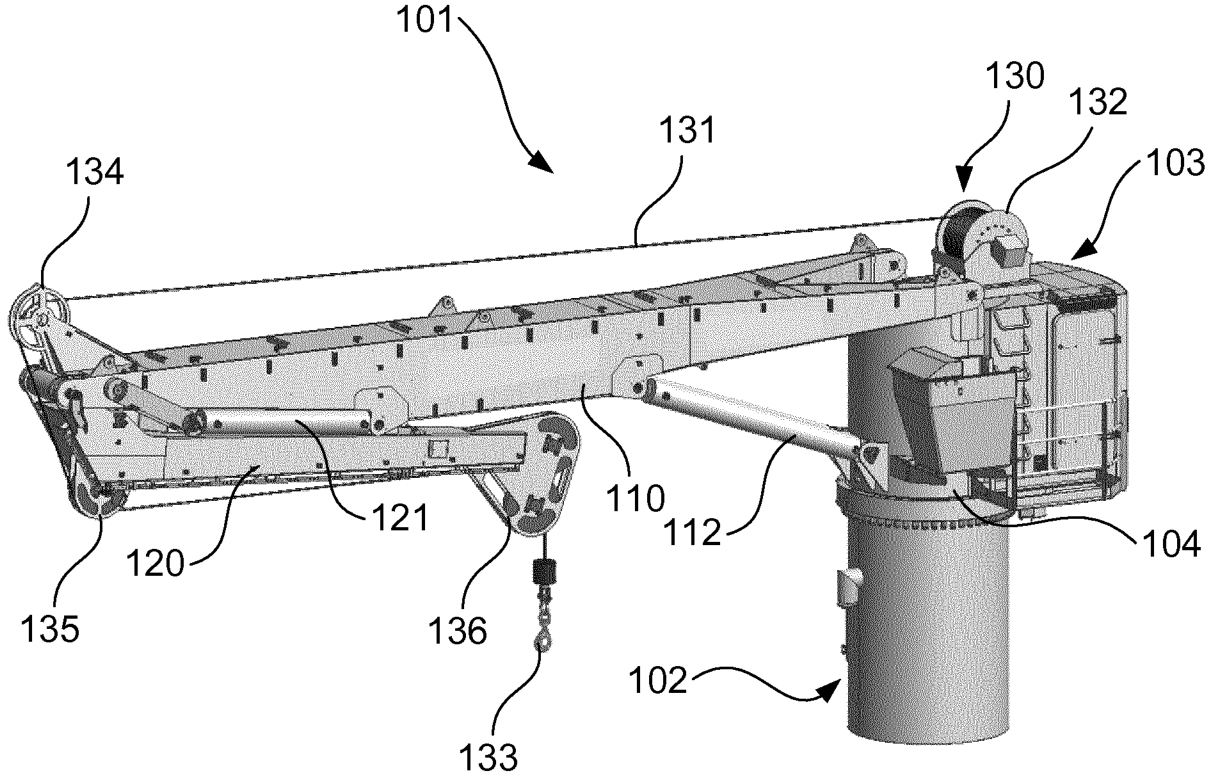

Fig. 1.

