(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 4 035 991 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
03.08.2022 Bulletin 2022/31

(21) Application number: **21153776.6**

(22) Date of filing: **27.01.2021**

(51) International Patent Classification (IPC):
B63H 23/30 *(2006.01)* ***B63H 5/125*** *(2006.01)*
B63H 21/20 *(2006.01)*

(52) Cooperative Patent Classification (CPC):
B63H 23/30; B63H 5/1252; B63H 21/20;
B63H 2005/1254; B63H 2021/205

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

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(54) MARINE DRIVE UNIT AND MARINE VESSEL

(57) The invention relates to a hybrid marine drive unit (103; 203) mounted to a transom (102; 202), which drive unit (103; 203) comprises a drive housing (104; 204) rigidly mounted on the transom (102; 202), a propelling unit (105; 205) rotatable about a vertical axis (X) and mounted to a lower surface (106; 206) of the drive housing (104; 204), and a transmission with at least a vertical drive shaft (210) located in the drive housing (104; 204) and extending into the propelling unit (105; 205), which vertical drive shaft is arranged transmit drive torque from at least one of multiple sources of drive torque (211, 221). The vertical drive shaft (210) is operably connected to at least one first source of drive torque (111; 211) arranged within the drive housing (104; 204), and the vertical drive shaft (210) is operably connected to a horizontal output shaft (220) extending into the drive housing (104; 204) through the transom (102; 202), wherein the horizontal output shaft (220) is connectable to a second source of drive torque (121; 221). The invention further relates to a marine vessel comprising such a drive unit.

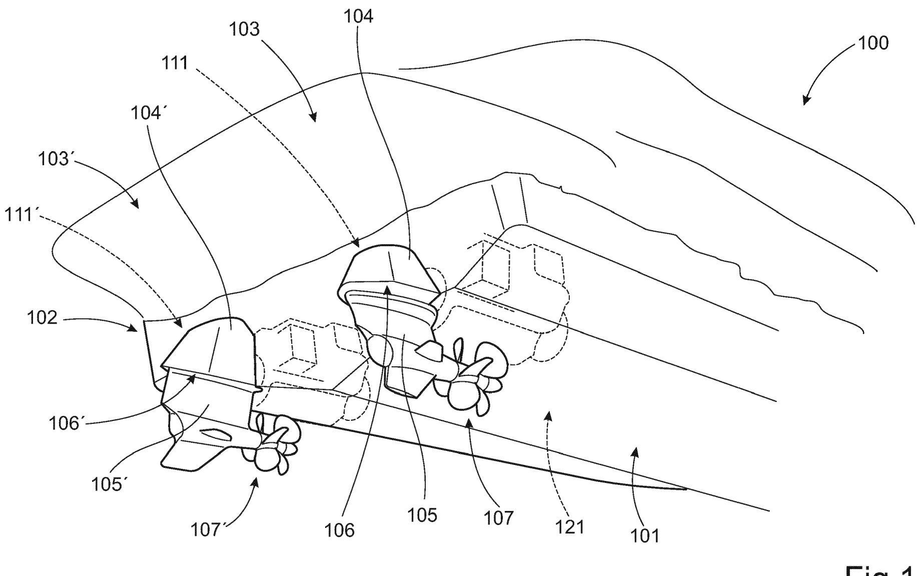

Fig.1

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Description

TECHNICAL FIELD

[0001] The present invention relates to a marine drive unit and a marine vessel with a hybrid driveline comprising such a drive unit.

BACKGROUND

[0002] Known marine vessels comprising a propulsion unit in the form of a pod drive are usually provided with an internal combustion engine (ICE) arranged within the hull of the vessel. Torque is then transmitted from the ICE to the drive via a transmission comprising shafts and gearing in order to drive a set of propellers on a steerable drive unit mounted to the hull.

[0003] When operating a vessel of this type at low speed it is sometimes desirable to be able to drive the vessel at reduced noise levels and/or without exhaust emissions. Operating conditions when this is an advantage is for instance when manoeuvring within a marina, while trolling or during docking. A possible solution to the above problems can be to provide an individual electric motor. However, such motors are more suited for smaller vessels with an outboard motor and are usually too small for operating vessels comprising one or more inboard engines with pod drives. A further solution to the problem is to provide a hybrid driveline with the inboard engine and electric motor arranged in series. Such a solution is known from US 2011/195618. A problem with this solution is that it takes up more space within the hull, reducing accommodation space for the occupants. Further, the control system for the engine and electric motor must be combined and becomes more complex. Such a control system will at best be difficult to adapt to an existing inboard driveline comprising one or more engines. Also, combining such a hybrid driveline with a pod drive will require additional space for the transmission and steering arrangement extending through the hull to the steerable pod beneath the hull.

[0004] The invention provides an improved marine drive unit aiming to solve the above-mentioned problems.

SUMMARY

[0005] An object of the invention is to provide a marine drive unit for a vessel, which drive unit solves the above-mentioned problems.

[0006] The object is achieved by a hybrid marine drive unit and a marine vessel with a hybrid driveline comprising such a drive unit according to the appended claims.

[0007] In the subsequent text, the term "drive unit" is defined as an assembly comprising an outdrive having two sub-units. An upper sub-unit comprises a drive housing containing at least one source of drive torque and a transmission comprising a vertical driveshaft enclosed by the drive housing. The drive housing is preferably, but not necessarily, completely submerged. A lower sub-unit forms a propulsor or propelling unit and contains an extension of the vertical driveshaft and a transmission comprising a gearbox providing power to a propeller shaft/-s for driving at least one propeller. The transmission in the lower sub-unit supplies power from the transmission in the upper sub-unit to the propellers. The component parts of the transmission in the lower sub-unit are enclosed in a gearbox housing. At least one drive unit is mounted to the transom of a marine vessel and forms part of a hybrid driveline comprising a first source of drive torque within the drive unit and an inboard, second source of drive torque. The terms "inboard" or "on-board" are used to indicate that a component is located within the hull of the vessel, i.e. not within the drive unit or its housing.

[0008] According to a first aspect of the invention, the invention relates to a hybrid marine drive unit arranged to be mounted to a transom on a marine vessel. The drive unit comprises a drive housing that is rigidly mounted on the transom, and is preferably, but not necessarily, submerged during operation. The drive unit further comprises a propelling unit rotatable about a vertical axis and mounted to a lower surface of the drive housing and a transmission with at least a vertical drive shaft located in the drive housing. The drive unit is an azimuthing pod drive removably attached to the transom. The vertical drive shaft is arranged to transmit drive torque from multiple sources of drive torque to the propelling unit for propelling the vessel. The vertical drive shaft is operably connected to at least one first source of drive torque arranged within the drive housing. In addition, the vertical drive shaft is also operably connected to a horizontal output shaft extending into the drive housing through the transom, wherein the horizontal output shaft is connectable to a second source of drive torque.

[0009] The first source of drive torque is preferably an electric motor with an independently excited rotor, wherein the rotor is arranged to be freewheeling when its excitation current is deactivated to demagnetize the rotor. A non-exhaustive list of suitable electric motors comprises polyphase synchronous motors, switched reluctance motors or synchronous reluctance motors.

[0010] The vertical drive shaft is operably connected to at least one first source of drive torque in the form of an electric motor arranged within the drive housing. According to one example, an electric motor with a vertical output shaft can be operably connected to the upper end of the vertical drive shaft. According to this example, the electric motor comprises a vertical output shaft drivingly connected to the vertical drive shaft extending directly into the propelling unit. For this electric motor, switching between a connected torque transmitting state and a disconnected freewheeling state relative to the vertical drive shaft is achieved by demagnetizing its rotor. This allows the vertical drive shaft to rotate without resistance from the electric motor, for instance, when propelling the vessel using the second source of drive torque only.

[0011] One or more additional sources of drive torque can be operably connected to the vertical drive shaft by a suitable gear unit. The gear unit can comprise a number of gears, such as bevel gears, wherein each gear is associated with a horizontal driving input shaft from a first source of drive torque or a driven output shaft from the second source of drive torque. Preferably, a single common gear unit is used for this purpose. The gears are preferably switchable between a connected, torque transmitting state and a disconnected, freewheeling state relative to their respective shaft. For additional first sources of drive torque comprising electric motors switching can be achieved by demagnetizing the rotor of the respective motor. According to a further example the at least one first source of drive torque comprises an electric motor with a vertical output shaft, as described above, and at least one electrical motor with a horizontal output shaft which can be operably connected to the gear unit. According to a further example the at least one first source of drive torque comprises at least one electrical motor with a horizontal output shaft which can be operably connected to the gear unit.

[0012] The drive unit is part of a hybrid driveline, wherein a first source of drive torque is an electric motor and a second source of drive torque can be an internal combustion engine. Consequently, the vertical drive shaft is operably connected to a second source of drive torque in the form of an internal combustion engine. The horizontal output shaft from the second source of drive torque is operably connected to the vertical drive shaft via the common gear unit. A separate clutch is provided for disconnecting the second source of drive torque from the gear unit during electrical operation of the drive unit. This clutch can be a friction clutch located adjacent the second source of drive torque within the hull of the vessel. Preferably, the second source of drive torque is operably connected to the vertical drive shaft via the gear unit comprising multiple bevel gears in driving connection. The at least one electric motor is operably connected directly to the vertical drive shaft and/or indirectly via the gear unit, as described above.

