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(71) Applicant: **Volvo Penta Corporation**
405 08 Göteborg (SE)

(72) Inventor: **CARLSSON, Lars-Gunnar**
423 39 Torslanda (SE)

(74) Representative: **Valea AB**
Box 1098
405 23 Göteborg (SE)

(54) **MARINE PROPULSION UNIT AND MARINE VESSEL**

(57) The invention relates to a marine propulsion unit comprising a stern drive (200) with a front end for mounting to a transom, which stern drive comprises a stern drive housing (203) and a gearbox housing (204); where the gearbox housing contains a gearbox (205) arranged to drive at least one propeller (206, 207) rotatable about a first axis (X_1). The stern drive housing contains at least two electric motors (211, 212) in driving connection with a vertical drive shaft (210) rotatable about a second axis (X2) and connected to the gearbox. Each electric motor (211, 212) has an output shaft (213, 214) comprising a pinion gear (215, 216), where the pinion gear (215, 216) of each output shaft (213, 214) is operably connected with a crown gear (217, 218) on the drive shaft (210). The output shafts (213, 214) are arranged with their axes of rotation (X3) at an offset (O) from the axes of rotation (X2) of the drive shaft (210), which drive shaft (210) comprises at least two crown gears (217, 218).

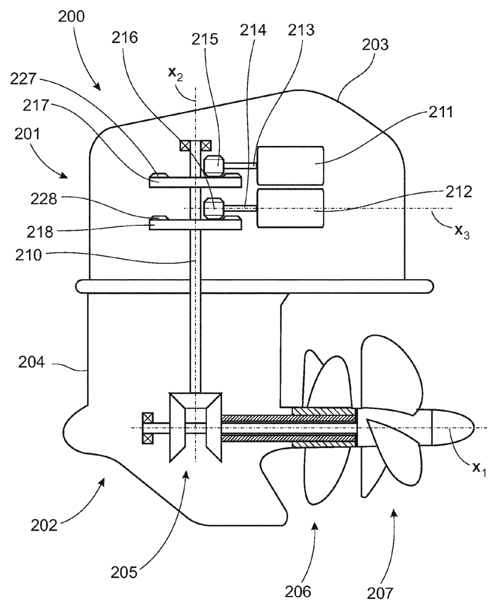

Fig.2

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Description

TECHNICAL FIELD

[0001] The present invention relates to a marine propulsion unit and a marine vessel with such a propulsion unit.

BACKGROUND

[0002] Known marine vessels comprising a propulsion unit in the form of a stern 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 stern drive via a transmission comprising shafts and gearing in order to drive a set of propellers on the stern drive.

[0003] Mounting a drive unit, such as an ICE or an electric motor, and the transmission required for such a drive unit within the hull of the vessel can require a significant amount of space. In operation, heat from the drive unit must be removed using a cooling system which as a rule employs water drawn in from the ambient marine environment. This often involves drawing in saline water from the sea and pumping it through the coolant system, which can cause problems with corrosion. Further, a vibration generated by rotary components in the drive unit and the transmission requires vibration isolation and dampers to be installed to avoid undesirable vibrations from being transmitted to the hull or other parts of the vessel. Finally, the transmission must pass through the transom of the vessel to reach the stern drive and the propellers. This requires a suitable sealing arrangement between an opening in the transom and a rotary transmission shaft to prevent water from leaking through the hull.

[0004] A possible solution to the above problems can be to provide an azimuthing propulsion unit or pod extending downwards beneath the hull. An example of such an azimuthing pod is shown in US 6 685 516. In this case the drive unit and its transmission can be mounted within a pod at one end of a leg extending downwards from the hull. However, this solution entails a significant draft and is mainly suited for larger vessels. In addition to the relatively large draft, it is not possible to tilt the propulsion unit out of the water when not in use. This will in turn increase the amount of marine growth on the submerged propulsion unit, which increases drag and reduces the efficiency of the propeller/-s.

[0005] The invention provides an improved marine propulsion unit aiming to solve the above-mentioned problems.

SUMMARY

[0006] An object of the invention is to provide a marine propulsion unit for a vessel, which propulsion unit solves the above-mentioned problems.

[0007] The object is achieved by a marine propulsion unit and a marine vessel comprising such a propulsion unit according to the appended claims.