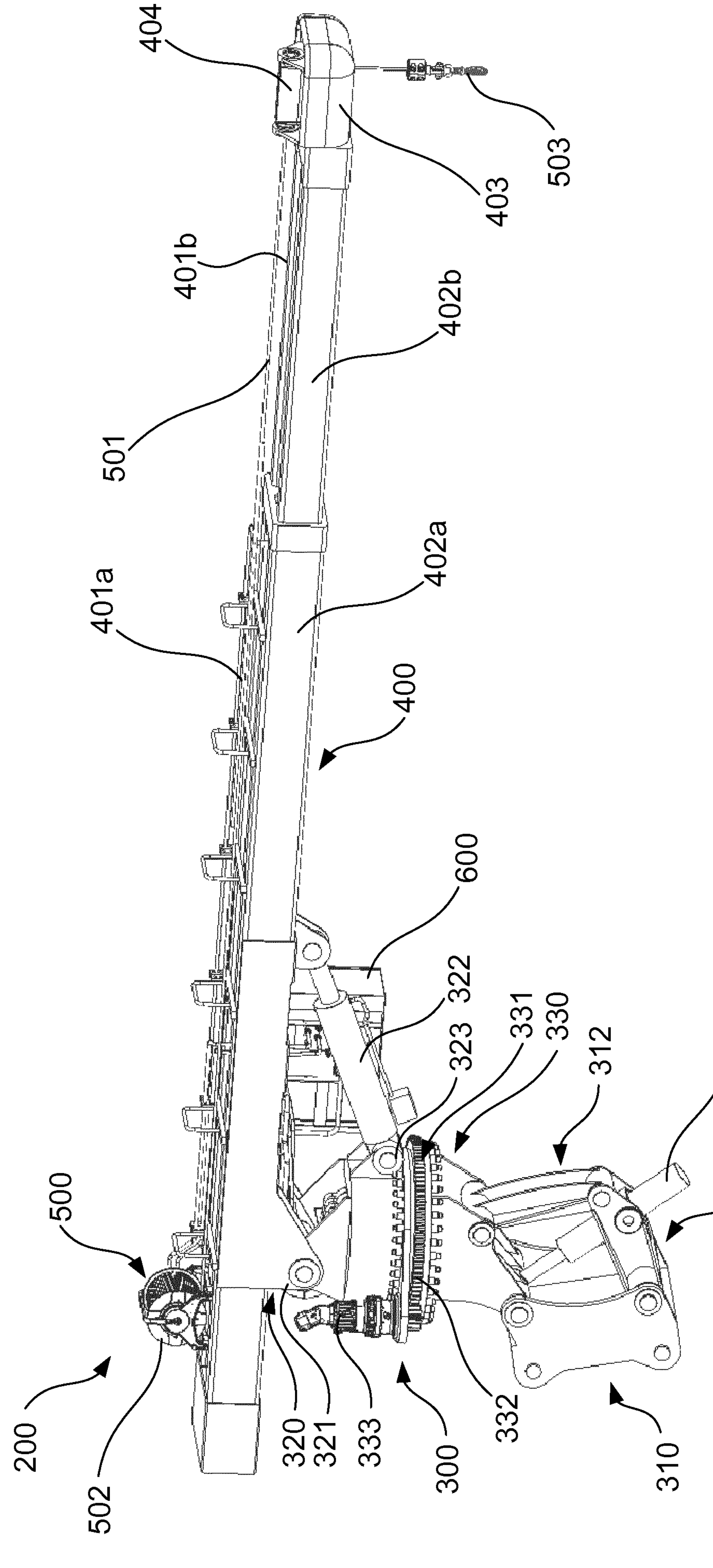
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Fig. 2a.