[0013] The horizontal output shafts from the internal combustion engine and/or at least one electric motor are operably connected to the vertical drive shaft via the common gear unit. The common gear unit can comprise a bevel gear mounted on each of the horizontal output shafts from the one or more electric motors and the internal combustion engine. Each driving bevel gear is operably connected with a pair of driven opposed bevel gears operatively connectable to the vertical drive shaft. When driven, the bevel gear on either one of the driving horizontal shafts will drive both the opposed bevel gears. The bevel gears on the vertical drive shaft are provided with controllable actuators allowing each gear to be placed in driving connection with the vertical drive shaft in turn. For the second source of drive torque one bevel gear is connected for forward propulsion and the opposite bevel gear is connected for reverse propulsion. Alternatively, both bevel gears can rotate freely relative to the vertical drive shaft.

[0014] Switching the bevel gears between a connected torque transmitting state and a disconnected freewheeling state relative to the vertical drive shaft is achieved by actuation or deactuation of a suitable controllable actuator in the form of a mechanical actuator or a fluid (hydraulically or pneumatically) operated clutch. An example of a suitable clutch is a wet or dry multi-plate clutch, also termed lamella clutch. Hence, torque transmission from each drive source is controllable between its connected and disconnected states by a corresponding actuator mounted adjacent the respective gear, preferably within the gear unit.

[0015] As described above, the marine drive unit comprises a propelling unit, such as a propeller, impeller or pod drive mounted to the lower surface of the drive housing. The propelling unit is arranged to be rotatable relative to the lower surface of the drive housing by a steering system in order to steer the vessel. The steering arrangement is located in the drive housing and comprises a steering system with a control unit and a steering drive unit for rotating the propelling unit about its vertical axis. The steering drive unit can comprise an electric motor. The propelling unit can comprise counter rotating forward facing propellers in the form of an azimuthing pod.

[0016] The drive housing can comprise a control unit and power electronics controller (PEC) for the at least one electric motor and for the steering arrangement. The outer enclosure for the drive housing provides a thermal mass to absorb the heat generated by the electric motor or the power electronics. In operation, the drive housing is immersed in water and the water provides effective convection cooling. The electric motor is connected to the PEC, which supplies current to the at least one electric motor from an energy storage, such as a high voltage battery pack via a propulsion voltage system comprising high voltage DC buses and a high voltage junction box. The high voltage junction box can also be used for joining and distributing high voltage buses to a number of different electrical components on-board the vessel. The battery pack can comprise a separate power electronics controller (PEC) and an electronic controller for calibrating and charging the battery pack. Power electronics controllers of this type are known in the art and will not be described in further detail here.

[0017] According to a further example, the drive housing can comprise a closed coolant and lubrication circuit for the transmission, including the gear unit and propeller unit, and the at least one electric motor. The drive housing can comprise a reservoir for a liquid lubricant and coolant. The closed coolant and lubrication circuit comprises a pump, a supply conduit connected to conduits for the electric motors and the transmission, and a return conduit connected to the reservoir. The pump is preferably, but not necessarily, located in the reservoir. The provision of a closed coolant and lubrication circuit allows the drive unit to be cooled without the use of water from the surrounding body of water. This is a particular advantage if the vessel is operated in saline or polluted waters. A further advantage is that the same system can be used for lubrication, wherein separate pumps and circuits for cooling and lubrication can be dispensed with, which provides a reduction of both cost and space requirement.

[0018] According to a second aspect of the invention, the invention relates to a marine vessel with a hybrid driveline comprising multiple sources of drive torque to propel the vessel, wherein the vessel is provided with at least one marine drive unit as described above. The at least one drive unit comprises at least one electric motor arranged within a drive housing and that the drive unit is operatively connected to an internal combustion engine arranged within the hull of the vessel. Exhaust from the internal combustion engine can be discharged through a suitable port through the hull or below the waterline through the propelling unit.

[0019] The drive unit according to the invention provides a way to mount a pod drive with a hybrid driveline without requiring significant modifications of a marine vessel intended for stern drive applications. In most cases the outer drive unit can be advantageously provided with a drive housing having the same or approximately the same shape and size as conventional stern drive housings. Further, the interface for mounting a pod drive and its steering gear connections to the transom can be maintained. For marine vessel intended for pod drive applications the invention eliminates the need for a sizable opening through the lower surface of the hull which is required for most types of pod drives, such as an IPS © pod drive manufactured by Volvo Penta. Further, by mounting the electric motors in the outer drive housing, it is possible to provide a hybrid drive unit without taking up space for electric motors or the pod drive itself within the hull. The provision of one or more on-board battery packs can be achieved without taking up accommodation space. The electric motor/-s and the inboard engine can drive the propellers together, independently or in variable combinations in response to different torque and power demands whereby the efficiency of the drive unit is improved. By allowing independent operation of at least a single motor the arrangement provides a redundancy for the drive unit and ensures that the vessel can be operated even if the engine or one or more electric motors are inoperable.

[0020] Further advantages and advantageous features of the invention are disclosed in the following description and in the dependent claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] With reference to the appended drawings, below follows a more detailed description of embodiments of the invention cited as examples. In the drawings:

- Fig.1 shows a lower perspective view of a schematically illustrated vessel comprising a pair of drive units;
- Fig.2 shows a schematic side view of a driveline according to a first example;
- Fig.3 shows a schematic side view of a driveline according to a second example;
- Fig.4 shows a schematic side view of a driveline according to a third example;
- Fig.5 shows a schematic transmission for the driveline in Figure 2;
- Fig.6 shows a schematic transmission for the driveline in Figure 3; and
- Fig.7 shows a schematic transmission for the driveline in Figure 4.

DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS OF THE INVENTION

[0022] Figure 1 shows a lower perspective view of a schematically illustrated marine vessel 100 comprising two marine drive units 103, 103' according to the invention. In this example, the marine drive units 103, 103' are identical and only one will be described in further detail below. The marine drive units 103, 103' are mounted to a transom 102 on the vessel 100. Each marine drive unit 103, 103' comprises an upper and a lower unit, wherein the upper unit is a drive housing 104, 104' rigidly mounted on the transom 102. The lower unit is a propelling unit 105, 105' rotatable about a vertical axis and mounted to a lower surface 106, 106' of each drive housing 104, 104'. The schematically indicated marine drive units 103, 103' in Figure 1 are preferably located below the waterline of the vessel hull 101. The example shown in Figure 1 shows propelling units in the form of steerable pods which comprise twin forward facing, pulling propellers 107, 107'. As will be described below, alternative propelling units can be employed within the scope of the invention.

[0023] The marine drive units in Figure 1 are controllable by a control means (not shown) such as a throttle lever located at an operating position on-board the vessel. The throttle lever can be connected to an electronic control unit (ECU) via suitable wiring, which ECU is connected to a source of energy, such as a battery pack or a fuel cell via additional wiring. Such an energy source is located within the hull of the vessel and can comprise a power electronic controller (PEC) and an electronic controller for calibrating and charging a battery pack. The throttle lever be used for controlling the first source of drive torque, such as at least one electric motor within the drive housing, and the second source of drive torque, such as an engine located within the hull of the vessel. The first and second sources of drive torque form a hybrid driveline and the sources can be operated individually or together. Electronic controllers of this type are known in the art and will not be shown or described in further detail here.

[0024] Figure 2 shows a cross-sectional side view of a drive unit 203 according to a first example shown in Figure 1. Figure 2 shows the drive unit 203 mounted to a transom 202 of a marine vessel (see Fig.1). The drive unit 203 comprises an upper drive housing 204, and a lower propelling unit 205, where the propelling unit 205 is rotatably mounted to a lower surface 206 of the drive housing 204 in order to steer the vessel. The drive housing 204 encloses a transmission comprising a vertical drive shaft 210 arranged transmit drive torque from at least one source of drive torque to a pair of forward-facing counter rotating propellers 207 on the propelling unit 205. The transmission further comprises a gear unit 213 operably connectable to an upper end of the vertical drive shaft 210. In Figure 2, a first source of drive torque is an electric motor 211 with a vertical output shaft 212 that is operably connected to the vertical drive shaft 210 directly through the gear unit 213. The electric motor 211 can be disconnected from the through shaft comprising the vertical drive shaft 210 and the vertical output shaft 212 by demagnetizing the rotor. A horizontal output shaft 220 is connected to a second source of drive torque in the form of an inboard ICE 221 located within the hull of the vessel (see Fig.2).

[0025] The gear unit 213 comprises a set of bevel gears 214, 215, 216 which are in constant driving contact with each other. Each bevel gear is associated with a respective driving or driven shaft 212, 210, 220 and is switchable between a connected state and a disconnected state for transferring torque to the vertical drive shaft 210. The bevel gear 216 is fixed to the horizontal output shaft 220 and is switchable between a driven state and a freewheeling state by a main clutch 224 adjacent the ICE 221. Each bevel gear 214, 215 on the vertical drive shaft 210 is controllable between its connected and disconnected states by a corresponding actuatable clutch 214', 215' mounted adjacent the respective bevel gear (see Fig. 5). Switching can be achieved by actuation or deactuation of a suitable controllable clutch or mechanical actuator. In the subsequent text switching is performed using wet or dry multi-plate clutches, or lamella clutches, hereafter referred to as "clutches". Lamella clutches of this type can be pneumatically or hydraulically actuated using a suitable source of fluid pressure. The design or control of such clutches is known in the art and will not be described in further detail here.

