US 20230041461A1

(19) United States
(12) Patent Application Publication
Gallagher et al.
(10) Pub. No.: US 2023/0041461 A1
(43) Pub. Date: Feb. 9, 2023

(54) **WATER ENGAGEMENT DEVICE ACTUATOR**

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(21) Appl. No.: **17/877,785**

(22) Filed: **Jul. 29, 2022**

Related U.S. Application Data

(60) Provisional application No. 63/230,253, filed on Aug. 6, 2021.

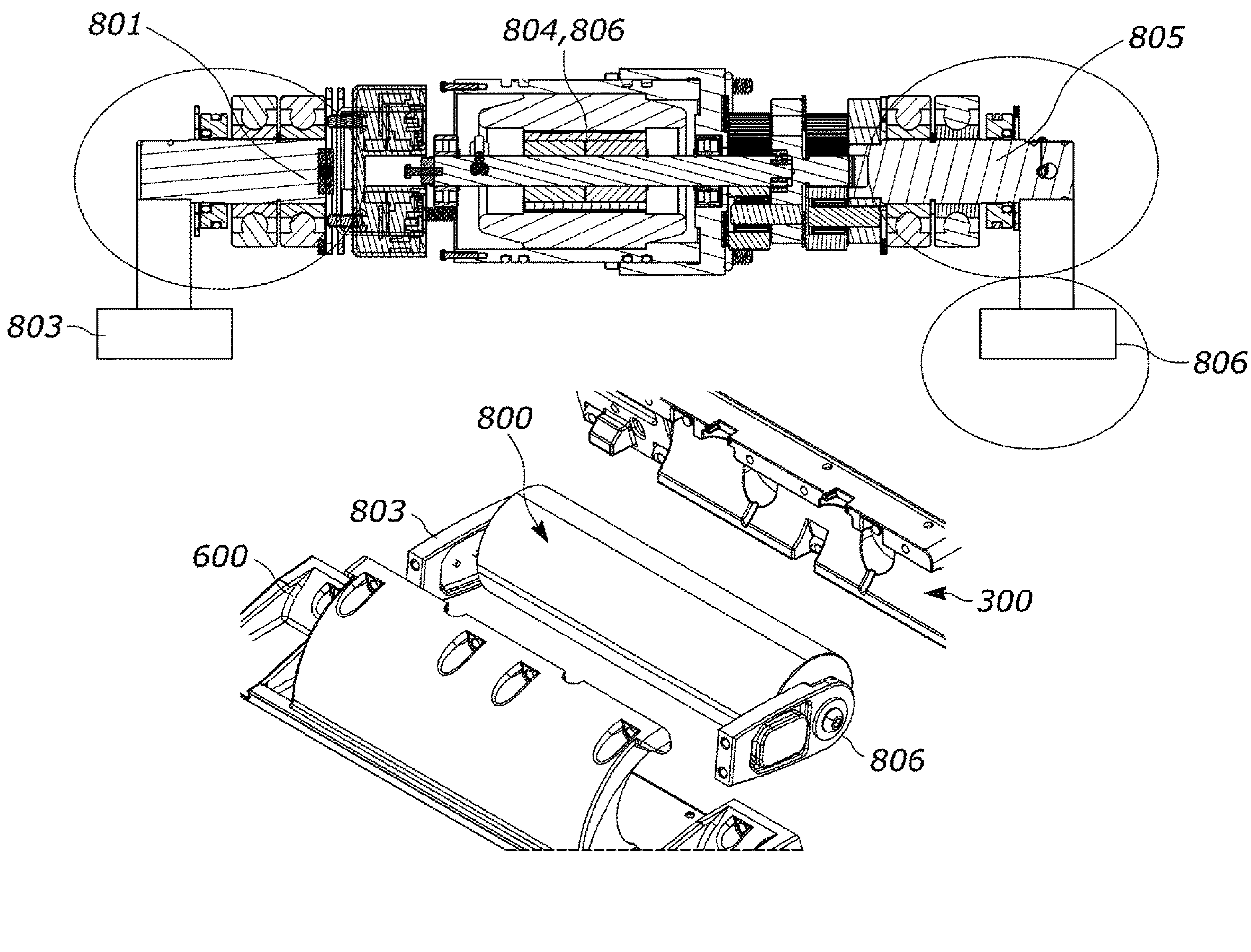
Publication Classification

(51) **Int. Cl.**
B63B 39/06 (2006.01)

(52) **U.S. Cl.**
CPC *B63B 39/06* (2013.01); *B63B 2039/065* (2013.01)

(57) **ABSTRACT**

A water engagement actuator system and device comprising a rotary actuator connected to a support structure adapted to be connected to a marine vessel is provided. The rotary actuator includes a driven shaft and a undriven slave shaft disposed opposite the driven shaft. The rotary actuator further comprises at least one pair of bearings enclosed within a clean sealed environment; water engagement device having an arced blade connected to the driven shaft; at least one encoder disposed in a space separating the undriven slave shaft from the driven shaft. A controller is communicatively connected to the rotary actuator to command rotation of the driven shaft such that the water engagement device is automatically moved to a position between a retracted position and a deployed position in order to provide dynamic active control of the marine vessel. The rotary actuator is further configured to absorb any hydrodynamic drag load generated from the marine vessel with no more than two rotary shaft seals and counteract any unintended disturbance by automatic deployment of the arced blade—at 100 mm/s or more—into the water and provide dynamic active control of a marine vessel.