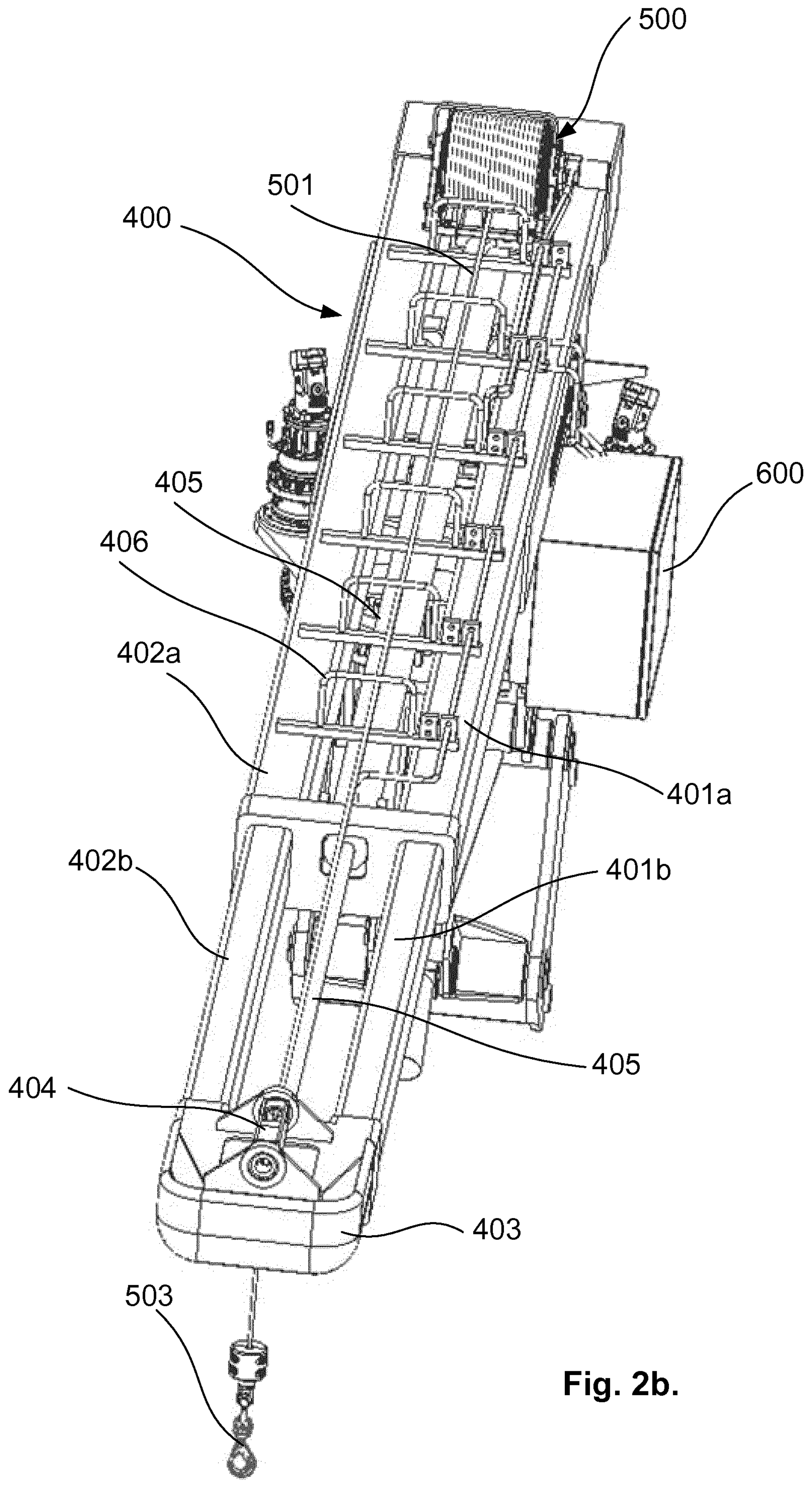

Fig. 2b.