[0026] In Figures 2 and 6, the vertical output shaft 212 of the electric motor 211 passes through the gear unit 213. The gear unit 213 comprises an upper first bevel gear 214 arranged on the vertical output shaft 212 and a lower second bevel gear 215 arranged on the vertical drive shaft 210. The first and second bevel gears 214, 215 are in driving connection with the intermediate third bevel gear 216 arranged on the horizontal output shaft 220. The horizontal output shaft 220 is connected to a second source of drive torque in the form of an inboard ICE 221 located within the hull of the vessel (see Fig.1). The horizontal output shaft 220 passes through a seal 222 in the transom 202 and is fixed in a vibration absorbing bushing 223 supported by the ICE output shaft. The clutch 224 is provided between the horizontal output shaft 220 and the ICE crankshaft to control the rotation of the horizontal output shaft 220. The first and second bevel gears 214, 215 are freely rotatable about the vertical output shaft 212 and the vertical drive shaft 210, respectively, in their disconnected state. Similarly, the third bevel gear 216 is freely rotatable with the horizontal output shaft 220 when the clutch 224 adjacent the ICE221 in its disconnected state. The bevel gears 214, 215 are selectably connected to the vertical drive shaft 210 in order to transmit torque from the ICE 221 to the vertical drive shaft 210 and the propellers. In this way, the vertical drive shaft 210 can be operably connected to the horizontal output shaft 220 which extends out of the drive housing 204 through the transom 202.

[0027] In operation, the driveline can be operated in electric mode using the electric motor 211 rotating the vertical output shaft 212 and the vertical drive shaft 210 directly as shown in Figures 2 and 5 to drive the vessel in a forward direction. Figure 5 shows a schematic view of the transmission for the driveline in Figure 2. In the electric mode, the rotor of the electric motor 211 is magnetized and the bevel gears 214, 215 are disconnected from the vertical drive shaft 210. Propelling the vessel in a reverse direction is achieved by switching the direction of rotation of the electric motor 211.

[0028] Alternatively, the driveline can be operated in ICE mode, wherein the rotor (not shown) of the electric motor 211 is demagnetized making the vertical output shaft 212 freely rotatable relative to the motor. In the gear unit 213, the first bevel gear 214 is maintained disconnected while the second bevel gear 215 is connected to the vertical drive shaft 210 by actuation of the clutch 215'. At the same time, the third bevel gear 216 is driven by the horizontal output shaft 220 by actuation of the main clutch 224. The ICE 221 can then be operated to transmit torque to the horizontal shaft 220 and the vertical drive shaft 210 via the third bevel gear 216 and the second bevel gear 215, in order to propel the vessel in a forward direction. In order to propel the vessel in a reverse direction the main clutch 224 is deactuated. The second bevel gear 215 is then disconnected by deactuation of the clutch 215', while the first bevel gear 214 is connected to the vertical output shaft 212 by actuation of the clutch 214'. Subsequently, the third bevel gear 216 continues to be driven by the horizontal output shaft 220 by actuation of the main clutch 224. The ICE 221 can then be operated to transmit torque to the horizontal shaft 220 and the vertical drive shaft 210 via the third bevel gear 216 and the first bevel gear 214.

[0029] According to a further example, the driveline can be operated in a hybrid mode using the electric motor 211 and the ICE 221 together. In the hybrid mode, the gear unit 213 is operated in the same way as in the ICE mode described above, wherein the rotor of the electric motor 211 is magnetized so that the motor can be operated to drive the vertical output shaft 212 to assist the ICE 221. The direction of rotation of the electric motor 211 is selected to correspond with the direction of rotation of the currently connected first or second bevel gear 214, 215.

[0030] The propelling unit 205 contains a gearbox 208 operably connected to a lower end of the vertical drive shaft 210, which can be rotated as shown by the arrow A_1 to drive the counter rotating propellers 207. Gearboxes for driving counter-rotating shafts of this type are well known and will not be described in further detail.

[0031] The drive housing 204 further comprises a control unit and power electronics controller (PEC) 230 for the electric motor 211. The combined control unit and power electronics controller (PEC) 230 is also used for controlling a steering arrangement 240 described below. The outer enclosure for the drive housing 204 provides a thermal mass to absorb the heat generated by the electric motor 211 and the PEC 230. In operation, the drive housing 204 is immersed in water and the water provides effective convection cooling. The electric motor 211 is connected to the PEC 230, which supplies current to the electric motor 211 from an inboard energy storage (not shown). Control means such as a throttle and a steering means (not shown) are provided at an operator station on-board the vessel.

[0032] The propelling unit 205 is arranged to be rotatable relative to the lower surface 206 of the drive housing by a steering arrangement 240 in order to steer the vessel. The steering arrangement 240 is located in the drive housing comprises a steering system with a control unit and a steering drive unit for rotating the propelling unit about its vertical axis. The steering drive unit can comprise an electric motor. The steering drive unit drives a steering transmission comprising a pinon gear that drives a gear fixed to the propelling unit 205 about the central axis X of the vertical drive shaft 210 as indicated by the arrow A_2.

[0033] The drive housing 204 in Figure 2 further comprises a coolant and lubricant circuit 250. Figure 2 schematically indicates a closed coolant and lubrication circuit for the gear unit 213, the vertical drive shaft 210, the steering arrangement 240 and the electric motor 211. The closed coolant and lubrication circuit comprises a pump, a reservoir, a supply conduit connected to conduits for cooling the electric motor 211 and a conduit supplying the coolant/lubricant to the gear unit and steering arrangement. The provision of a closed coolant and lubrication circuit allows internal components to be cooled without using water from the surrounding body of water. As described above, the outer enclosure of the drive housing 204 can provide additional cooling by using it as a thermal mass to absorb the heat generated by the electric motor 211 and the PEC 230. The arrangement also allows the same system to be used for both cooling and lubrication.

[0034] Figure 3 shows a schematic side view of a driveline according to a second example. Figure 3 shows the drive unit 303 mounted to a transom 302 of a marine vessel (see Fig.1). The drive unit 303 comprises an upper drive housing 304, and a lower propelling unit 305, where the propelling unit 305 is rotatably mounted to a lower surface 306 of the drive housing 304 in order to steer the vessel. The drive housing 304 encloses a transmission comprising a vertical drive shaft 310 arranged to transmit drive torque from at least one source of drive torque to a pair of forward-facing counter rotating propellers 307 on the propelling unit 305. The transmission further comprises a gear unit 313 operably connectable to an upper end of the vertical drive shaft 310, which passes directly through the gear unit 313. In Figures 3 and 6, a first source of drive torque is an electric motor 311 with a horizontal output shaft 312 that is operably connectable to the vertical drive shaft 310 directly through the gear unit 313. Figure 6 shows a schematic view of the transmission for the driveline in Figure 3. The electric motor 311 can be disconnected from the horizontal output shaft 312 and the through shaft comprising the vertical drive shaft 310 and a vertical support shaft 318 by demagnetizing the rotor. A horizontal output shaft 320 is connected to a second source of drive torque in the form of an inboard internal combustion engine (ICE) 321 located within the hull of the vessel (see Fig. 3 or 1).

[0035] The gear unit 313 comprises a set of bevel gears 315, 316, 317, 319 which are in constant driving contact with each other. Each bevel gear is associated with a respective driving or driven shaft 310, 320, 312, 318 and is switchable between a connected state and a disconnected state for transferring torque to the vertical drive shaft 210. The bevel gear 316 fixed to the horizontal output shaft 320 from the ICE 321 is switchable between a driven state and a freewheeling state by a main clutch 324 adjacent the ICE 321. The bevel gear 317 fixed to the horizontal output shaft 312 from the electric motor 311 is switchable between a driven state and a freewheeling state by magnetizing and demagnetizing the rotor of the electric motor 311. Each bevel gear 319, 315 on the vertical drive shaft 310 is controllable between its connected and disconnected states by a corresponding actuatable clutch 319', 315' mounted adjacent the respective bevel gear. Switching the bevel gears 319, 315 can be achieved by actuation or deactuation of a suitable controllable clutch or mechanical actuator. In the subsequent text switching is performed using wet multi-plate clutches, or lamella clutches, hereafter referred to as "clutches". Hence, each bevel gear 319, 315 on the vertical drive shaft 310 is controllable between its connected and disconnected states by a corresponding actuatable clutch 319', 315' mounted adjacent the respective bevel gear.