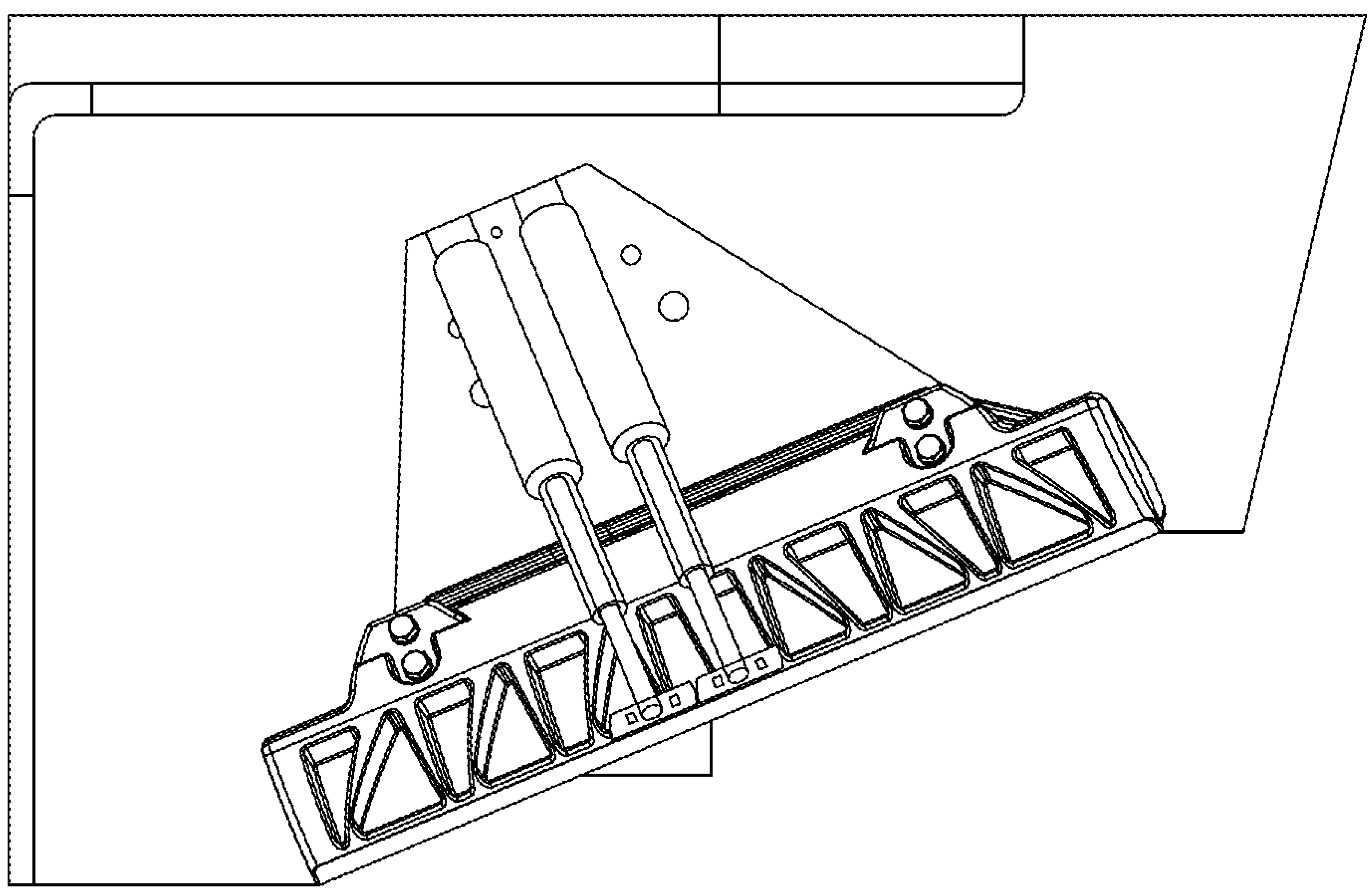


FIG. 1

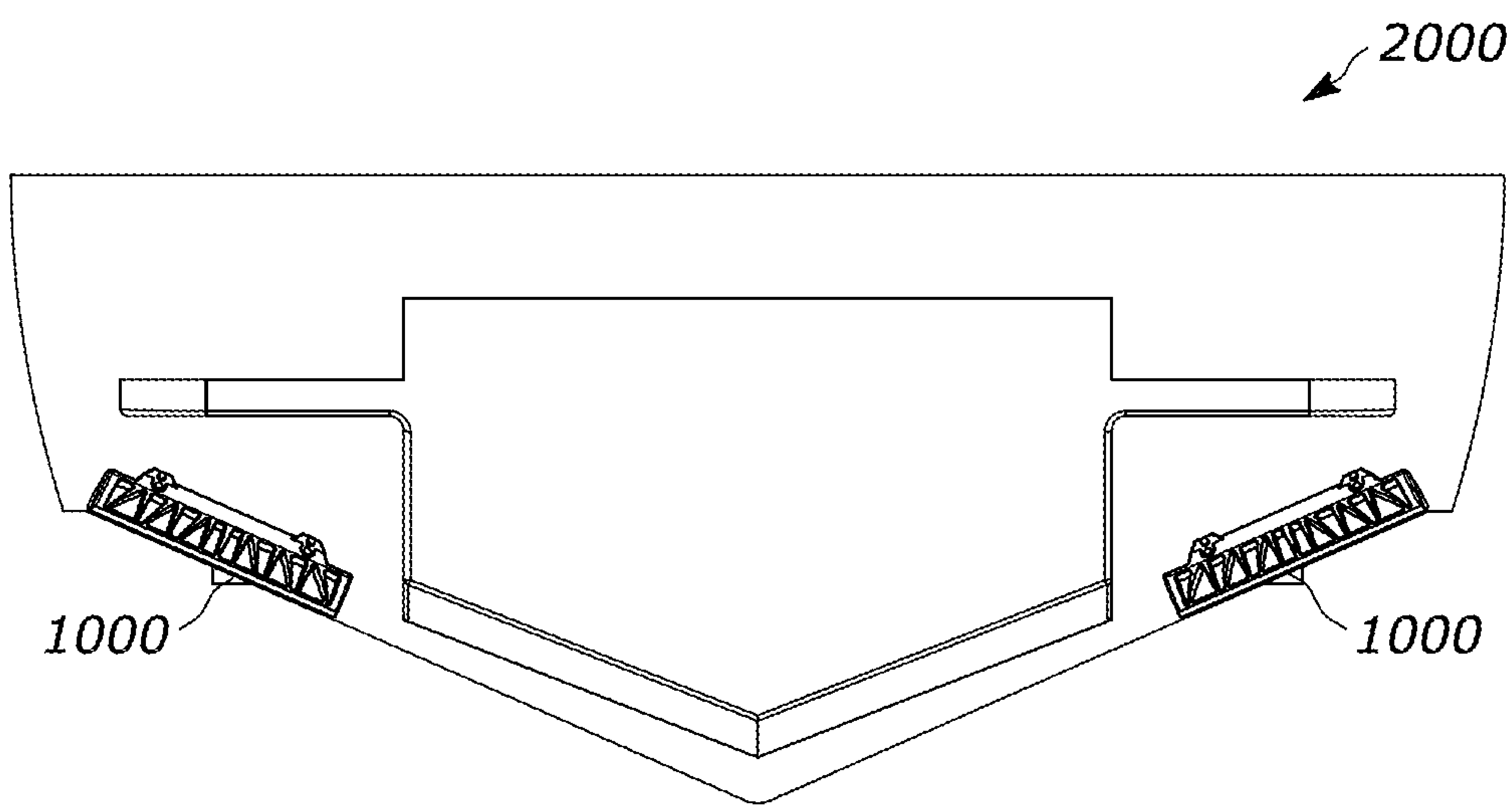


FIG. 2

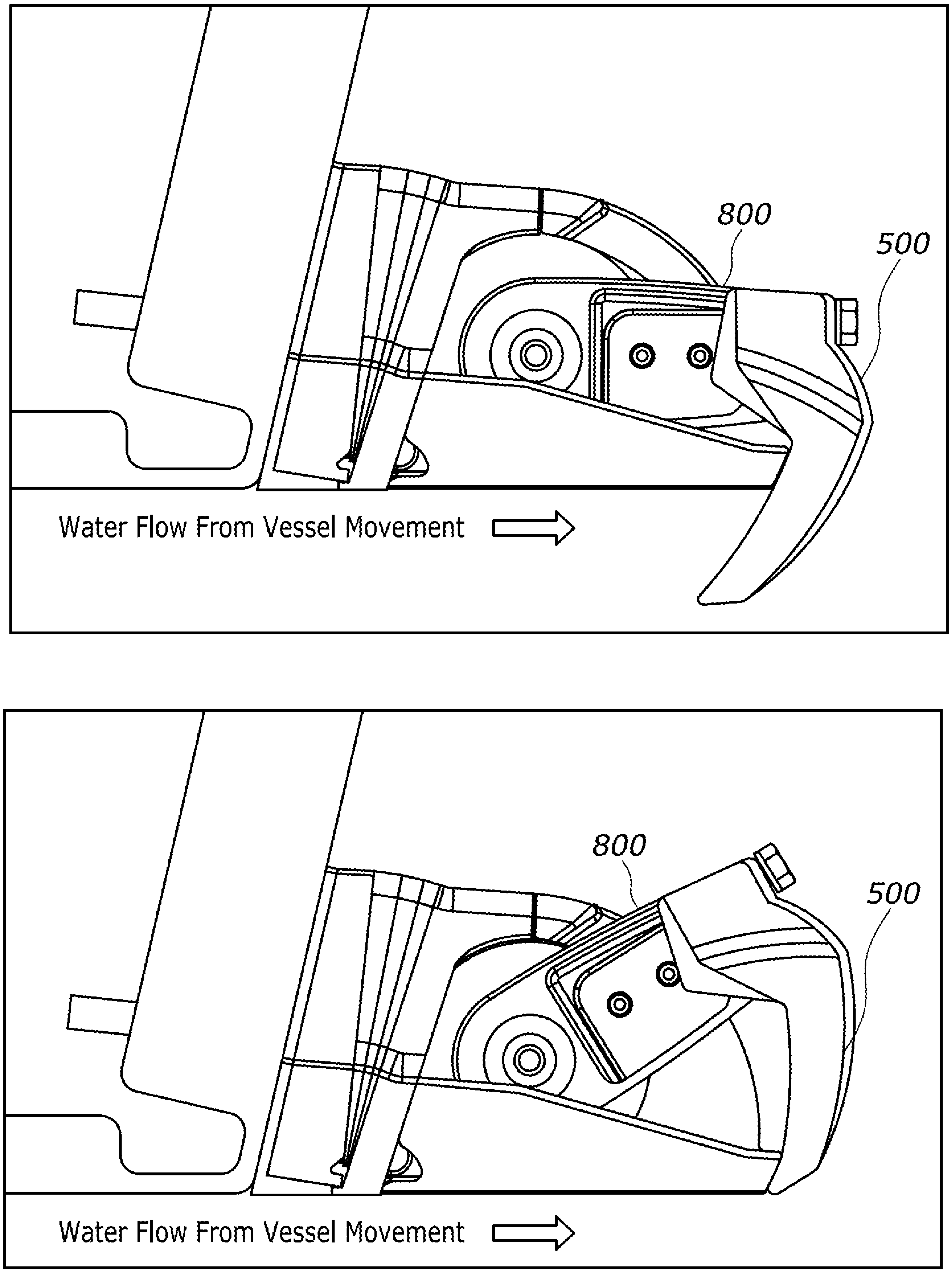

800
500
Water Flow From Vessel Movement
800
500
Water Flow From Vessel Movement

FIG. 3

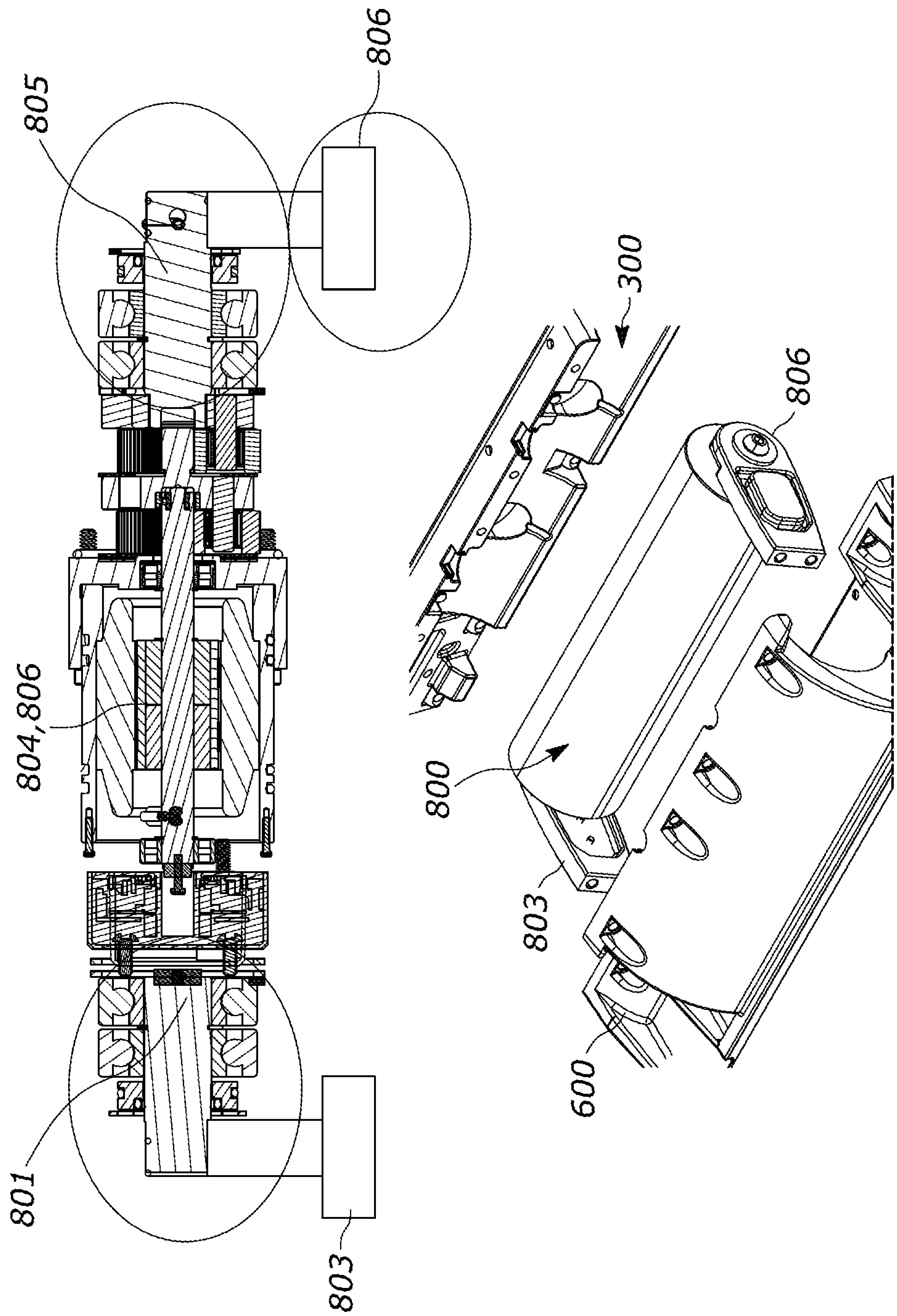


FIG. 4A

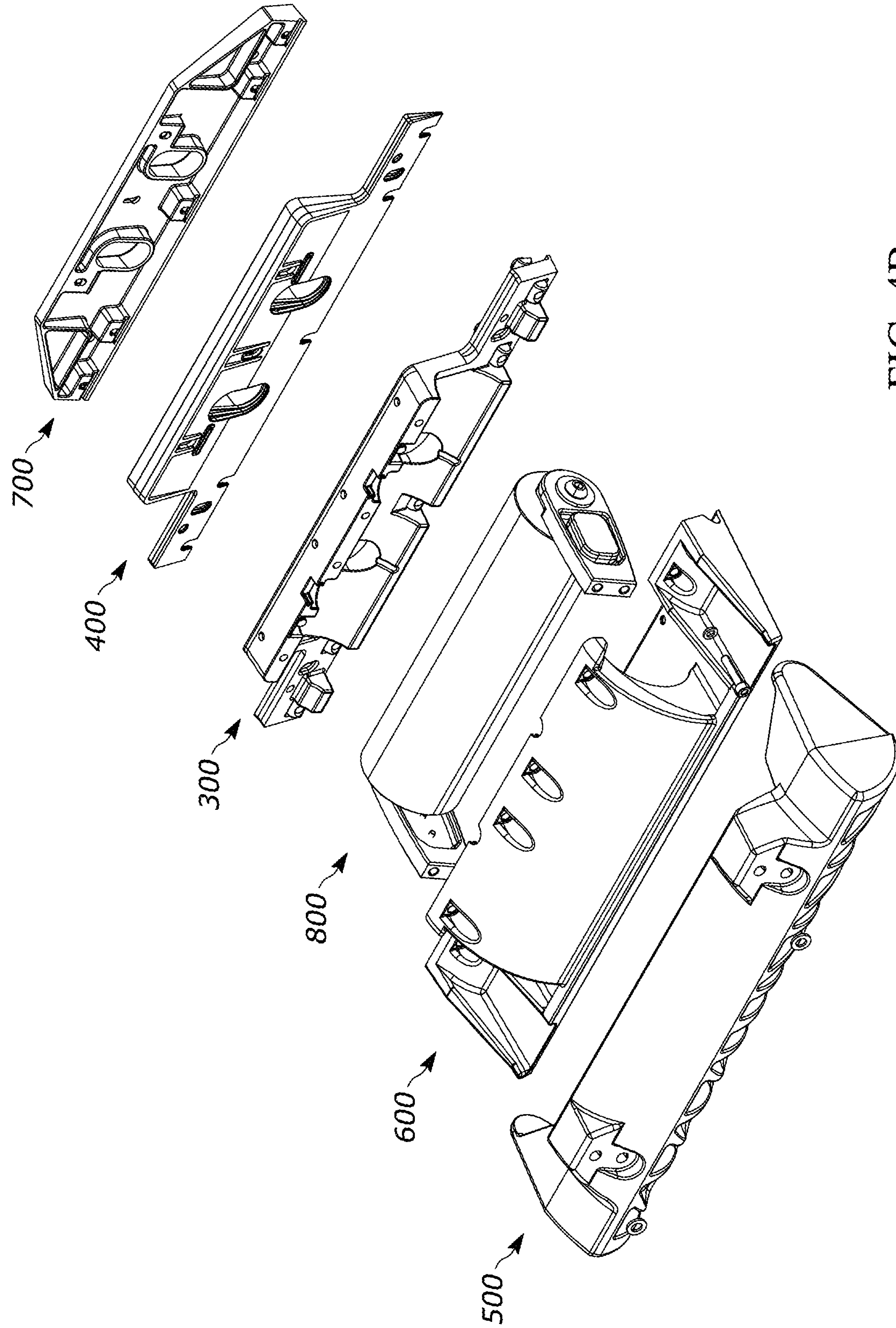


FIG. 4B

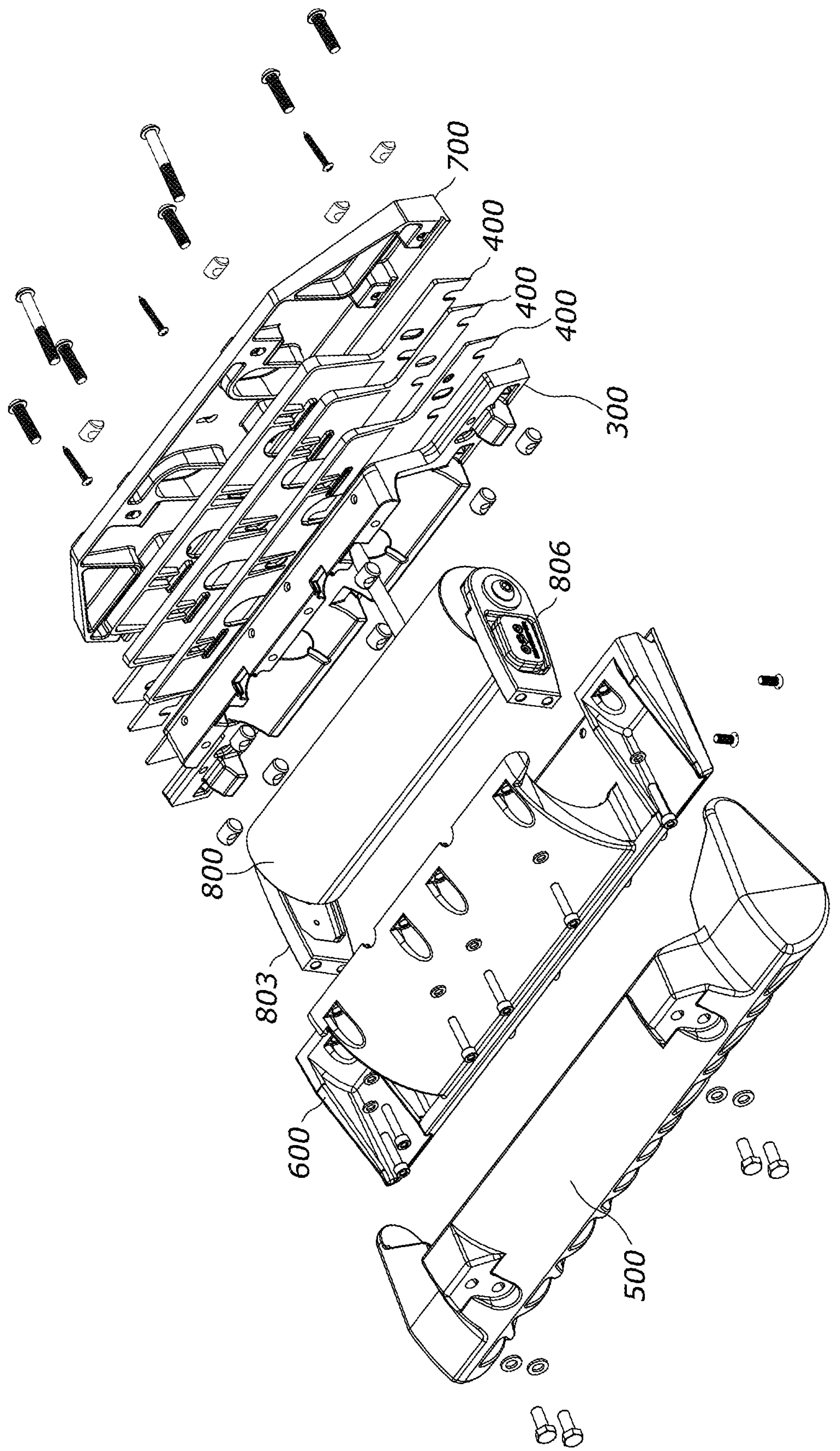


FIG. 4C

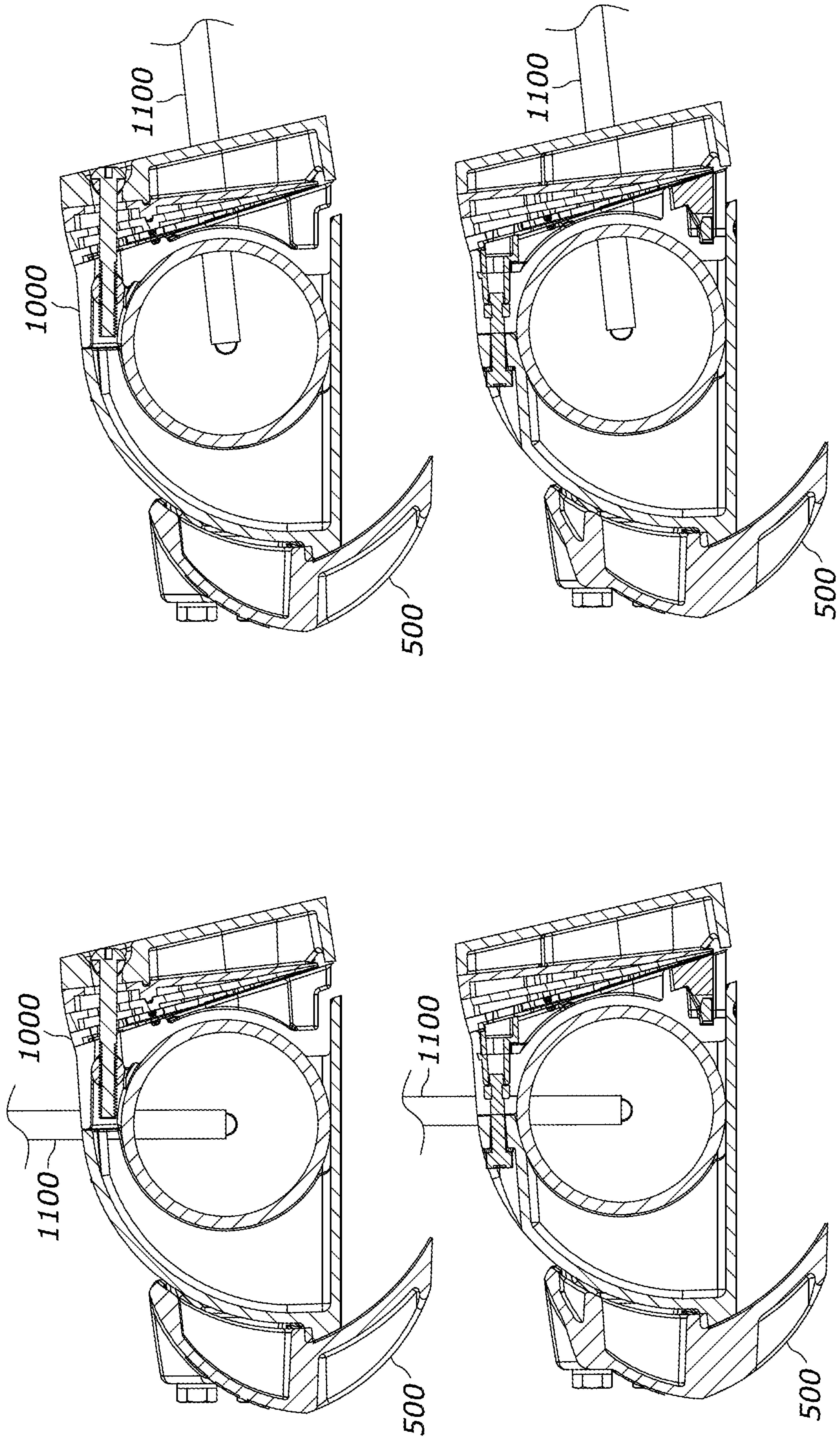