[0008] In the subsequent text, the term "stern drive" is defined as an assembly comprising an outdrive having two sub-units. An upper unit contains drive units and a transmission and is enclosed in a stern drive housing. A lower unit contains a vertical driveshaft receiving power from the transmission in the upper unit and a gearbox providing power to a propeller shaft for driving at least one propeller. The component parts of the lower unit are enclosed in a gearbox housing. The upper and lower units are separated by a cavitation plate. A stern drive according to the invention is mounted to the transom of a marine vessel but differs from a conventional stern drive in that it does not comprise an inboard drive unit. The vessel is steered by pivoting the propulsion unit, or outdrive, relative to the transom. The propulsion unit can be pivoted up for trailer travel and between uses to avoid fouling. In the subsequent text, a stern drive according to the invention can be described as having a front portion or a rear portion. In this context, the front end of the stern drive will be the end arranged to be mounted on a transom on a marine vessel. This terminology is in line with the conventional definition of a front end and a rear end of a vessel in the main longitudinal direction thereof. Directional terms such as "forward", "rearward", "transverse" and "sideways" are to be interpreted according to this definition. The main longitudinal direction of the vessel also coincides with its direction of straight-ahead travel. Further, a plane defined as "passing through an axis" is considered to coincide with and contain the entire axis.

[0009] According to a first aspect, the invention relates to a marine propulsion unit comprising a stern drive mounted to a transom of a marine vessel. The stern drive comprises an upper unit enclosed in a stern drive housing and a lower unit enclosed in a gearbox housing. The stern drive housing contains drive units and a transmission in the form of a reduction gearing. The gearbox housing contains a gearbox arranged to drive at least one propeller. The at least one propeller is mounted on a propeller shaft at the free end of an output shaft from the gearbox and is rotatable about a first axis. The first axis coincides with or is parallel to the main longitudinal axis of the marine vessel onto which the propulsion unit is mounted, depending on the number of stern units and its/their location on the transom. The propulsion unit further comprises at least two electric motors arranged in the stern drive housing, which electric motors are in driving connection with a vertical output shaft rotatable about a second axis and connected to the gearbox driving the propellers. The electric motors are preferably high-speed motors as defined below. In the subsequent text, the above-mentioned first and second axes will be referred to when defining the mounting positions of the electric motors within the stern drive housing. Each electric motor has an output shaft comprising a pinion gear, wherein the pinion gear of each output shaft is in driving connection with a crown gear on the drive shaft. The output shafts are arranged with their axes of rotation at an offset from the axes of rotation of the drive shaft. The drive shaft comprises at least two axially separated crown gears and each crown gear can be driven by one or more electric motors. The number of electric motors can be selected depending on the desired output power of the stern drive.

[0010] According to a preferred example, the crown gears are hypoid gears. A hypoid gear is a type of spiral bevel gear whose axis does not intersect with the axis of the meshing gear. A hypoid gear comprises a ring-shaped crown gear or crown wheel having a planar pitch surface and a planar root surface, both of which are perpendicular to the axis of rotation. The shape of a hypoid gear is a revolved hyperboloid, that is, the pitch surface of the hypoid gear is a hyperbolic surface. In comparison, the shape of a conventional spiral bevel gear is normally conical. The hypoid gear places the axis of the pinion gear off-axis or offset to the axis of the crown gear which allows the pinion gear to be larger in diameter and have more contact area. The helical design produces less vibration and noise than conventional straight-cut or spur-cut gear with straight teeth. In hypoid gear design, the pinion gear and crown gear are practically always of opposite hand, and the spiral angle of the pinion is usually larger than that of the crown gear. The hypoid pinion is then larger in diameter than an equivalent angled bevel pinion.

[0011] The transmission has a gear ratio of at least 3:1 from the output shafts of the electric motors to the vertical drive shaft connected to the crown gears. In order to achieve a configuration that allows the stern drive housing to be kept a size that is the same or marginally larger than a conventional stern drive housing, the size of the electric motors should be selected accordingly. One way of achieving this is to use high speed electric motors. In this context, a high-speed electric motor is defined as a motor operable at speeds up to approximately 10.000 rpm or higher. A suitable maximum rotational speed of the vertical shaft driving the gearbox can be selected between 3.500-4.000 rpm, when it is desirable to use a conventional gearbox for the propellers in a stern drive normally operated by an ICE. For electrical motors operable at speeds up to 10.000 rpm a suitable gear ratio for the transmission in the upper unit would be 3:1, while a suitable gear ratio for electrical motors operable up to 25.000 rpm would be 6:1.

[0012] According to a first example, the drive shaft comprises at least two separate crown gears which crown gears comprise individual crown gear wheels which are axially separated along the drive shaft. According to one alternative example, the at least two axially separated crown gears have an annular set of gear teeth facing in the same direction. In this way, the set of gear teeth on each gear wheel can face either in an upward direction or in a downward direction. According to a further alternative example, the at least two axially separated crown gears have annular sets of gear teeth facing in opposite directions. In this way, the gear teeth on one of a pair of gear wheels faces in an upward direction while the gear teeth on the other gear wheel faces in a downward direction. Combinations of two, three or more crown gears which can be arranged with facing and/or opposing teeth can be employed within the scope of the invention.