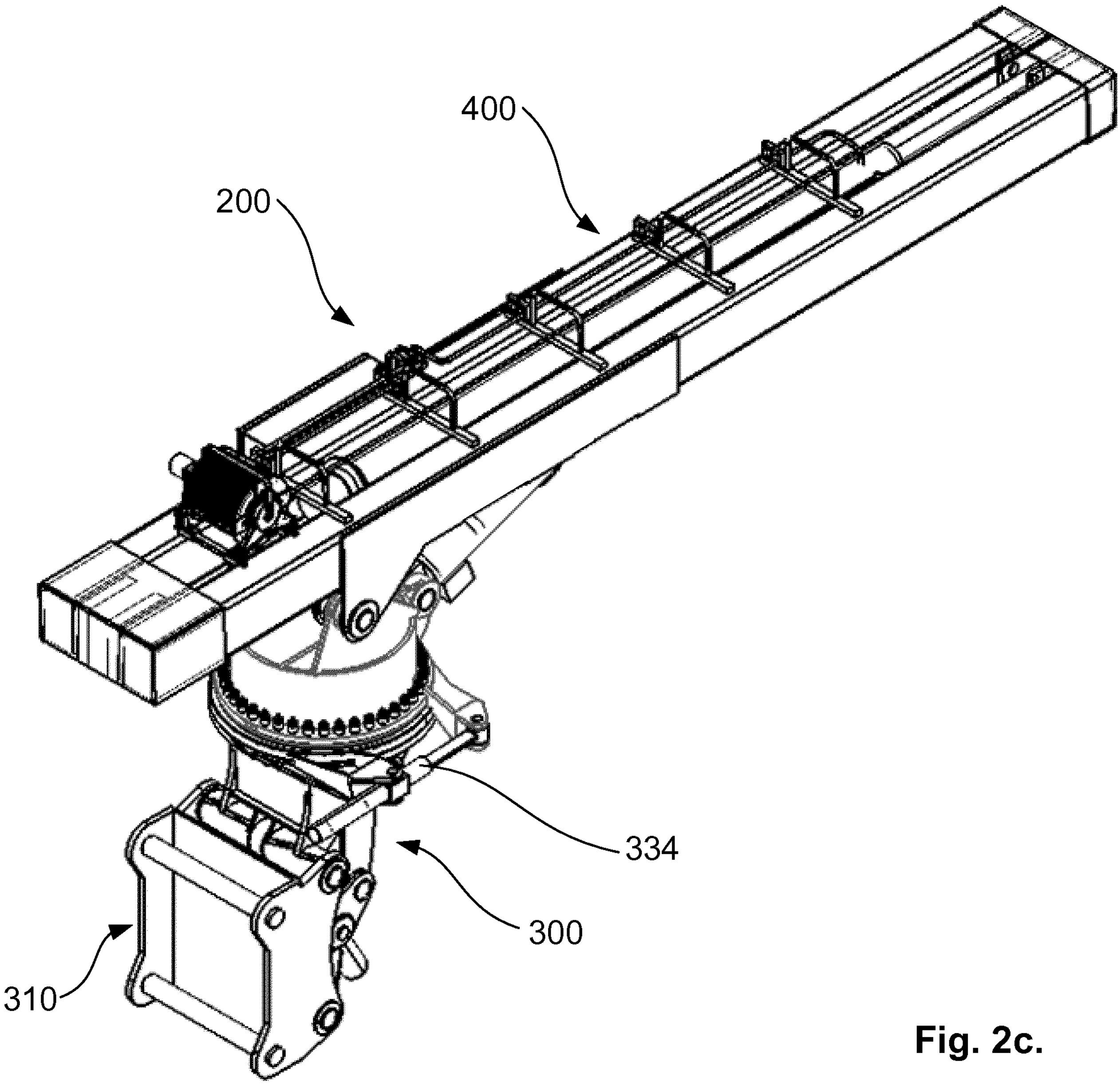

Fig. 2c.