FIG. 5

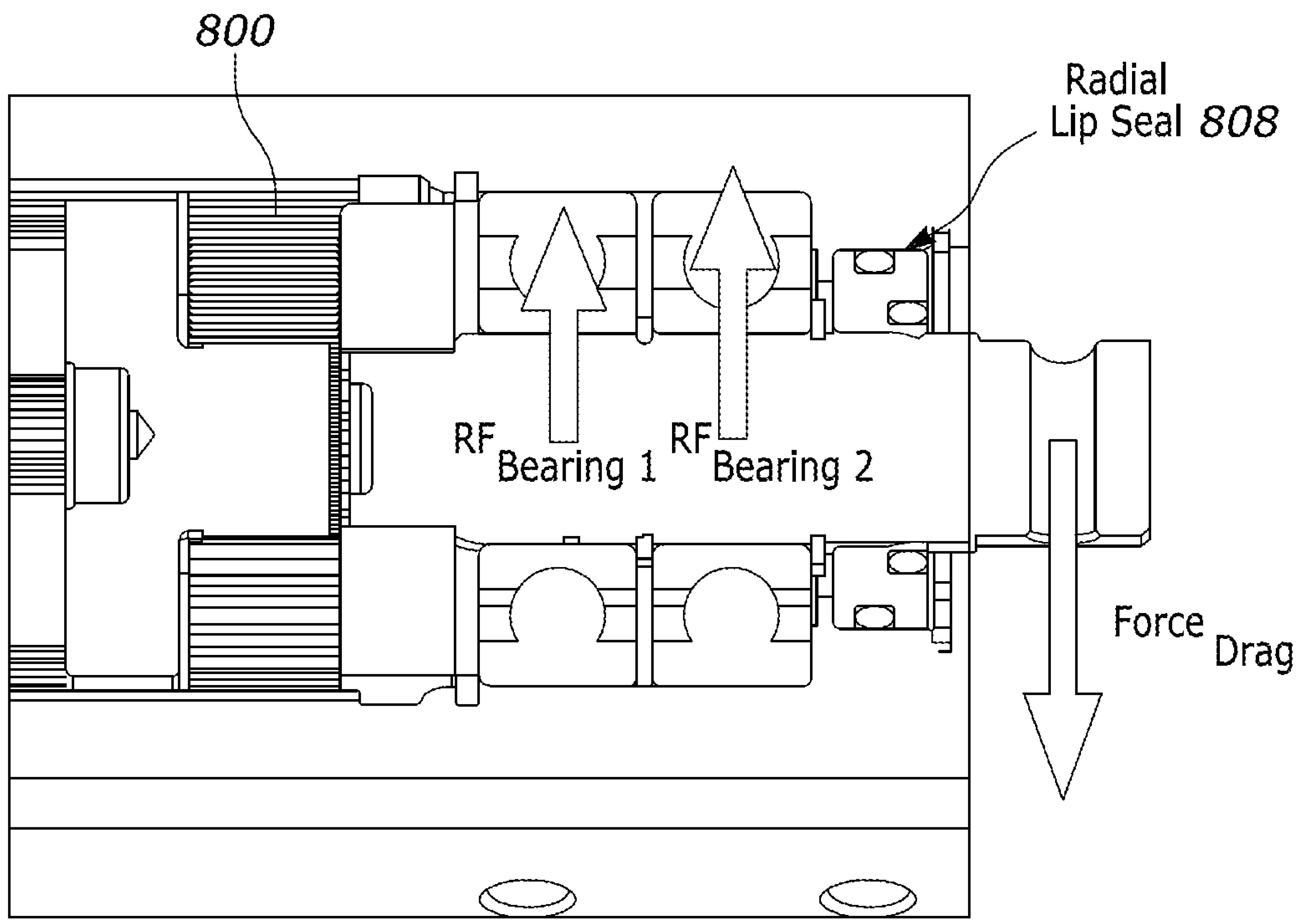


FIG. 6

WATER ENGAGEMENT DEVICE ACTUATOR

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of and priority to U.S. Provisional Application No. 63/230,253, filed Aug. 6, 2021, the content of which is hereby incorporated by reference.

FIELD OF THE DISCLOSURE

[0002] The present disclosure generally relates to an improved water engagement system and device for providing optimum performance and control of dynamic active motions of a marine vessel (DAC). More particularly, the present disclosure is directed to a water engagement device actuator having a rotary actuator configured and enabled for horizontal mounting and fast deployment of an arced blade for optimizing the dynamic active control of a marine vessel while minimizing power consumption required for such dynamic active control of a marine vessel.