[0036] With reference to Figure 6, the vertical drive shaft 310 passes directly upwards through the gear unit 313 and exits as the upper supporting shaft 318. The gear unit 313 comprises an upper first bevel gear 319 and a lower second bevel gear 315 arranged on the vertical drive shaft 310. The first and second bevel gears 319, 315 are in driving connection with an intermediate third bevel gear 316 fixed to a first horizontal output shaft 320 connected to a main clutch 324 via a main clutch 324. The first and second bevel gears 319, 315 are further in driving connection with an intermediate fourth bevel gear 317 arranged on a second horizontal output shaft 312. The fourth bevel gear 317 is arranged opposite the third bevel gear 316 coaxially with the first horizontal output shaft 320. The second horizontal output shaft 312 is connected to a first source of drive torque in the form of an electric motor 311. The first horizontal output shaft 320 is connected to a second source of drive torque in the form of an inboard ICE 321 located within the hull of the vessel (see Fig.1). The first horizontal output shaft 320 passes through a seal 322 in the transom 302 and is fixed in a vibration absorbing bushing 323 supported by the ICE output shaft. A main clutch 324 is provided between the first horizontal output shaft 320 and the ICE crankshaft to control the rotation of the first horizontal output shaft 320. The first and second bevel gears 319, 315 are freely rotatable about the supporting shaft 318 and the vertical drive shaft 310, respectively, in their disconnected state. Similarly, the third bevel gear 316 is freely rotatable with the first horizontal output shaft 320 in its disconnected state. The fourth bevel gear 317 is freely rotatable about the second horizontal output shaft 312 with the main clutch 324 in its disconnected state. The upper and lower bevel gears 319, 315 are selectably connected to the vertical drive shaft 310 in order to transmit torque from the electric motor 311 and/or the ICE 321 to the vertical drive shaft 310 and the propellers. In this way, the vertical drive shaft 310 can be operably connected to the first horizontal output shaft 320, which extends out of the drive housing 304 through the transom 302, and to the second horizontal output shaft 312.

[0037] In operation, the driveline can be operated in electric mode using the electric motor 311 for rotating the horizontal second output shaft 312 and the vertical drive shaft 310 to drive the vessel in a forward direction. In this mode, the third bevel gear 316 is allowed to rotate freely by disconnection of the main clutch 324. In the gear unit 313, the first bevel gear 319 is maintained disconnected while the second bevel gear 315 is connected to the vertical drive shaft 310 by actuation of the lower clutch 315'. At the same time, the rotor of the electric motor 311 is magnetized allowing it to be operated to transmit torque to the second horizontal output shaft 312 and the vertical drive shaft 310 via the fourth bevel gear 317 and the second bevel gear 315, in order to propel the vessel in a forward direction. Propelling the vessel in reverse direction is achieved by switching the direction of rotation of the electric motor 311.

[0038] Alternatively, the driveline can be operated in ICE mode, wherein the rotor (not shown) of the electric motor 311 is demagnetized making the second horizontal output shaft 312 freely rotatable. In the gear unit 313, the first bevel gear 319 is maintained disconnected while the second bevel gear 315 is connected to the vertical drive shaft 310 by actuation of the clutch 315'. At the same time, the third bevel gear 316 and the first horizontal output shaft 320 are operatively connected to the ICE 321 by actuation of the main clutch 324. The ICE 321 can then be operated to transmit torque to the horizontal shaft 320 and the vertical drive shaft 310 via the third bevel gear 316 and the second bevel gear 315, in order to propel the vessel in a forward direction. In order to propel the vessel in a reverse direction the main clutch 324 is deactuated. The second bevel gear 315 is then disconnected by deactuation of the clutch 315', while the first bevel gear 319 is connected to the vertical support shaft 318 by actuation of the clutch 319'. Subsequently, the third bevel gear 316 continues to be driven the horizontal output shaft 320 by actuation of the main clutch 324. The ICE 321 can then be operated to transmit torque to the horizontal shaft 320 and the vertical drive shaft 310 via the third bevel gear 316 and the first bevel gear 319.

[0039] According to a further example, the driveline can be operated in a hybrid mode using the electric motor 311 and the ICE 321 together. In the hybrid mode, the gear unit 313 is operated in the same way as in the ICE mode described above, wherein the rotor of the electric motor 311 is magnetized so that the motor can be operated to drive the vertical output shaft 312 to assist the ICE 321. The direction of rotation of the electric motor 311 is selected to correspond with the direction of rotation of the currently connected first or second bevel gears 314, 315 selected for forward or reverse operation of the vessel using the ICE 321.

[0040] The propelling unit 305 contains a gearbox 308 operably connected to a lower end of the vertical drive shaft 310, which can be rotated as shown by the arrow A_1 to drive the counter rotating propellers 307. Gearboxes for driving counter-rotating shafts of this type are well known and will not be described in further detail.

[0041] The drive housing 304 further comprises a control unit and power electronics controller (PEC) 330 for the electric motor 311. The combined control unit and power electronics controller (PEC) 330 is also used for controlling a steering arrangement 340 described below. The outer enclosure for the drive housing 304 provides a thermal mass to absorb the heat generated by the electric motor 311 and the PEC 330. In operation, the drive housing 304 is immersed in water and the water provides effective convection cooling. The electric motor 311 is connected to the PEC 330, which supplies current to the electric motor 311 from an inboard energy storage (not shown). Control means such as a throttle and a steering means (not shown) are provided at an operator station on-board the vessel.

[0042] The propelling unit 305 is arranged to be rotatable relative to the lower surface 306 of the drive housing by a steering arrangement 340 in order to steer the vessel. The steering arrangement 340 is located in the drive housing comprises a steering system with a control unit and a steering drive unit for rotating the propelling unit about its vertical axis. The steering drive unit can comprise an electric motor. The steering drive unit drives a steering transmission comprising a pinon gear that drives a gear fixed to the propelling unit 305 about the central axis X of the vertical drive shaft 310 as indicated by the arrow A_2.

[0043] The drive housing 304 in Figure 3 further comprises a coolant and lubricant circuit of the same type as described with reference to Figure 2 above.

[0044] Figure 4 shows a schematic side view of a driveline according to a third example. Figure 4 shows the drive unit 403 mounted to a transom 402 of a marine vessel (see Fig.1). The drive unit 403 comprises an upper drive housing 404, and a lower propelling unit 405, where the propelling unit 405 is rotatably mounted to a lower surface 406 of the drive housing 404 in order to steer the vessel. The drive housing 404 encloses a transmission comprising a vertical drive shaft 410 arranged to transmit drive torque from at least one source of drive torque to a pair of forward-facing counter rotating propellers 407 on the propelling unit 405. The transmission further comprises a gear unit 413 operably connected to an upper end of the vertical drive shaft 410. In Figures 4 and 7, one first source of drive torque is an electric motor 411 with a vertical output shaft 412 that is operably connectable to the vertical drive shaft 410 directly through the gear unit 413. A further first source of drive torque is a second electric motor 417 with a horizontal output shaft 418 that is operably connectable to the vertical drive shaft 410 via the gear unit 413. Figure 7 shows a schematic view of the transmission for the driveline in Figure 4. The electric motors 411, 417 can be disconnected from their respective shaft 412, 418 and the through shaft comprising the vertical drive shaft 410 by demagnetizing their respective rotors. A horizontal output shaft 320 is connected to a second source of drive torque in the form of an inboard ICE 321 located within the hull of the vessel (see Fig. 4 and 1).

[0045] The gear unit 413 comprises a set of bevel gears 414, 415, 416, 419 which are in constant driving contact with each other. Each bevel gear is associated with a respective driving or driven shaft 412, 410, 420, 418 and is switchable between a connected state and a disconnected state for transferring torque to the vertical drive shaft 410.

The bevel gear 416 fixed to the horizontal output shaft 420 from the ICE 421 is switchable between a driven state and a freewheeling state by a main clutch 424 adjacent the ICE 421. The bevel gear 419 fixed to the horizontal output shaft 418 from the electric motor 417 is switchable between a driven state and a freewheeling state by magnetizing and demagnetizing the rotor of the electric motor 417. Each bevel gear 414, 415 on the vertical drive shaft 410 is controllable between its connected and disconnected states by a corresponding actuatable clutch 414', 415' mounted adjacent the respective bevel gear. Switching the bevel gears 414, 415 can be achieved by actuation or deactuation of a suitable controllable clutch or mechanical actuator. In the subsequent text switching is performed using wet multi-plate clutches, or lamella clutches, hereafter referred to as "clutches". Hence, each bevel gear 414, 415 is controllable between its connected and disconnected states by a corresponding actuatable clutch 414', 415' mounted adjacent the respective bevel gear.