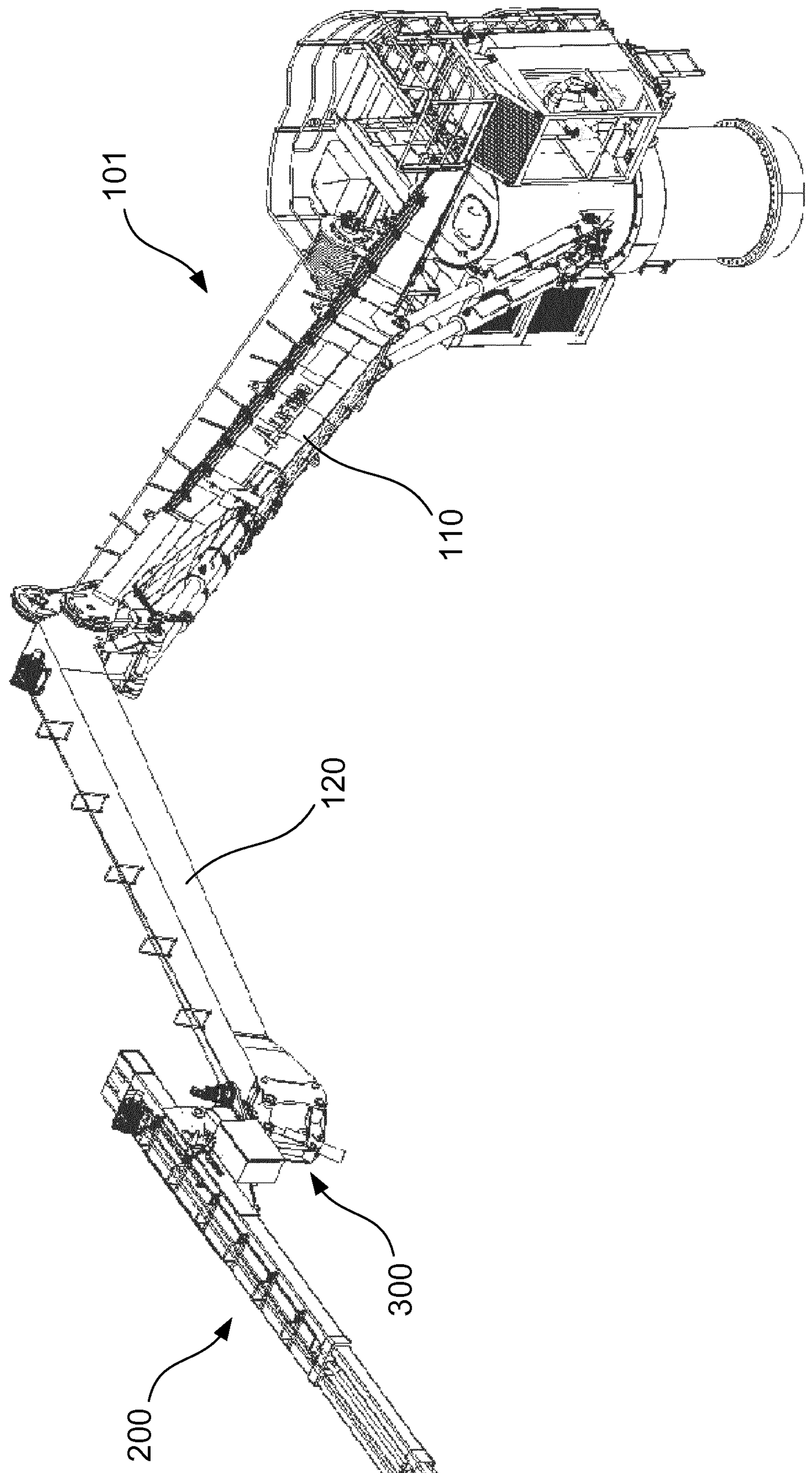

Fig. 3a.

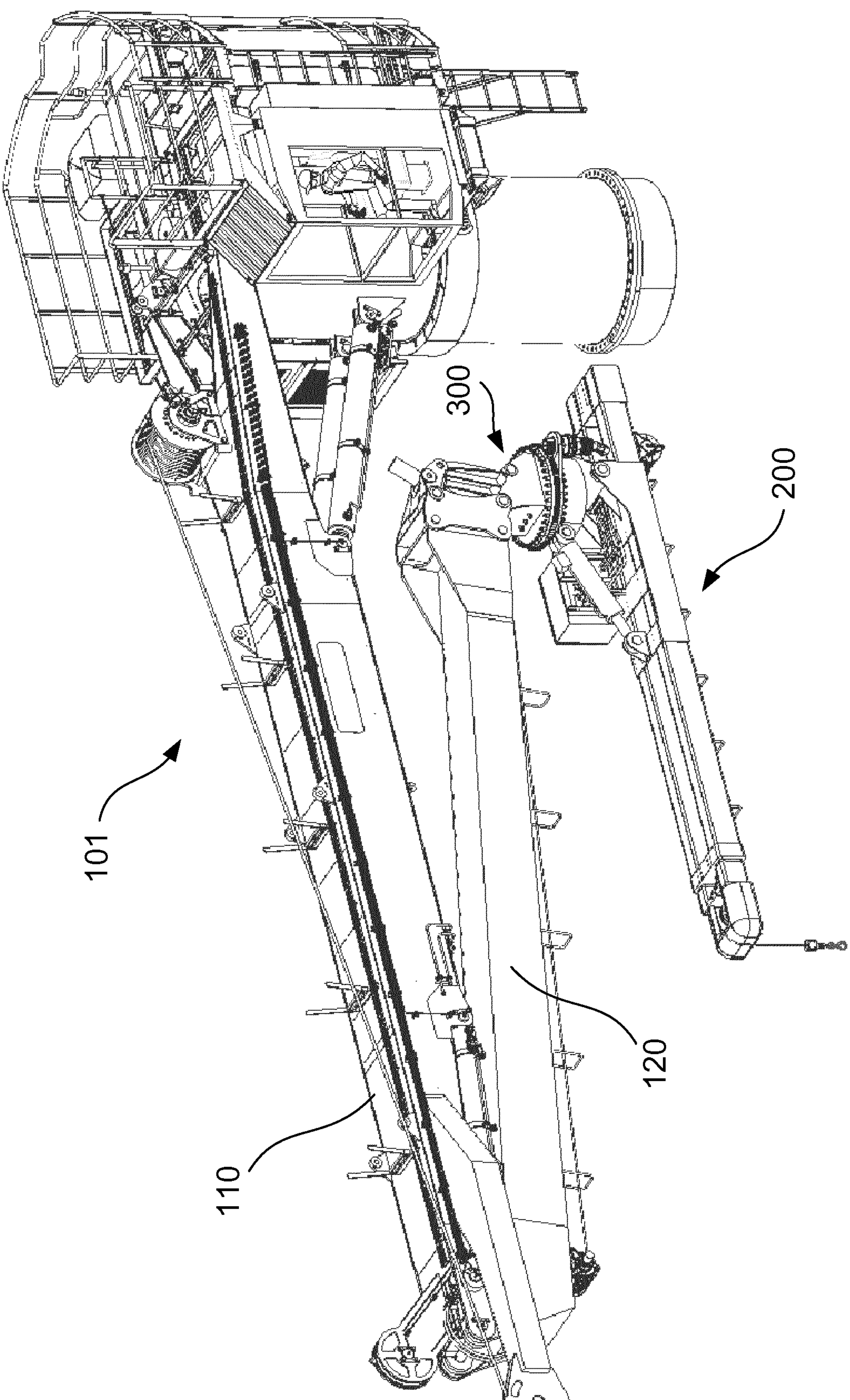

Fig. 3b.