BACKGROUND

[0003] The following terms and related definitions are used in the marine stabilization industry. "Trim Control" means the control of the average angle about the lateral or pitch axis of a marine vessel, averaged over one second or more. "List Control" or "Roll Control" means the control of the average angle about the longitudinal or roll axis of a marine vessel, averaged over one second or more. "Yaw Control" means the control of the average angle about the yaw axis of a marine vessel, averaged over one second or more. A "Water Engagement Device" or "WED" means a mechanical or electromechanical device configured to generates a variable amount of lift in a marine vessel by selective engagement of the device with or into the water flow under or adjacent to a transom surface of the marine vessel when the marine vessel is underway in a certain (or forward) direction or by changing the angle of attack of the device relative to the water flow during operation of a marine vessel in a forward direction. A WED can also be referred to as a Controller in the system disclosed herein and any reference to a Controller and/or a WED means the same device. A WED delta position is defined as the difference between port and starboard WED deployments. "Deployment" means selective engagement of the WED with or into the water flow or a change in the WED angle of attack. A Roll Moment in a marine vessel is the result of a force applied to the vessel that causes the vessel to rotate about its longitudinal or roll axis. A Pitch Moment in a marine vessel is the result of a force applied to the vessel that causes the vessel to rotate about its lateral or pitch axis. A Yaw Moment in a marine vessel is the result of a force applied to the vessel that causes the vessel to rotate about its vertical or yaw axis. For instance, (1) a "Roll Moment" can be generated if the port and starboard WEDs are deployed asymmetrically in a marine vessel that may cause the vessel to roll; (2) a "Yaw Moment" can be generated when port and starboard WEDs are deployed asymmetrically which may cause a heading change; and (3) a "Pitch Moment" can be generated if the port and starboard WEDs are deployed symmetrically or if a single WED is deployed about the center of the marine vessel which may cause the vessel to pitch

[0004] A WED is referred to as a Controller in the system disclosed herein and any reference to a Controller and/or a WED means the same device. A WED delta position is defined as the difference between port and starboard WED deployments. "Deployment" means selective engagement of the WED with or into the water flow or a change in the WED angle of attack. A Roll Moment in a marine vessel is the result of a force applied to the vessel that causes the vessel to rotate about its longitudinal or roll axis. A Pitch Moment in a marine vessel is the result of a force applied to the vessel that causes the vessel to rotate about its lateral or pitch axis. A Yaw Moment in a marine vessel is the result of a force applied to the vessel that causes the vessel to rotate about its vertical or yaw axis.

[0005] A "Roll Moment" can be generated if the port and starboard WEDs are deployed asymmetrically in a marine vessel that may cause the vessel to roll. A "Yaw Moment" can be generated when port and starboard WEDs are deployed asymmetrically which may cause a heading change and a "Pitch Moment" can be generated if the port and starboard WEDs are deployed symmetrically or if a single WED is deployed about the center of the marine vessel which may cause the vessel to pitch.

[0006] Conventional marine stabilization techniques allow the proportional deployment of a WED to generate a continuous lift while simultaneously allowing adjustment of the trim and list angles of the marine vessel. A few examples of commercially available WEDs—not to be considered exhaustive by any means—are interceptors, trim tabs, and fins and other similar devices that can engage in similar fashion and provide similar functionality. Marine stabilization technologies are key to experiencing the joy of cruising over waters without the attendant random environmentally induced disturbances of the boat. These disturbances—for example, a sudden unexpected roll—can be annoying and disruptive for boaters.

[0007] In the existing prior art systems, WEDs are designed and configured to control list and trim—to get the marine vessel to an average angle in the roll and pitch axis. Smaller marine vessels used in the recreational market generally have manually actuated WEDs, while larger vessels operating in the commercial space use automatic actuated systems to stabilize the motion. However, such prior art systems are generally high power devices and have certain minimum vertical height requirements for installation on the transom in order to achieve fast deployment of the WEDs (deployment speed of 100 mm/s or more). As illustrated in FIG. **4**, the linear actuation system having a certain minimum high vertical height and installed on the transom of the marine vessel is shown below. A DAC—via deployment of the WEDs disclosed herein—is configured to simultaneously control accelerations, rates, and angles in the roll, pitch, and yaw axes of the marine vessel.

[0008] Conventional fast linear movement of the actuator is challenging with respect to obtaining a watertight seal. This is primarily due to the perpetual change in the shaft surface where the sealing takes place and any marine growth on the shaft surface or on the seal must be worn off. In addition, segments of the shaft must be moved from a clean sealed environment to a dirty salt water environment. Contrary to the fast linear movement seal—as disclosed herein—it is much more economical to make fast rotational movement watertight as it always seals the same shaft surface.

[0009] Currently available recreational and commercial fin roll stabilization systems that use linear hydraulic actuators have many disadvantages. For example, the actuators for deploying the WEDs are almost always located inside the vessel. During operation of the actuator hydraulic oil leak associated with any seal failure does not pass into the water (e.g., the sea) by virtue of the actuator being located inside the vessel. Conventional actuators are mostly configured with electric linear actuators located inside the vessel to prevent damage of the electric motor from seal failure. In other words, conventional WED actuators do not comprise of WEDs without a linear actuator and/or a linear shaft seal. The WED actuator disclosed herein allows the speed actuator to be mounted external to the vessel which significantly reduces installation issues and attendant costs.

[0010] A WED actuator using a rotary actuator with a concave arced blade—as disclosed herein—can address various shortcomings of prior art WED actuator systems, including, but not limited to, the capability to deploy the WEDs in significantly less time than the currently available fastest recreational marine stability control system—deployment/retraction at 100 mm/s or more. The WED actuator provides significant power savings due to coupling of the WED with an arced blade and a plurality of bearings in a sealed clean environment with a limited number of shaft seals.

[0011] The present disclosure is directed to a WED actuator having a uniquely designed and configured rotary actuator that enables fast deployment (deployment speed of 100 mm/s or more) of a WED without a linear shaft seal for providing dynamic active control of a marine vessel (DAC).

BRIEF SUMMARY OF THE INVENTION

[0012] A water engagement device actuator system comprises an actuator assembly comprising a rotary actuator connected to a support structure adapted to be connected to a marine vessel so that a longitudinal axis of the rotary actuator is disposed transverse to a longitudinal axis of the marine vessel. The rotary actuator includes a driven shaft and an undriven slave shaft opposite the driven shaft. A water engagement device is connected to the driven shaft and a controller is communicatively connected to the rotary actuator to command rotation of the driven shaft such that the water engagement device is automatically moved to a position between a retracted position and a deployed position in order to provide dynamic active control of the marine vessel.

[0013] The water engagement device comprising an arced blade is connected to the driven shaft and at least one encoder is disposed in a space separating the undriven slave shaft from the driven shaft. In another embodiment, the arced blade is a concave arced blade. The controller is communicatively connected to the rotary actuator—the controller configured to command rotation of the driven shaft such that the water engagement device is automatically moved to a position between a retracted position and a deployed position during marine operations. The rotary actuator is further configured to absorb any hydrodynamic drag load generated from the marine vessel with no more than two rotary shaft seals. In addition, the rotary actuator is configured to counteract any unintended disturbance by automatic deployment of the arced blade at 100 mm/s or more into the water and provide dynamic active control of a marine vessel.

[0014] The actuator assembly comprises rotary shaft seals configured for easy mounting and fast vertical deployment of a water engagement device for dynamic active control of a marine vessel. The rotary actuator is disposed between an actuator plate and a seal plate of a support structure adapted to be connected to a marine vessel so that a longitudinal axis of the rotary actuator is disposed transverse to a longitudinal axis of the marine vessel. The support structure in addition to the seal plate and the actuator plate, comprises a wedge pack and a transom plate—the components attached to each other in order to provide structural support for the retraction and deployment of the water engagement device—the arced blade during marine operations. The water engagement device or the arced blade connected to the water engagement device actuator (the rotary actuator) comprises at least one pair of bearings enclosed within a clean sealed environment.

[0015] As noted above and further detailed below, the water engagement device actuator assembly—specifically the rotary actuator is further configured to absorb any hydrodynamic drag load generated from the marine vessel with no more than two rotary shaft seals. The support structure can be installed either above or below the water line of the marine vessel such that the hydrodynamic forces generated from the deployment of the arced blade intersect at a center of rotation of the driven shaft of the rotary actuator, as further described in detail below. The controller is further configured to command the rotary actuator to rotate so that the water engagement device is moved to the retracted position when the rotary actuator fails or is deactivated. The rotary actuator further comprises a first actuator arm and a second actuator arm integrated to the driven shaft at a first end and at a second end respectively—the first actuator arm and the second actuator arm extend in a radial direction from the rotary actuator along a plane perpendicular to the longitudinal axis of the rotary actuator. In another embodiment, the first actuator arm and the second actuator arm are further connected to blade support arm or other equivalent structure within the water engagement device or the rotary actuator assembly. The arced blade is rotatably connected to the rotary actuator via the first actuator arm and the second actuator arm—the WEDA system providing deployment of the arced blade into the water at 100 mm/s or more.

[0016] The installation of the WEDA on the transom of a marine vessel require no significant power to overcome hydrodynamic losses associated with forces on the blade. The arced blade rotatably connected to the actuator via actuator arms that extend in a radial direction from the cylindrical body of the rotary actuator—attached and positioned at least partially forward of the seal plate. As further described in the detailed disclosure below, the arced blade is further configured with side shields which are molded in with the blade as one assembly. The blade is further connected (fastened) and secured to the actuator arms using standard industry fasteners (e.g., bolts) and positioned to be loaded in tension. The device disclosed herein is designed to keep water from spraying into the other components of the WEDA and/or the engine(s) of the marine vessel. The rotary actuator is further configured to enable easy horizontal mounting and vertical deployment of the arced blade. During operations of the marine vessel, the rotary actuator is configured to pivotally move the water engagement device—the arced blade—relative to the support structure between a fully/partially deployed state and a fully/partially retracted state in order to counteract any unintended disturbance in the marine vessel motion.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] Certain embodiments are shown in the drawings. However, it is understood that the present disclosure is not limited to the arrangements and instrumentality shown in the attached drawings.