[0046] With reference to Figure 7, the vertical output shaft 412 of the electric motor 411 passes directly through the gear unit 413. The gear unit 413 comprises an upper first bevel gear 414 arranged on the vertical output shaft 412 and a lower second bevel gear 415 arranged on the vertical drive shaft 410. The first and second bevel gears 414, 415 are in driving connection with an intermediate third bevel gear 416 arranged on a first horizontal output shaft 420 connected to a main clutch 424 via a main clutch 424. The first and second bevel gears 414, 415 are further in driving connection with an intermediate fourth bevel gear 419 arranged on a second horizontal output shaft 418. The fourth bevel gear 419 is arranged opposite the third bevel gear 416 coaxially with the first horizontal output shaft 420. The second horizontal output shaft 418 is connected to an optional further source of drive torque in the form of a second electric motor 417. The first horizontal output shaft 420 is connected to a second source of drive torque in the form of an inboard ICE 421 located within the hull of the vessel (see Fig.1). The first horizontal output shaft 420 passes through a seal 422 in the transom 402 and is fixed in a vibration absorbing bushing 423 supported by the ICE output shaft. A clutch 424 is provided between the first horizontal output shaft 420 and the ICE crankshaft to control the rotation of the first horizontal output shaft 420. The first and second bevel gears 414, 415 are freely rotatable about the vertical output shaft 412 and the vertical drive shaft 410, respectively, in their disconnected state. Similarly, the third bevel gear 416 is freely rotatable about the first horizontal output shaft 420 in its disconnected state. The fourth bevel gear 419 is freely rotatable about the second horizontal output shaft 418 in its disconnected state. The upper and lower bevel gears 414, 415 are selectably connected to their respective shaft in order to transmit torque from the ICE 421 and/or from the second electric motor 417 to the vertical drive shaft 410 and the propellers. In this way, the vertical drive shaft 410 can be operably connected to the first horizontal output shaft 420 which extends out of the drive housing 404 through the transom 402.

[0047] In operation, the driveline can be operated in electric mode using the electric motor 411 rotating the output shaft 412 and the vertical drive shaft 410 directly to drive the vessel in a forward direction, as described for Figures 4 and 6. The second electric motor 417 can be operated together with, or instead of the electric motor 411 in electric mode. In this mode, the third bevel gear 416 is allowed to rotate freely by disconnection of the main clutch 424. This is achieved by maintaining the first bevel gear 414 disconnected. At the same time, or alternatively, the fourth bevel gear 419 is connected to the second horizontal output shaft 418 by actuation of the clutch 419' and the second bevel gear 415 is connected to the vertical drive shaft 410 by actuation of the clutch 415'. Propelling the vessel in reverse direction is achieved by switching the direction of rotation of the electric motors 411, 417. The provision of two electric motors provides a degree of redundancy in case one motor should malfunction.

[0048] Alternatively, the driveline can be operated in ICE mode, wherein the rotors (not shown) of the electric motors 411, 417 are demagnetized making the vertical output shaft 412 and the second horizontal output shaft 418 freely rotatable. In the gear unit 413, the first bevel gear 414 is maintained disconnected while the second bevel gear 415 is connected to the vertical drive shaft 410 by actuation of the clutch 415'. At the same time, the third bevel gear 416 and the first horizontal output shaft 420 are operatively connected to the ICE 421 by actuation of the main clutch 424. The ICE 421 can then be operated to transmit torque to the horizontal shaft 420 and the vertical drive shaft 410 via the third bevel gear 416 and the second bevel gear 415, in order to propel the vessel in a forward direction. In order to propel the vessel in a reverse direction the main clutch 424 is deactuated. The second bevel gear 415 is then disconnected by deactuation of the clutch 415', while the first bevel gear 414 is connected to the vertical output shaft 412 by actuation of the clutch 414'. Subsequently, the third bevel gear 416 continues to be driven by the horizontal output shaft 420 by actuation of the main clutch 424. The ICE 421 can then be operated to transmit torque to the horizontal shaft 420 and the vertical drive shaft 410 via the third bevel gear 416 and the first bevel gear 414.

[0049] According to a further example, the driveline can be operated in a hybrid mode using the electric motors 411, 417 and the ICE 421 together. In the hybrid mode, the gear unit 413 is operated in the same way as in the ICE mode described above, wherein the rotor of the electric motor 411 and/or the electric motor 417 is magnetized so that the motors can be operated to drive the vertical output shaft 412 to assist the ICE 421. The direction of rotation of the electric motors 411, 417 is selected to correspond with the direction of rotation of the currently connected first or second bevel gears 414, 415 selected for forward or reverse operation of the vessel using the ICE 421.

[0050] The propelling unit 405 contains a gearbox 408 operably connected to a lower end of the vertical drive shaft 410 , which can be rotated as shown by the arrow A_1 to drive the counter rotating propellers 407. Gearboxes for driving counter-rotating shafts of this type are well known and will not be described in further detail.

[0051] The drive housing 404 further comprises a control unit and power electronics controller (PEC) 430 for the electric motor 411. The combined control unit and power electronics controller (PEC) 430 is also used for controlling a steering arrangement 440 described below. The outer enclosure for the drive housing 404 provides a thermal mass to absorb the heat generated by the electric motor 411 and the PEC 430. In operation, the drive housing 404 is immersed in water and the water provides effective convection cooling. The electric motor 411 is connected to the PEC 430, which supplies current to the electric motor 411 from an inboard energy storage (not shown). Control means such as a throttle and a steering means (not shown) are provided at an operator station on-board the vessel.

[0052] The propelling unit 405 is arranged to be rotatable relative to the lower surface 406 of the drive housing by a steering arrangement 440 in order to steer the vessel. The steering arrangement 440 is located in the drive housing comprises a steering system with a control unit and a steering drive unit for rotating the propelling unit about its vertical axis. The steering drive unit can comprise an electric motor. The steering drive unit drives a steering transmission comprising a pinon gear that drives a gear fixed to the propelling unit 405 about the central axis X of the vertical drive shaft 410 as indicated by the arrow A_2.

[0053] The drive housing 404 in Figure 4 further comprises a coolant and lubricant circuit of the same type as described with reference to Figure 2 above.

[0054] It is to be understood that the present invention is not limited to the embodiments described above and illustrated in the drawings; rather, the skilled person will recognize that many changes and modifications may be made within the scope of the appended claims.

Claims

1. Hybrid marine drive unit (103; 203; 303; 403) mounted to a transom (102; 202; 302; 402), which drive unit (103; 203; 303; 403) comprises

   - a drive housing (104; 204; 304; 404) rigidly mounted on the transom (102; 202; 302; 402),
   - a propelling unit (105; 205) rotatable about a vertical axis (X) and mounted to a lower surface (106; 206; 306; 406) of the drive housing (104; 204; 304; 404), and
   - a transmission with at least a vertical drive shaft (210; 310; 410) located in the drive housing (104; 204; 304; 404) and extending into the propelling unit (105; 205; 305; 405), which vertical drive shaft is arranged to transmit drive torque from at least one of multiple sources of drive torque (111, 121; 211, 221; 311, 321; 411, 417, 421),

   wherein:

   - the drive unit (103; 203; 303; 403) is an azimuthing pod drive removably attached to the transom (102; 202; 302; 402)
   - the vertical drive shaft (210; 310; 410) is operably connected to at least one first source of drive torque (111; 211; 311; 411, 417) arranged within the drive housing (104; 204; 304; 404), and that

- the vertical drive shaft (210; 310; 410) is operably connected to a horizontal output shaft (220; 320; 420) extending into the drive housing (104; 204; 304; 404) through the transom (102; 202; 302; 402), wherein the horizontal output shaft (220; 320; 420) is connectable to a second source of drive torque (121; 221; 321; 421).

2. Hybrid marine drive unit according to claim 1, wherein the first source of drive torque is an electric motor (111; 211; 311; 411, 417) with an independently excited rotor; wherein the rotor is arranged to be freewheeling when its excitation current is deactivated.

3. Hybrid marine drive unit according to claim 2, wherein the at least one electric motor (111; 211; 311; 411, 417) is a polyphase synchronous motor, a switched reluctance motor or a synchronous reluctance motor.

4. Hybrid marine drive unit according to claim 1 or 2, wherein the at least one first source of drive torque (111; 211; 411) is operably connected to the upper end (212; 412) of the vertical drive shaft (210; 410) above a gear unit (213; 413). (Figure 2 & 6)

5. Hybrid marine drive unit according to any one of claims 1-3, wherein the at least one electric motor (111; 211; 411) is directly connected to the propelling unit (105; 205; 405) via the vertical drive shaft (210; 410).

6. Hybrid marine drive unit according to claim 1 or 2, wherein the at least one electric motor is operably connected to the vertical drive shaft (310) by a gear unit (313).

7. Hybrid marine drive unit according to claim 6, wherein the first and second sources of drive torque are operably connected to the vertical drive shaft (310) via the gear unit (313) .

8. Hybrid marine drive unit according to any one of claims 1-7, wherein the horizontal output shaft (220; 320; 420) is operably connected to the vertical drive shaft (210; 310; 410) via the gear unit (213; 313; 413).

9. Hybrid marine drive unit according to any one of claims 3-8, wherein the gear unit (213; 313; 413) comprises opposing bevel gears operatively connected to the horizontal output shaft (220; 320; 420), wherein each bevel gear is connected or disconnected to the vertical drive shaft (210) by a controllable actuator.

10. Hybrid marine drive unit according to claim 9, wherein the controllable actuator is a clutch.

11. Hybrid marine drive unit according to any one of claims 1-9, wherein each source of drive torque is arranged to drive the vertical drive shaft (210) independently or in combination.

12. Hybrid marine drive unit according to any one of claims 1-11, wherein the drive housing (104; 204) comprises a control unit and power electronic controller (240) for the at least one electric motor.

13. Hybrid marine drive unit according to any one of claims 1-11, wherein the drive housing (104; 204) comprises a steering system (230) with a control unit and a steering drive unit (230) for rotating the propelling unit (105; 205) about its vertical axis (X).