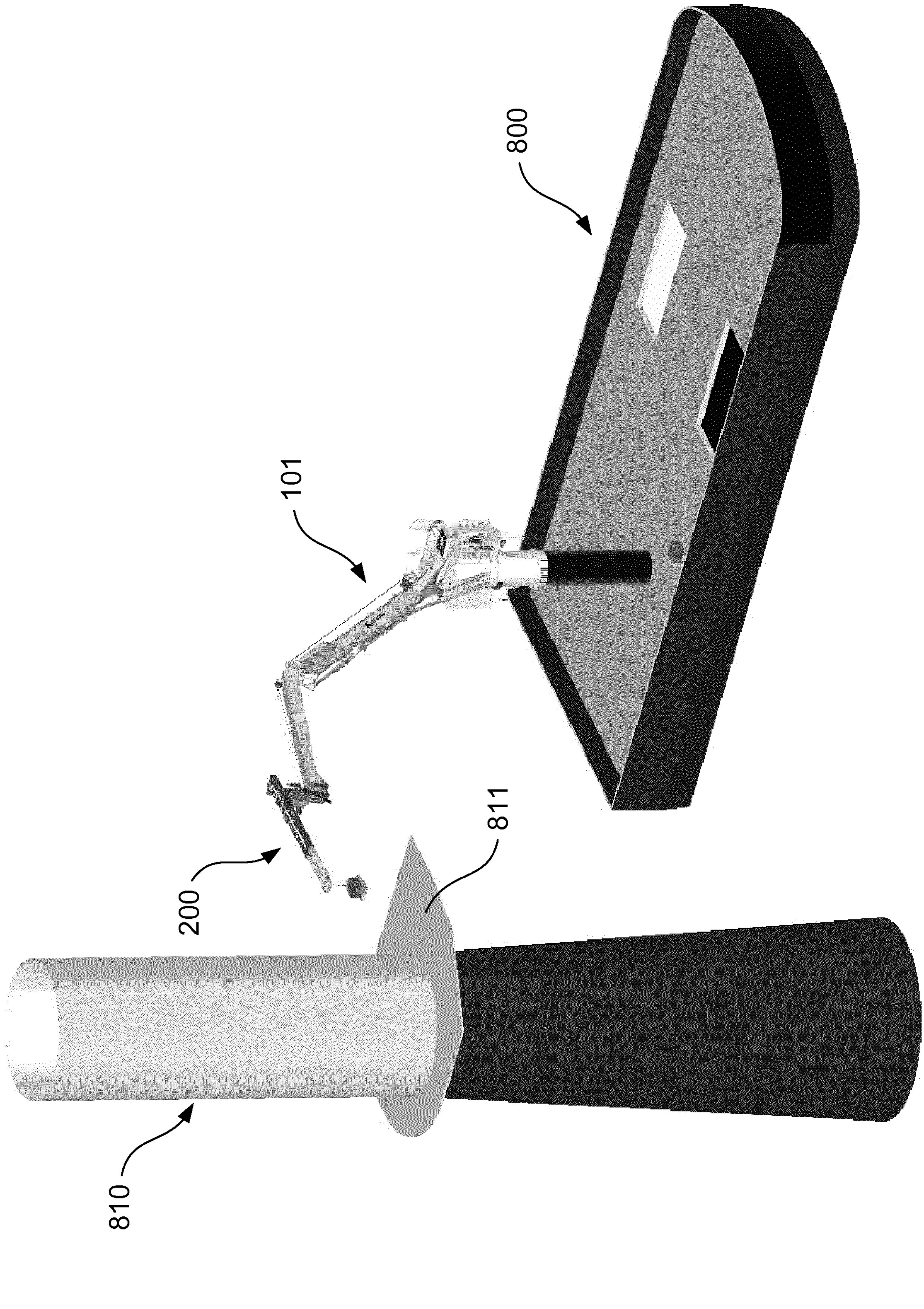

Fig. 3c.