[0018] FIG. **1** shows a generic conventional linear actuation system used for marine stabilization.

[0019] FIG. **2** shows the forward looking transom view of a marine vessel depicting two water engagement device actuators installed on the transom of the marine vessel according to one aspect of the present disclosure.

[0020] FIG. **3** shows the fully deployed and the fully retracted state of the water engagement device (the arced blade) in relation to the flow of water from the vessel movement according to one aspect of the present disclosure.

[0021] FIGS. **4A-4C** show perspective (exploded) and cross-section views of the water engagement device actuator assembly according to one aspect of the present disclosure.

[0022] FIG. **5** shows the water engagement device actuator assembled to be connected along the transom of a marine vessel according to one aspect of the present disclosure.

[0023] FIG. **6** shows the mechanism used by the water engagement device actuator for absorption of hydrodynamic drag load with minimal friction loss according to one aspect of the present disclosure.

DETAILED DESCRIPTION OF THE DISCLOSURE

[0024] For the purposes of promoting and understanding the principles disclosed herein, reference is now made to the preferred embodiments illustrated in the drawings, and specific language is used to describe the same. Embodiments disclosed in the present disclosure provide a novel and improved water engagement device actuator assembly—the WEDA **1000**—as will be described with reference to FIGS. **1-6**. Furthermore, a preferred embodiment and alternative embodiments for a water engagement device actuator assembly will be disclosed.

[0025] FIG. **1** is a generic conventional linear actuation system used for marine stabilization. FIG. **2** shows the forward looking transom view of a marine vessel depicting two water engagement device actuators installed on the transom of the marine vessel according to one aspect of the present disclosure. FIG. **3** shows the deployed and the retracted state of the water engagement device—the arced blade **500**—according to one aspect of the present disclosure in relation to the flow of water from the vessel movement. As shown in FIG. **3**, the arced blade **500** is in a fully extended (or deployed) and in a fully retracted state.

[0026] FIGS. **4**A-C show perspective (exploded) and cross-section views of the water engagement device actuator assembly (WEDA **1000**) according to a preferred embodiment of the invention—the WEDA **1000** configured to be attached to the transom of a marine vessel **2000**. The WEDA **1000**, disclosed herein, is configured to be attached to a substantially vertical surface of the stern extending along a portion of the horizontal width of the vertical surface along the transom edge of the stern of the marine vessel **2000**. FIGS. **4**A-C show one WEDA according to an embodiment of the present disclosure. However, it should be noted that the invention is not limited to such a number only. The invention can be implemented with two, three or more WEDAs in accordance with the needs of the application and as shown, for example, in FIG. **2**. In one aspect, the marine vessel **2000** may include at least one pair of WEDAs—one rotary actuator **800** positioned on the port side and one on the starboard side of the marine vessel **2000**, as shown in FIG. **2**. The two WEDAs—two rotary actuators—may be actuated in series, meaning that each rotary actuator **800** actuate in the same manner at a given time. Alternatively, each rotary actuator **800** may be actuated differentially to provide dynamic active control of the marine vessel **2000**.

[0027] As shown in FIGS. **4**A-C—the water engagement device actuator assembly **1000** comprises the rotary actuator **800**, the arced blade **500** along with the support structure (comprising seal plate **600**, actuator plate **300**, wedge pack **400**, the transom plate **700**)—the support structure used for installing the WEDA assembly **1000** (including the rotary actuator **800** and the arced blade **500**) on the transom of a marine vessel **2000**. As illustrated, the rotary actuator **500** is disposed between an actuator plate **300** and a seal plate **600** of a support structure adapted to be connected to a marine vessel **2000** so that a longitudinal axis of the rotary actuator **500** is disposed transverse to a longitudinal axis of the marine vessel **2000**. The arced blade **500** shaped as a concave arced blade is connected to a driven shaft of the rotary actuator **800**. The rotary actuator **800** further includes a driven shaft and an undriven slave shaft opposite the driven shaft. A controller is communicatively connected to the rotary actuator **800** to command rotation of the driven shaft such that the arced blade **500** is automatically moved to a position between a retracted position and a deployed position in order to provide dynamic active control of the marine vessel **2000** (as shown in FIG. **3**).

[0028] The configuration and installation of the WEDA **1000**—specifically the rotary actuator **800**—ensure that the hydrodynamic forces generated from the deployment of the arced blade **500** intersect at a center of rotation of the driven shaft. As noted above, the rotary actuator **800** further comprises an undriven slave shaft oppositely disposed to the driven shaft and at least one encoder disposed in a space separating the undriven slave shaft from the driven shaft of the rotary actuator **800**. As illustrate, the rotary actuator **800** further comprises at least one pair of bearings enclosed within a clean sealed environment—the rotary actuator **800** is further configured to absorb any hydrodynamic drag load generated from the marine vessel with no more than two rotary shaft seals. The rotary actuator **800** further comprises a first actuator arm **803** and a second actuator arm **806** (also known as the torque arms) integrated to the driven shaft at a first end and at a second end respectively—the first actuator arm **803** and the second actuator arm **806** extend in a radial direction from the rotary actuator **800** along a plane perpendicular to the longitudinal axis of the rotary actuator **800**. As further illustrated, the arced blade **500** is rotatably connected to the rotary actuator via the first actuator arm **803** and the second actuator arm **806**.

[0029] The WEDA **1000** is communicatively coupled to one or more controllers (e.g., embedded processor based software modules) configured to control the actuator **800** and transition the water engagement device—the arced blade **500**—between a deployed state and a retracted state, as shown in FIG. **3**. The controller/software module communicatively connected with the rotary actuator **800** can be configured with proprietary inertial sensing hardware and software in order to learn, capture and make a determination and/or predict the various motions of the marine vessel in all three axes and command fast deployment of the blades **500** to counteract any pitch, roll, and yaw motions of the vessel as well as provide total vessel pitch axis control. The rotary actuator **800** can operate automatically to provide dynamic active control of a marine vessel based on different input signals such as speed, steering, sensors inputs etc. In addition, an operator of the boat can also maneuver the marine vessel performances (trim, steering etc.) via a control panel communicatively connected to the rotary actuator **800**.

[0030] Referring back to FIGS. **4**A-C, the arced blade **500** is configured to be pivotally moveable by the rotary actuator **800**—the various components of the support structure fixedly attached to each other in order to provide support for the full (or partial) deployment and/or full (or partial) retraction of the arced blade **500** during marine operations. For instance, the transom plate **700** has a front surface that is adapted to be connected to the marine vessel **2000**. The actuator plate **300** also has a front surface and a flange extending from the front surface, wherein the flange is configured and shaped to be disposed under a bottom side of the transom plate **700**. A clamping assembly may be configured to engage the transom plate **700** with the actuator plate **300** in order to connect the actuator plate **300** to the transom plate **700**. The components of the support structure are sized and shaped to accommodate the rotary actuator **800** as well as the arced blade **500**. In one aspect, the arced blade **500** may be positioned within the seal plate **600** in a close tolerance relationship preventing high pressure water generated during deployment or retraction of the blade **500** from entering the seal plate **400** or other components of the WEDA **1000**. In addition, as shown, the supporting structure may include holes formed therein for accommodating and capturing the various components of the WEDA **1000**, as will be discussed in more detail below. The seal plate **600** is further configured to flex in order to fully circumferentially engage the rotary actuator **800** and secure the rotary actuator **800** into its position within the plate. In another embodiment, the thickness of the top flange of the seal plate **600** is slightly increased (a seal plate **600** with a thicker top flange) such that the fasteners (e.g., the plurality of bolts/screws securing the seal plate **600**—as shown in FIG. **4**C) can apply the requisite compression force without any deformation and maintain a tight seal against the actuator plate **300**.

[0031] Referring back to FIGS. **4**A-C, the transom plate **700** is configured to be fixedly attached to the transom of the marine vessel **2000** via a certain marine-grade or other suitable adhesive. In another embodiment, the transom plate **700** can be bolted on, or screwed on to the transom of the marine vessel **2000** by using various standard fasteners. The wedge pack **400** consist of single or multiple wedges or shims each providing a range of angles, either individually or in combination, and arranged to be placed between the back surface of the transom plate **700** and the actuator plate **300**. The wedge pack **600** provides additional options to adjust an angle of the seal plate **600** with respect to the transom of the marine vessel **2000**—providing further flexibility on for installing the WEDA **1000** on various types of transoms.