14. Marine vessel with a hybrid driveline comprising multiple sources of drive torque (111, 121; 211, 221; 311, 321; 411, 417, 421) to propel the vessel, wherein the vessel is provided with at least one hybrid marine drive unit (103; 203; 303; 403) according to claim 1.

15. Marine vessel according to claim 14, wherein the at least one hybrid marine drive unit (103; 203) comprises at least one electric motor (111; 211; 311; 411, 417) arranged within a drive housing (104; 204; 304; 404) and that the drive unit (103; 203) is operatively connected to an internal combustion engine (121; 221; 321; 421) arranged within the hull (101) of the vessel (100).

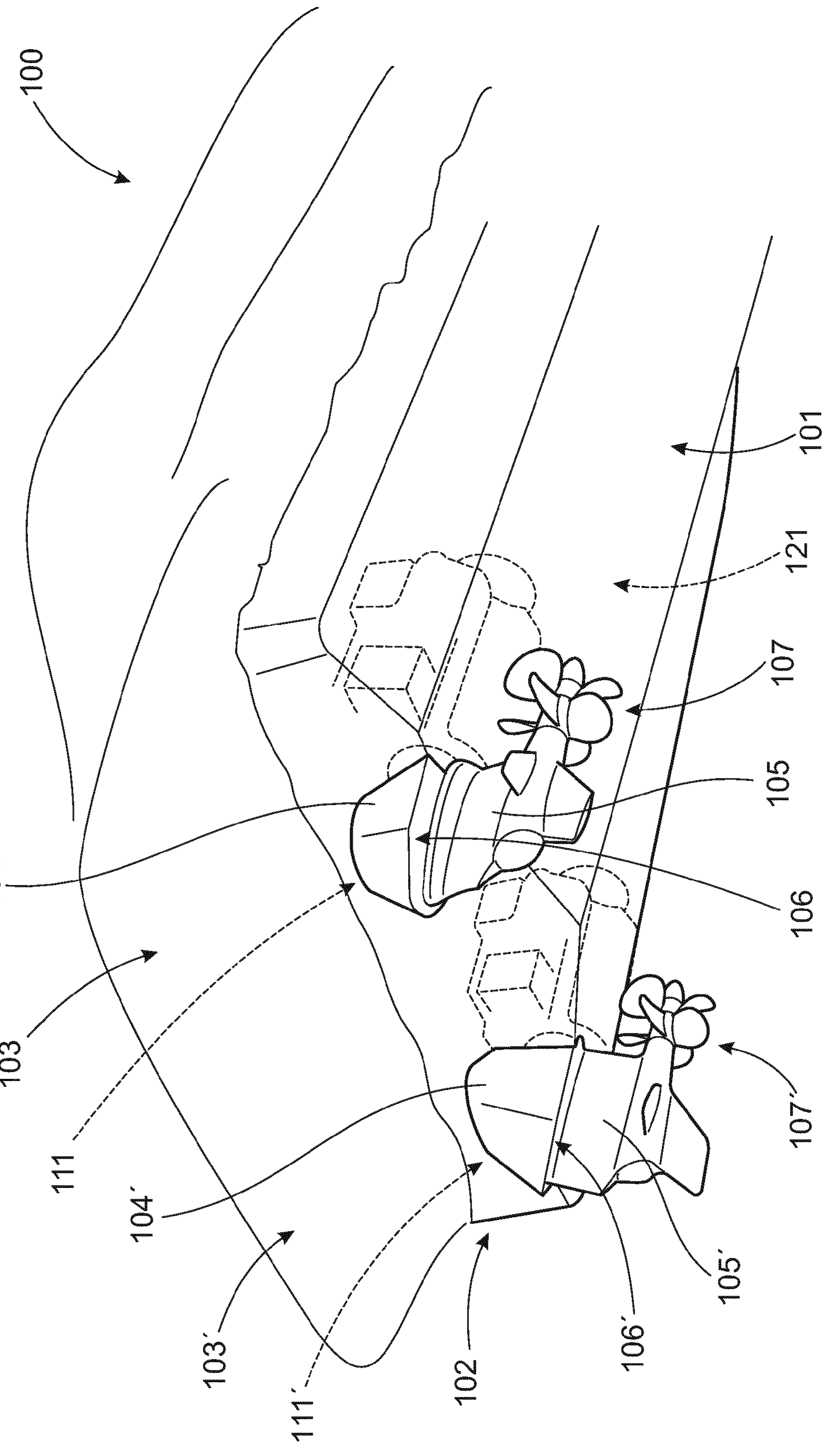

Fig.1

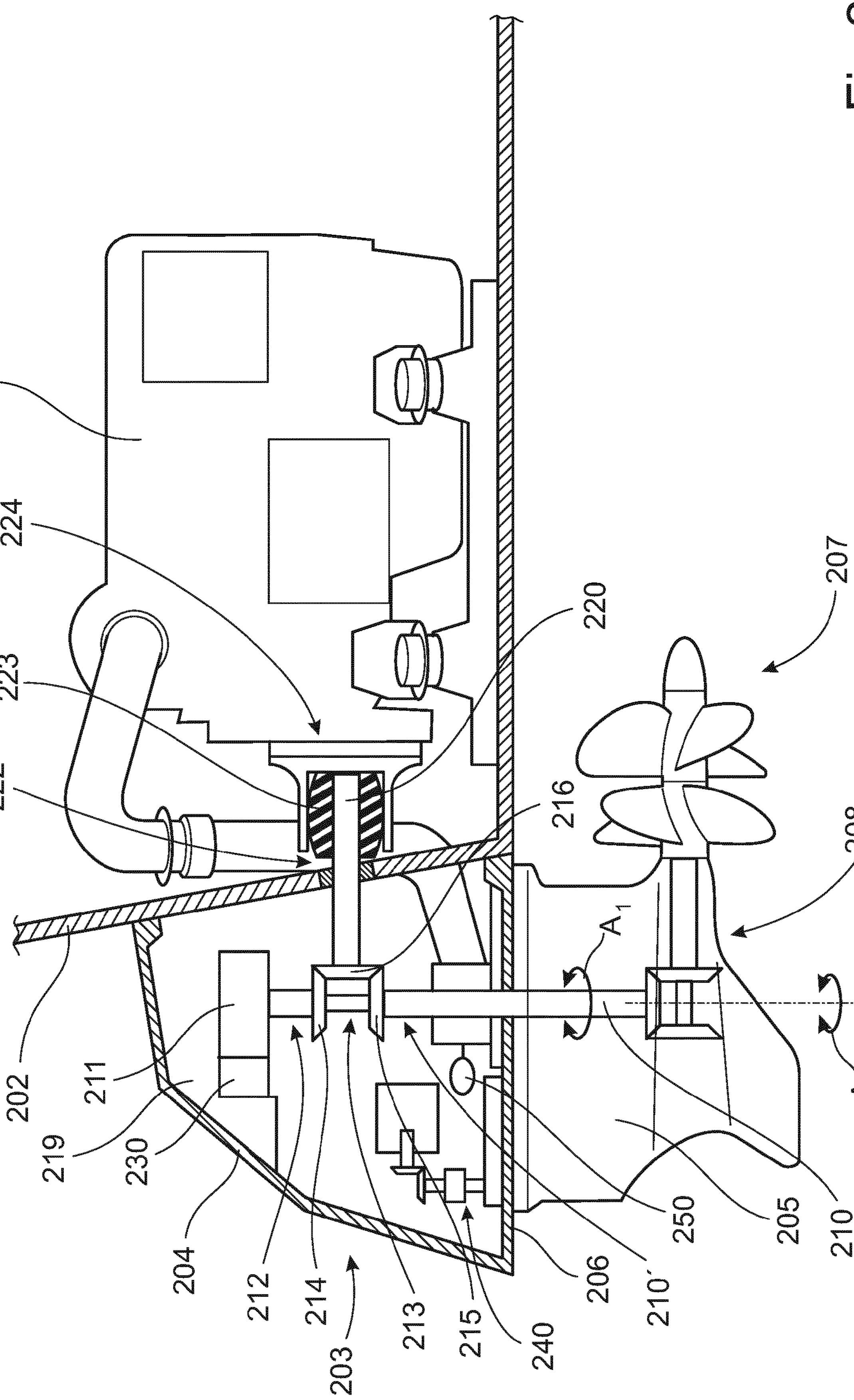
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Fig.2