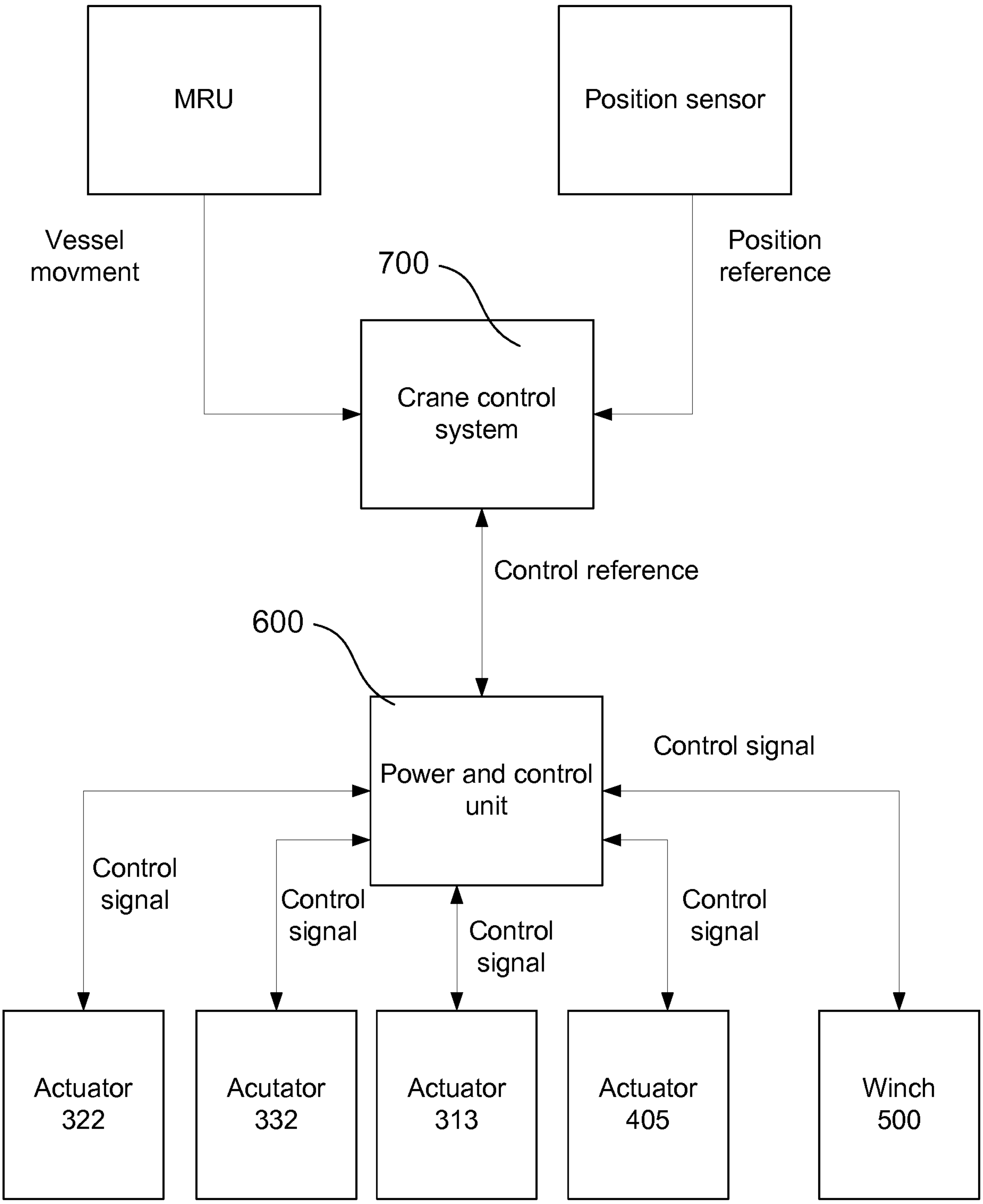
MRU
Position sensor
Vessel movment
Position reference
700
Crane control system
Control reference
600
Power and control unit
Control signal
Control signal
Control signal
Control signal
Control signal
Actuator 322
Acutator 332
Actuator 313
Actuator 405
Winch 500

Fig. 4.