[0032] Referring back to FIGS. **4**A-C, various additional attachment means (comprising fasteners, bolts, screws via the numerous through-holes and cut-outs of the components—shown in FIGS. **4**B and **4**C) are provided for joining the transom plate **700** to the actuator plate **300** via the wedge pack **400** as well as attaching the seal plate **600** to the actuator plate **300**. One or more coatings of zinc can be applied around the actuator arms **803**, **806** in order to act as a barrier and prevent corrosion from repeated use in the marine environment. As shown, the actuator arms **803**, **806** are rotatably connected to the sides of the actuator **800** and extend in a radial direction from the cylindrical body of the rotary actuator **800**. As illustrated, in order to fully assemble the WEDA **1000**—the seal plate **600** having a plurality of embedded contoured cut-out ribs (as shown in FIGS. **4**A-C) is attached to the actuator plate **300** while the cylindrical body of the rotary actuator **800** is press-fitted inside the seal plate **600** and the actuator plate **300**. Standard industry fasteners can be used to hold all the components of the WEDA **1000** fixedly attached together while allowing the rotary actuator **800** to pivotally retract or deploy the blade **500**. The rotary actuator **800** is arranged between a front part of the actuator plate **300** and the recessed rear part of the seal plate **600**—the seal plate **600** enveloping and capturing the rotary actuator **800** within the embedded cut-outs and/or recesses of the plate **600** such that the rotary actuator is pivotally attached to the frame of the seal plate **600**. Various attachment means are provided to attach the actuator plate **300** to the rear recessed side of the seal plate **600** and capture the rotary actuator **800** between the seal plate **600** and the actuator plate **300**. The number of recesses and/or cut-outs built into the various components of the WEDA **1000** allow efficient movement of the actuator arms (**803**, **806**) of the rotary actuator **800** without any hindrance during operation of the marine vessel **2000**.

[0033] The various components of the WEDA **1000** can be suitably manufactured from materials persistent to and able to survive marine conditions. For example, materials such as fiber reinforced polymer resin, non-reinforced or reinforced plastic or composite materials, metals (e.g. stainless steel or aluminium), rubber or other materials with equivalent properties and characteristics may be used for the various components. The WEDA **1000** is a form of a module that may be disposed within a cutout (or hole) of the marine vessel. Alternatively, the WEDA **1000** comprising the arced blade **500** may be a modular self-contained structure that may be commercially sold separately for various types of marine vessels.

[0034] Referring back to FIGS. **4**A-C, the actuator arms **803**, **806** extends in a radial direction from a first end and a second end of the rotary actuator **800** and are connected to the blade support arm(s) in order to provide electrical power to the WEDA assembly. The driven shaft and the undriven slave shaft oppositely disposed to the driven shaft inside the rotary actuator **800** are further tapered and configured for an interference fit with the actuator arms **803**, **806** (the torque arms of the actuator). It is to be noted that other interfaces to the torque arms that can be contemplated by one of ordinary skill the art are possible (including, but not limited to, splined tooth arrangement, non-tapered interface, etc.). In addition, the encoder disposed in a space separating the undriven slave shaft from the driven shaft is configured to enable absolute position measurement as well as to support commutation of a brushless motor within the actuator. In another embodiment, the encoder can act as a position sensor—the encoder attached to the driven shaft to monitor a position of the arced blade **500** relative to the WEDA **1000**.

The encoder (or position sensor) may include a potentiometer or equivalent device used to communicate position data to the controller or another centrally controlled computer disposed within the marine vessel **2000** and communicatively and operatively connected to the WEDA **1000**. The undriven slave shaft and the driven shaft inside the rotary actuator **800** are not internally connected. The configuration of the separate shafts enables the encoder(s) to be contained within the sealed clean environment of the WEDA assembly **1000**. The arced blade **500** is further configured with side shields which are molded in with the blade **500** as one assembly—configured to enable easy horizontal mounting and fast deployment/retraction of the concave arced blade **500** during marine operations.

[0035] Referring back to the FIGS. **4**A-C and FIG. **5**, the shaft and the actuator arms **803**, **806** are further held together by using standard and conventional fasteners (e.g., bolts). The support arms **801**, **805** attached to the shaft provides an electrical signal to actuate and deploy the arced blade **500** into the water during operation of the marine vessel **2000**—the arced blade **500** configured to move (or displaceable vertically) between a fully (or partially) deployed position and/or a fully (or partially) retracted position in relation to the WEDA (as shown in FIG. **3**)—at 100 mm/s or more (preferably more than 250 mm/s). The WEDA **1000** is further configured to be mounted and installed in multiple orientations (e.g., four (4) different orientations) in order to facilitate the installation of the rotary actuator **800** above or below the water line of the marine vessel **2000**. For instance, the rotary actuator **800** can be assembled with controller in either of two holes which are molded in the top of the seal plate **600** depending on desired cable exit required for the application. The actuator cable can be routed to a desired height up the transom of the marine vessel **2000** and the additional components can be used to turn the cable 90 degrees in order to penetrate through the transom of the marine vessel **2000**. Each orientation of the WEDA **1000** uses a different configuration and layout of the wiring for the actuator **800**—for power and signal communication—and to provide for the deployment of the blade **500** at 100 mm/s or more.

[0036] The rotary shaft seals allows the rotary actuator **800** to use commercial off-the-shelf bearings in a sealed environment—bearings that can absorb hydrodynamic drag load associated with blade **500** deployment. As shown in FIG. **6**, the multi-bearing (e.g., four bearing) arrangement enables the use of bearings in a sealed environment with only two radial shaft seals. The bearing arrangement is further configured to enable all four bearings to be secured by a maximum of two rotary seals per WEDA at the expense of variable reaction forces—generated from the two rotary seals of the WEDA. The rotary shaft seals combined with the arced blade **500** and the commercial off-the-shelf bearings—in combination—are configured to enable a fast response time for deployment/retraction of the blade **500** while providing very low power consumption while enabling the fast response time relative to prior art water engagement device systems. In prior art—phenolic bearings are generally used to avoid the complexities of incorporating four shaft seals. Such prior art bearings generate significantly greater rolling losses than bearings within the WEDA **1000**, disclosed herein. The configurations of the bearings are not limited and can be placed on either end of the shaft to support the actuator arms **803**, **806**. The novel configuration and design of the WEDA **1000** enables the absorption of drag loads with very low friction losses while relying only on two rotary seals for each rotary actuator **800**—the novel water engagement device actuator assembly providing a significant reduction in power is required to deploy the blade relative to the prior art water engagement devices.

[0037] Referring back to FIGS. **4**A-C, the hinge located at the center of the shaft of the rotary actuator **800** forms the center of rotation for the rotary actuator **800**. Once the WEDA **1000** is installed, the arc of the blade surface and the seal plate **600** of the WEDA can be positioned to align parallel to the bottom of the marine vessel **2000**. The WEDA **1000** is further configured such that the hydrodynamic forces associated with deploying the arced blade **500** in the water (the water flowing past the boat at a certain speed) act perpendicular to the surface of the arc of the blade **500**. The arc of the arced blade **500** is shaped such that a force acting perpendicular to its surface will intersect the center of rotation of the arced blade. In other words, the distance to the center of rotation is zero since the hydrodynamic force vector intersects the center of rotation. Therefore, one of the many advantages of this novel WEDA assembly **1000** is that the rotary actuator **800** requires no torque (measured as force multiplied by distance—the distance being equal to zero) to overcome the hydrodynamic loads associated with the deployment of the blade **500** in the water. The embodiment described herein can be accomplished for many different geometries and dimensions of the various components forming the WEDA assembly **1000**, as can be contemplated by one of ordinary skill in the art.

[0038] In another embodiment, the WEDA **1000** can operate under a Safe Default Failure Mode (SDFM). For instance, during operation of the marine vessel a jet created by the gap between the seal plate **600** and the blade **500** acts on the blade **500** and cause the blade **500** to auto-retract (lift out of effective engagement with the water) when the actuator fails or is deactivated.

[0039] It is understood that the preceding is merely a detailed description of some examples and embodiments of the present disclosure, and that numerous changes to the disclosed embodiments may be made in accordance with the disclosure made herein without departing from the spirit or scope of the disclosure. The preceding description, therefore, is not meant to limit the scope of the disclosure, but to provide sufficient disclosure to allow one of ordinary skill in the art to practice the disclosure without undue burden. It is further understood that the scope of the present disclosure fully encompasses other embodiments that may become obvious to those skilled in the art.

[0040] Differential and differentially are defined within this document as unequal, off center and/or involving differences in: angle, speed, rate, direction, direction of motion, output, force, moment, inertia, mass, balance, application of comparable things, etc. The terms Dynamic and/or Dynamic Active Control may mean the immediate action that takes place at the moment they are needed. Any use of the term Immediate, in this application, means that the control action occurs in a manner that is responsive to the extent that it prevents or mitigates vessel motions and attitudes before they would otherwise occur in the uncontrolled situation.

[0041] A person of ordinary skilled in the art understands the relationship between sensed motion parameters and required effector response in terms of the maximum overall delay that can exist while still achieving the control objectives. Dynamic and/or Dynamic Active Control may be used in describing interactive hardware and software systems involving differing forces and may be characterized by continuous change and/or activity. Dynamic may also be used when describing the interaction between a vessel and the environment. As stated above, marine vessels may be subject to various dynamic forces generated by its propulsion system as well as the environment in which it operates. Any reference to vessel attitude may be defined as relative to three rotational axes including pitch attitude or rotation about the Y, transverse or sway axis, roll attitude or rotation about the X, longitudinal or surge axis, and yaw attitude or rotation about the Z, vertical or heave axis.