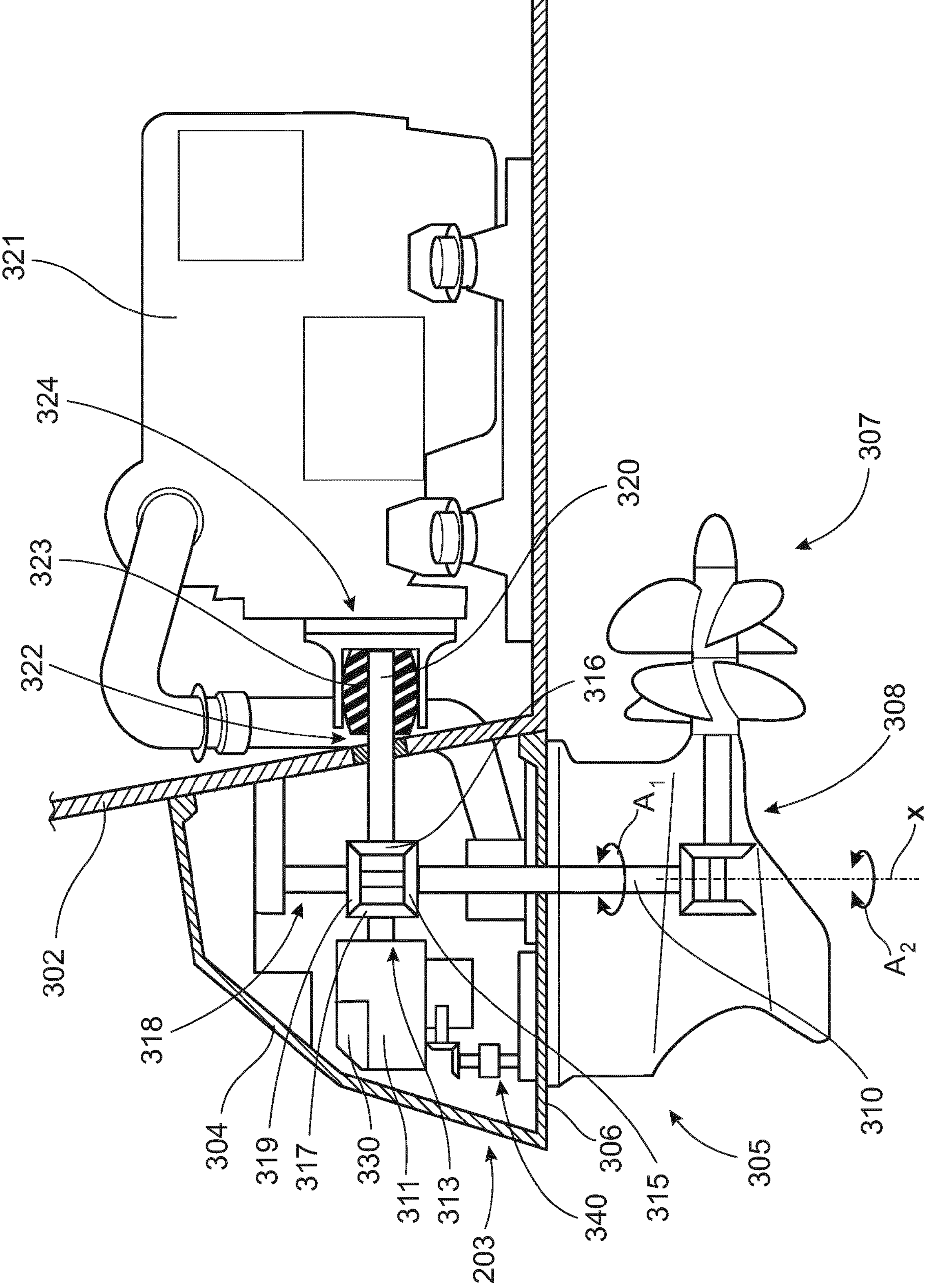
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Fig.3

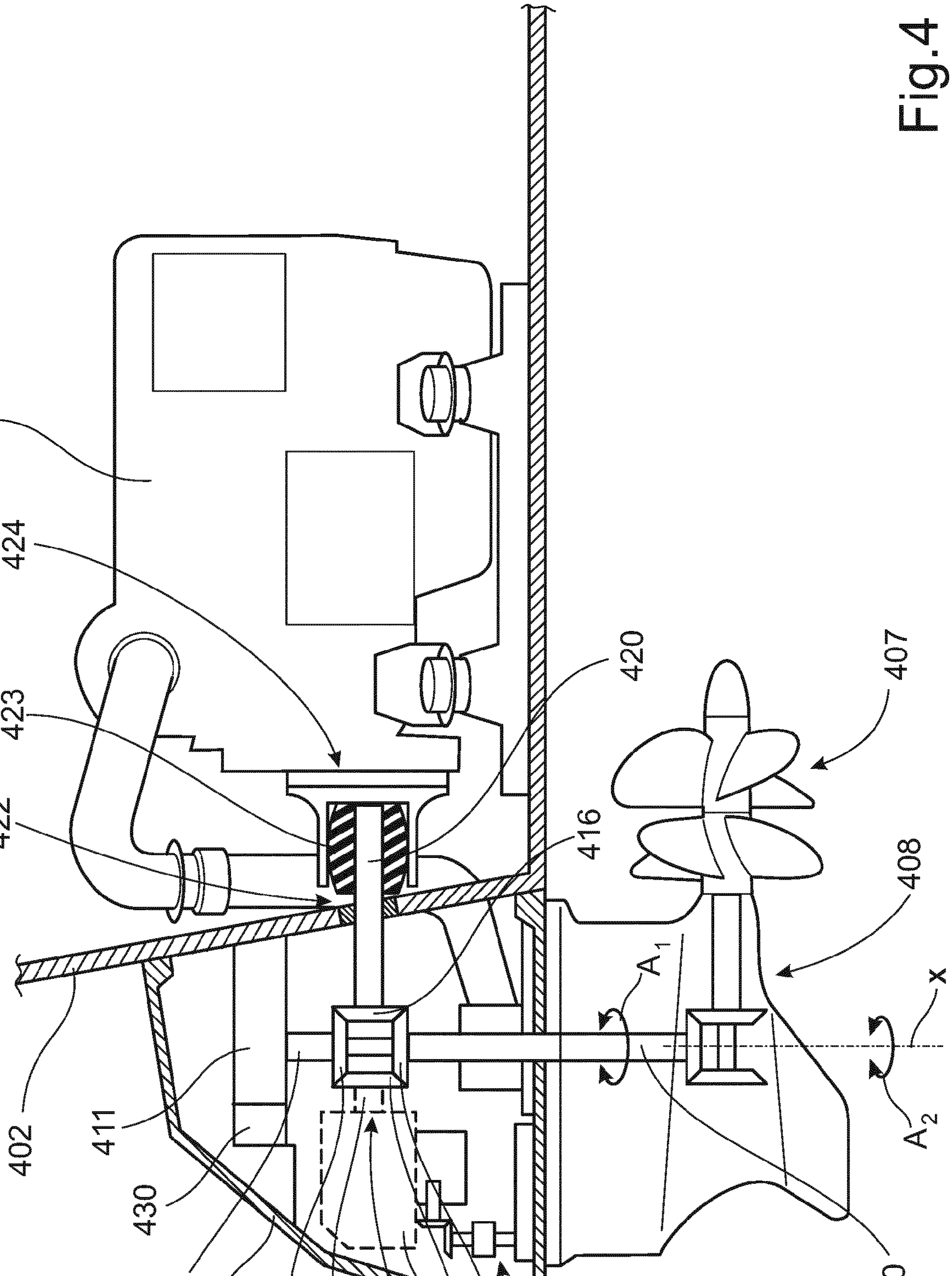
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Fig.4