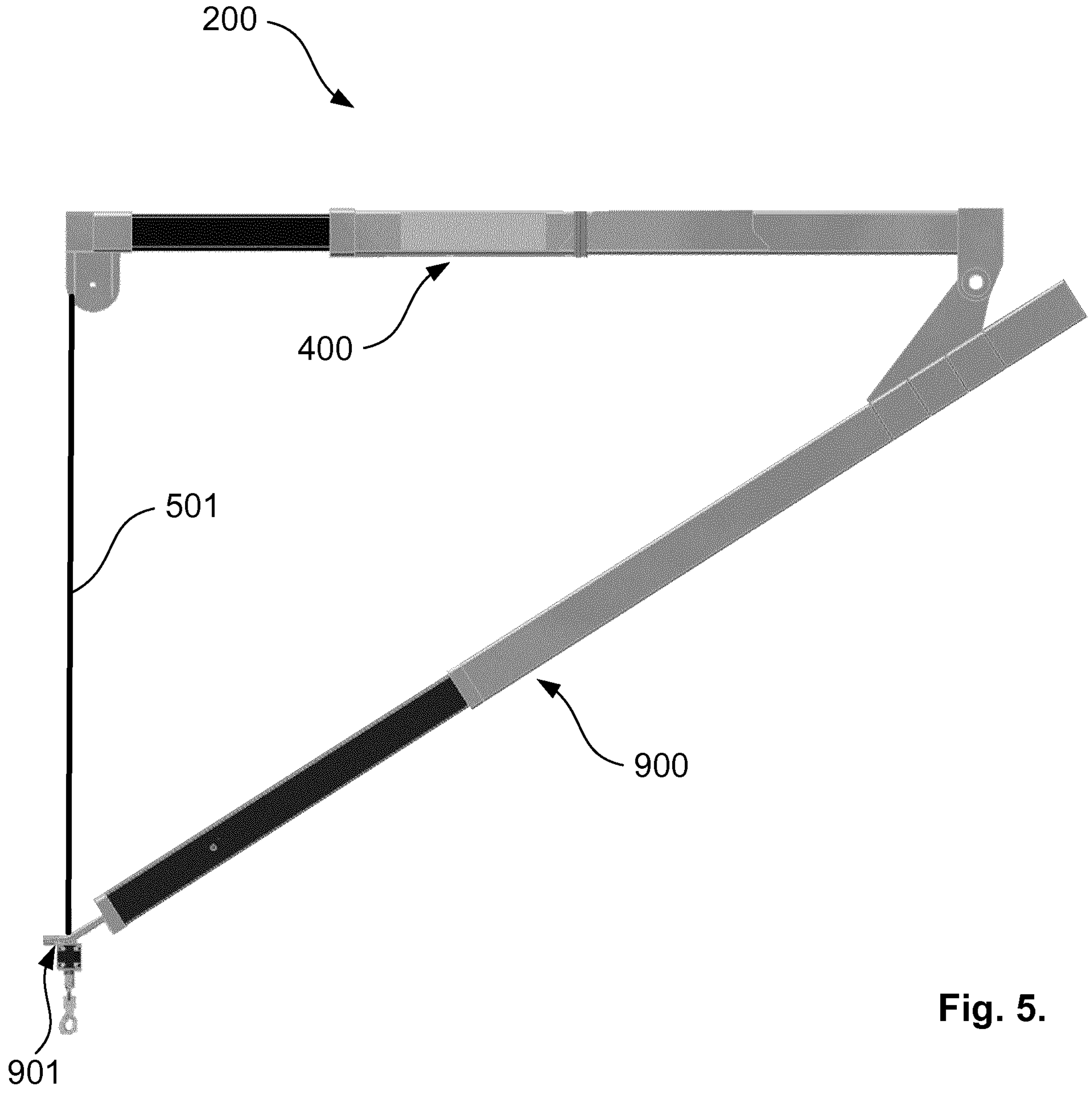

Fig. 5.

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/081474

A. CLASSIFICATION OF SUBJECT MATTER
INV. B66C13/02 B66C23/52
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)
B66C B63B

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.
A	US 2010/089855 A1 (KJOLSETH PAUL M [US]) 15 April 2010 (2010-04-15) paragraph [0019] - paragraph [0031]	1-10
A	WO 2013/070080 A1 (IHC HOLLAND IE BV [NL]) 16 May 2013 (2013-05-16) claim 1; figure 1	1-10
A	WO 2006/052907 A2 (NORCROSS RICHARD J [US]; MAY EDWARD L [US]; BOSTELMAN ROGER [US]; KJOL) 18 May 2006 (2006-05-18) paragraph [0018]; figure 2	1-10

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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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

"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

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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
21 February 2017	01/03/2017

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	Serôdio, Renato

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2016/081474

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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