[0042] Various features of the example embodiments described herein may be implemented using hardware, software, or a combination thereof and may be implemented in one or more computer systems or other processing systems. However, the manipulations performed in these embodiments were often referred to in terms, such as determining, which are commonly associated with mental operations performed by a human operator. No such capability of a human operator is necessary in any of the operations described herein. Rather, the operations may be completely implemented with machine operations. Useful machines for performing the operation of the exemplary embodiments presented herein include general purpose digital computers or similar devices. With respect to hardware, a CPU typically includes one or more components, such as one or more microprocessors for performing the arithmetic and/or logical operations required for program execution, and storage media, such as one or more disk drives or memory cards (e.g., flash memory) for program and data storage, and a random access memory for temporary data and program instruction storage. With respect to software, a CPU typically includes software resident on a storage media (e.g., a disk drive or memory card), which, when executed, directs the CPU in performing transmission and reception functions.

[0043] The CPU software may run on an operating system stored on the storage media, such as, for example, UNIX or Windows (e.g., NT, XP, Vista), Linux, and the like, and can adhere to various protocols such as the Ethernet, ATM, TCP/IP, CAN, LIN protocols and/or other connection or connectionless protocols. As is known in the art, CPUs can run different operating systems, and can contain different types of software, each type devoted to a different function, such as handling and managing data/information from a particular source, or transforming data/information from one format into another format. It should thus be clear that the embodiments described herein are not to be construed as being limited for use with any particular type of server computer, and that any other suitable type of device for facilitating the exchange and storage of information may be employed instead.

[0044] A CPU may be a single CPU, or may include multiple separate CPUs, wherein each is dedicated to a separate application, such as, for example, a data application, a voice application, and a video application. Software embodiments of the example embodiments presented herein may be provided as a computer program product, or software, that may include an article of manufacture on a machine-accessible or non-transitory computer-readable medium (i.e., also referred to as "machine readable medium") having instructions. The instructions on the machine-accessible or machine-readable medium may be used to program a computer system or other electronic device. The machine-readable medium may include, but is not limited to, floppy diskettes, optical disks, CD-ROMs, magneto-optical disks, USB thumb drives, and SD cards or other type of media/machine-readable medium suitable for storing or transmitting electronic instructions. The techniques described herein are not limited to any particular software configuration. They may find applicability in any computing or processing environment. The terms "machine-accessible medium," "machine-readable medium," and "computer-readable medium" used herein shall include any non-transitory medium that is capable of storing, encoding, or transmitting a sequence of instructions for execution by the machine (e.g., a CPU or other type of processing device) and that cause the machine to perform any one of the methods described herein. It is to be noted that it is common—as a person skilled in the art can contemplate—in the art to speak of software, in one form or another (e.g., program, procedure, process, application, module, unit, logic, and so on) as taking an action or causing a result. Such expressions are merely a shorthand way of stating that the execution of the software by a processing system causes the processor to perform an action to produce a result.

[0045] The use of the terms "a" and "an" and "the" and similar referents in the context of describing the invention (especially in the context of the following claims) is to be construed to cover both the singular and the plural, unless otherwise indicated herein or clearly contradicted by context. The terms "comprising," "having," "including," and "containing" are to be construed as open-ended terms (i.e., meaning "including, but not limited to,") unless otherwise noted. Recitation of ranges of values herein are merely intended to serve as a shorthand method of referring individually to each separate value falling within the range, unless otherwise indicated herein, and each separate value is incorporated into the specification as if it were individually recited herein. All methods described herein can be performed in any suitable order unless otherwise indicated herein or otherwise clearly contradicted by context.

[0046] The use of any and all examples, or exemplary language (e.g., "such as") provided herein, is intended merely to better illuminate the invention and does not pose a limitation on the scope of the invention unless otherwise claimed. It is understood that the preceding is merely a detailed description of some examples and embodiments of the present disclosure, and that numerous changes to the disclosed embodiments may be made in accordance with the disclosure made herein without departing from the spirit or scope of the disclosure. The preceding description, therefore, is not meant to limit the scope of the disclosure, but to provide sufficient disclosure to allow one of ordinary skill in the art to practice the disclosure without undue burden.

[0047] It is further understood that the scope of the present disclosure fully encompasses other embodiments that may become obvious to those skilled in the art. Features illustrated or described as part of one embodiment can be used in another embodiment to yield a still further embodiment. Thus, it is intended that the present disclosure cover such modifications and variations as come within the scope of the appended claims and their equivalents. It is to be understood by one of ordinary skill in the art that the present discussion is a description of exemplary embodiments only, and is not intended as limiting the broader aspects of the present disclosure, which broader aspects are embodied in the exemplary constructions.

1. A water engagement device actuator system comprising:

a rotary actuator connected to a support structure adapted to be connected to a marine vessel so that a longitudinal axis of the rotary actuator is disposed transverse to a longitudinal axis of the marine vessel, where the rotary actuator includes a driven shaft;

a water engagement device connected to the driven shaft; and

a controller communicatively connected to the rotary actuator to command rotation of the driven shaft such that the water engagement device is automatically moved to a position between a retracted position and a deployed position in order to provide dynamic active control of the marine vessel.

2. The system of claim **1**, wherein the water engagement device is an arced blade.

3. The system of claim **2**, wherein the arced blade is a concave arced blade.

4. The system of claim **1**, wherein hydrodynamic forces generated from the deployment of the water engagement device intersect at a center of rotation of the driven shaft.

5. The system of claim **1**, wherein the rotary actuator further comprises an undriven slave shaft oppositely disposed to the driven shaft.

6. The system of claim **5**, wherein the rotary actuator further comprises at least one encoder disposed in a space separating the undriven slave shaft from the driven shaft.

7. The system of claim **1**, wherein the rotary actuator further comprises at least one pair of bearings enclosed within a clean sealed environment; and

wherein the rotary actuator is further configured to absorb hydrodynamic drag load generated from the marine vessel with no more than two rotary shaft seals.

8. The system of claim **1**, wherein the support structure can be installed either above or below the water line of the marine vessel.

9. The system of claim **1**, wherein the controller is further configured to command the rotary actuator to rotate so that the water engagement device is moved to the retracted position when the rotary actuator fails or is deactivated.

10. The system of claim **1**, wherein the rotary actuator is configured to enable deployment of the water engagement device at a speed of 100 mm/s or more.

11. A water engagement device comprising:

a rotary actuator disposed between an actuator plate and a seal plate of a support structure adapted to be connected to a marine vessel so that a longitudinal axis of the rotary actuator is disposed transverse to a longitudinal axis of the marine vessel, where the rotary actuator includes a driven shaft;

a water engagement device having an arced blade connected to the driven shaft;

a controller communicatively connected to the rotary actuator to command rotation of the driven shaft such that the water engagement device is automatically moved to a position between a retracted position and a deployed position in order to provide dynamic active control of the marine vessel.

12. The water engagement device of claim **11**, wherein the arced blade is a concave arced blade.

13. The water engagement device of claim **11**, wherein hydrodynamic forces generated from the deployment of the water engagement device intersect at a center of rotation of the driven shaft.

14. The water engagement device of claim **11**, wherein the rotary actuator further comprises an undriven slave shaft oppositely disposed to the driven shaft.

15. The water engagement device of claim **14**, wherein the rotary actuator further comprises at least one encoder disposed in a space separating the undriven slave shaft from the driven shaft.

16. The water engagement device of claim **11**, wherein the rotary actuator further comprises at least one pair of bearings enclosed within a clean sealed environment; and

wherein the rotary actuator is further configured to absorb any hydrodynamic drag load generated from the marine vessel with no more than two rotary shaft seals.

17. The water engagement device of claim **11**, wherein the support structure can be installed either above or below the water line of the marine vessel.

18. The water engagement device of claim **11**, wherein the controller is further configured to command the rotary actuator to rotate so that the water engagement device is moved to the retracted position when the rotary actuator fails or is deactivated.

19. The water engagement device of claim **11**, wherein the rotary actuator is configured to enable deployment of the water engagement device at a speed of 100 mm/s or more.

20. The water engagement device of claim **11**, wherein the rotary actuator further comprises:

a first actuator arm and a second actuator arm integrated to the driven shaft at a first end and at a second end respectively; and

wherein the first actuator arm and the second actuator arm extend in a radial direction from the rotary actuator along a plane perpendicular to the longitudinal axis of the rotary actuator.

21. The water engagement device of claim **20**, wherein the arced blade is rotatably connected to the rotary actuator via the first actuator arm and the second actuator arm.

22. A marine vessel comprising:

a rotary actuator connected to a support structure adapted to be connected to a marine vessel so that a longitudinal axis of the rotary actuator is disposed transverse to a longitudinal axis of the marine vessel, wherein the rotary actuator includes a driven shaft and an undriven slave shaft disposed opposite the driven shaft;

wherein the rotary actuator further comprises at least one pair of bearings enclosed within a clean sealed environment;

a water engagement device having an arced blade connected to the driven shaft;

at least one encoder disposed in a space separating the undriven slave shaft from the driven shaft;

a controller communicatively connected to the rotary actuator to command rotation of the driven shaft such that the water engagement device is automatically moved to a position between a retracted position and a deployed position in order to provide dynamic active control of the marine vessel; and

wherein the rotary actuator is further configured to absorb any hydrodynamic drag load generated from the marine vessel with no more than two rotary shaft seals; and wherein the rotary actuator is configured to counteract any unintended disturbance by automatic deployment of the arced blade into the water and provide dynamic active control of a marine vessel.

23. The marine vessel of claim **22**, wherein the rotary actuator is configured to enable deployment of the arced blade at a speed of 100 mm/s or more.

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