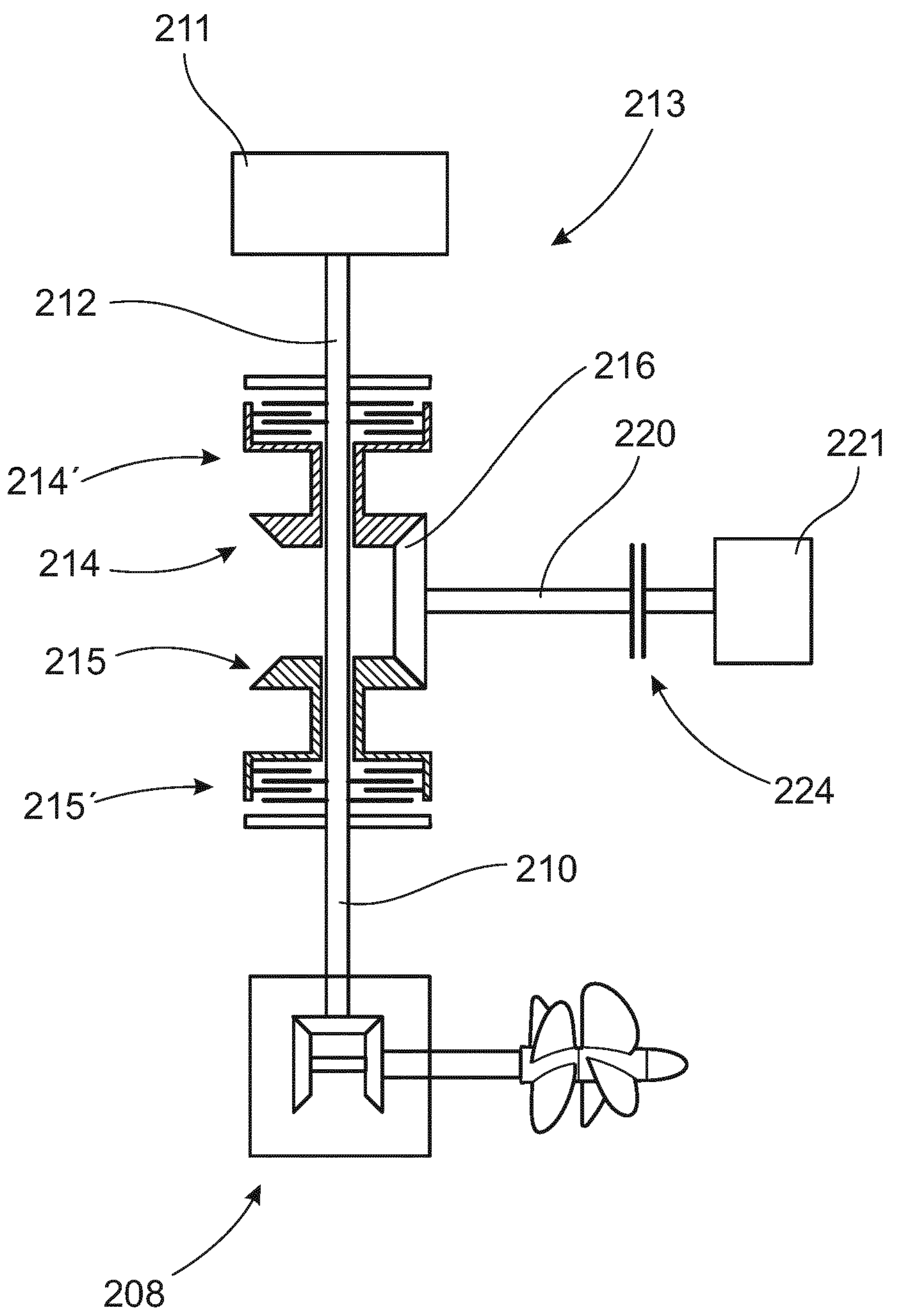
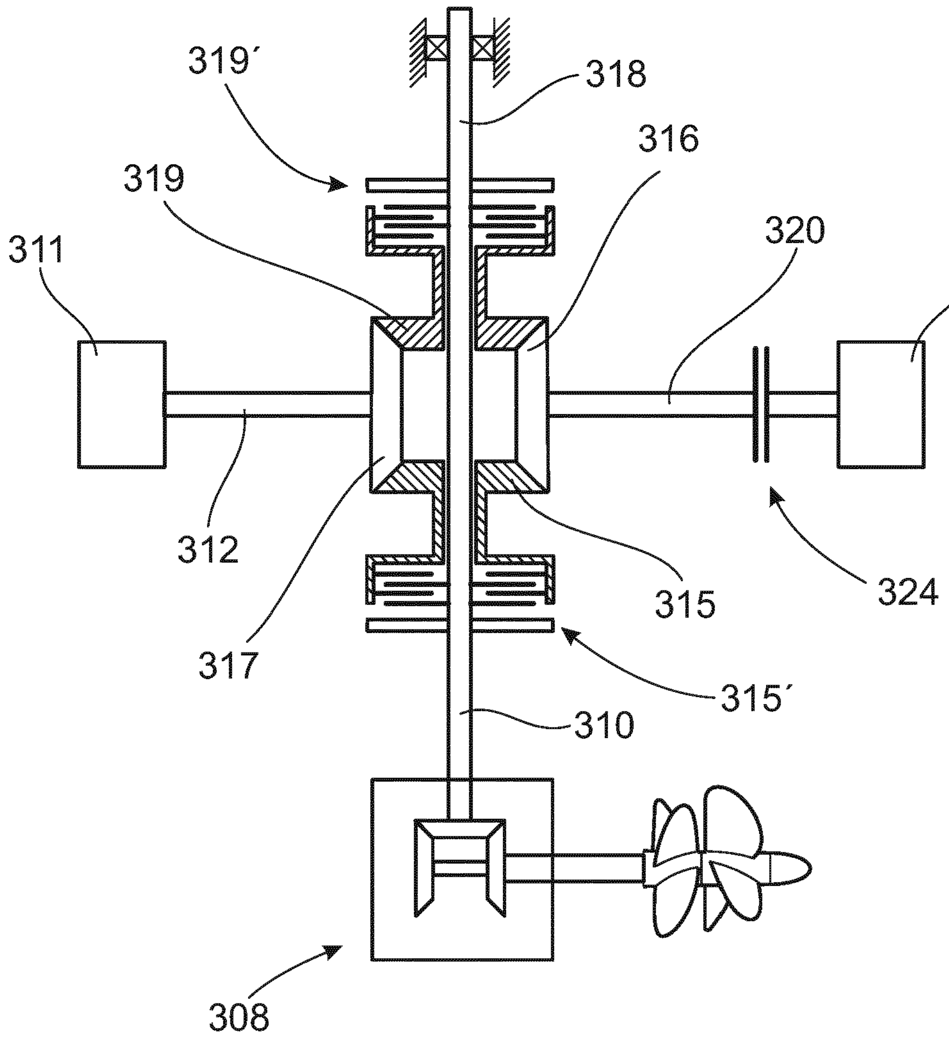


Fig.5



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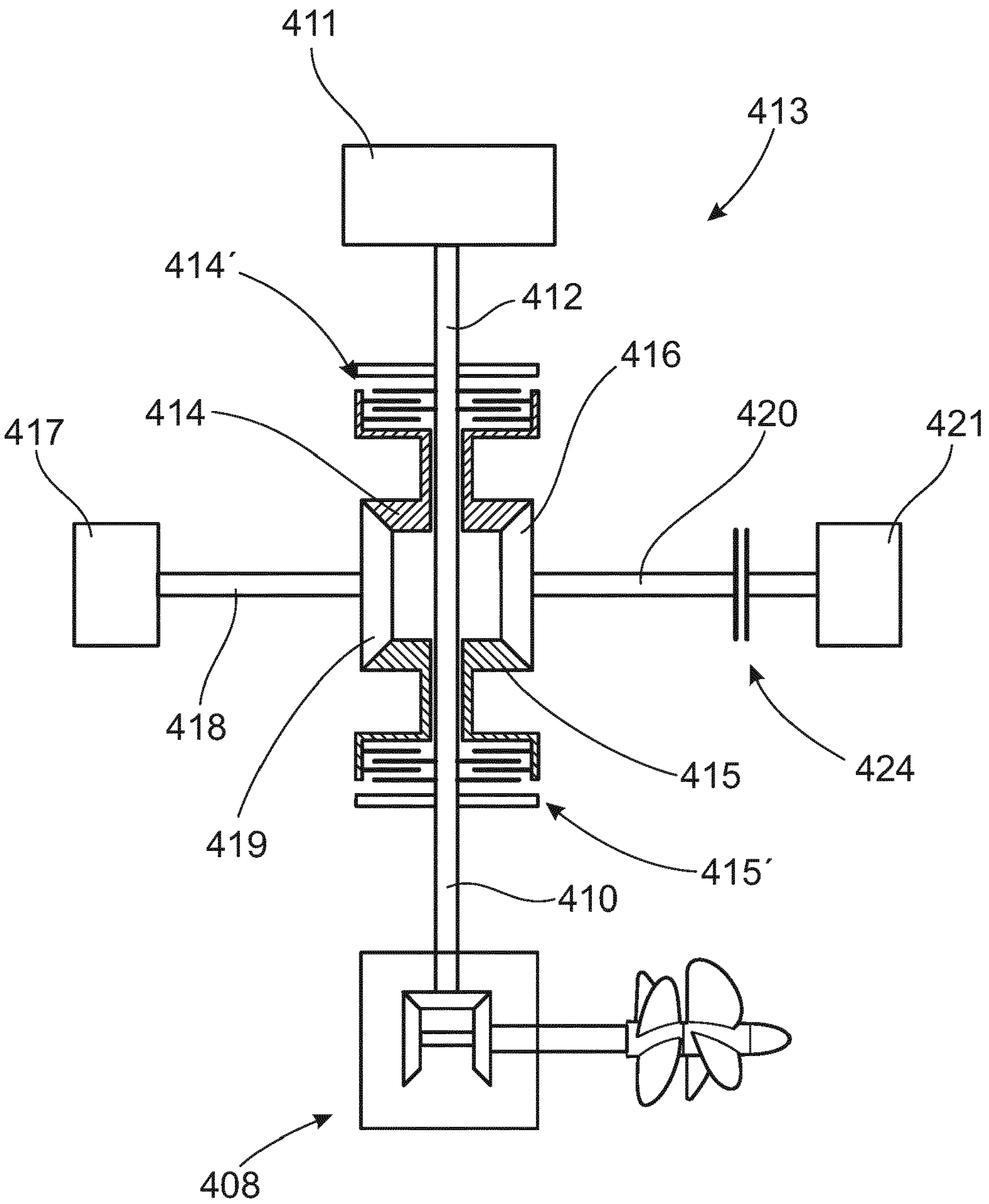

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EUROPEAN SEARCH REPORT

Application Number
EP 21 15 3776

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Y	US 2009/209146 A1 (JEGEL FRANZ PETER [AT]) 20 August 2009 (2009-08-20) * paragraph [0021] - paragraph [0022]; figure 1 * -----	1-15	INV. B63H23/30 B63H5/125 B63H21/20
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B63H

The present search report has been drawn up for all claims

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Place of search	Date of completion of the search	Examiner
The Hague	21 July 2021	Martínez, Felipe

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