[0013] According to a second example, the drive shaft comprises at least one pair of separate crown gears arranged on opposite sides of a double-sided crown gear. In this example, the crown gears have annular sets of gear teeth facing in opposite directions. One or more double-sided crown gear wheels can be mounted axially separated along the drive shaft.

[0014] In both the first and second examples described above, each set of annular gear teeth on a respective crown gear can be driven by one or more electric motors, depending on the desired power requirement for the stern unit. Examples of such arrangements will be described in further detail below.

[0015] As indicated above, the propulsion unit comprises at least two electric motors arranged in the stern drive housing, which electric motors are in driving connection with a vertical output shaft. According to one example, at least two electric motors are arranged on the same side of the vertical drive shaft relative to a plane through the second axis, associated with the drive shaft, and at right angles to the first axis, associated with the propeller shaft. According to a further example, at least two electric motors are arranged on opposite sides of the vertical drive shaft relative to plane through the second axis and at right angles to the first axis. In this way, two, three, four or more electric motors can be arranged in front of, to the rear of or distributed on opposite sides of the vertical drive shaft relative to plane through the second axis and at right angles to the first axis. The location of the electric motors can for instance be selected in dependence of the available packaging space within the stern drive housing.

When selecting a location for mounting the electric motors, at least one electric motor can be arranged with the output shaft axis arranged parallel to the first axis and the plane of the crown gear. For instance, if it is desired to provide a stern drive housing having relatively limited dimensions in the transverse direction of the housing, then it is advantageous to locate the output shaft of at least one electric motor parallel to the first axis. In this way the electric motors will extend forwards and/or rearwards in the longitudinal direction of the stern drive housing, which helps in reducing the overall width of the stern drive housing. This arrangement can assist in balancing the mass of the electric motors on either side of the center of gravity of the stern drive housing and would also contribute to a reduced overall width of the stern drive housing.

[0016] Alternatively, the dimensions of the stern drive housing can be further reduced if the output shaft of at least one electric motor has an axis arranged at an angle out of a vertical plane through the first axis and in a plane parallel to the plane of the crown gear. This angle can be selected in the range up to and including 45° out of the vertical plane through the first axis if it is desired to provide a drive unit assembly that can allows the size of the stern drive housing to be maintained. Angles up to 90° are of course possible, but larger angles will result in an increase in width of the stern drive housing. It can be desirable to select an angle in the lower portion of the range as a larger angle can increase the hypoid offset which results in a reduction of mechanical efficiency and a consequent increase in the power requirement. The angle selection is balanced against the fact that a higher hypoid offset allows the gear to transmit higher torque.

[0017] The axis of the at least one output shaft can be angled out of the vertical plane through the first axis from a position located in front of or to the rear of the axis of the drive shaft depending on the location of the respective electric motor. In this way the mass of the electric motors would be located even closer to the center of gravity of the stern drive housing while the output shaft with its pinion gear would be aimed outwards towards the annular toothed periphery of the crown gear.

[0018] According to a further alternative, the output shaft axis of at least one motor can be angled up to 30° out of the plane of its crown gear. This would allow for a reduction in the longitudinal extension of the stern drive housing but would require additional height. An arrangement of this type would be useful for solutions involving a double-sided crown gear, as it allows the electric motors to be mounted with a larger spacing. This will provide easier access for servicing and improves the cooling of the electrical motors. Also, it would allow larger electrical motors to be fitted, which motors might not fit side-by-side if mounted parallel with a plane through the crown gear.

[0019] Should multiple motors be used then they can be stacked in the vertical direction which would add to the height, or vertical dimension of the stern drive housing. As more than one electrical motor can be in driving connection with a single crown gear, the height is dependent on factors such as the number of electrical motors, the location of each electrical motor, the angle out of the vertical plane through the first axis and in a plane parallel to the plane of the crown gear, as well as the angle out of the plane of the crown gear.

[0020] If the dimensions of the stern drive housing are less relevant to the overall design, then the electric motors can be distributed around the drive shaft with the output shafts at any suitable angle out of a vertical plane through the first axis.

[0021] According to a further example the vertical drive shaft comprises a pair of concentric shafts connected to different motors via separate crown gears. In this way, electrical motors connected to individual crown gears can drive separate propellers in a duo prop arrangement rotatable about the first axis. This arrangement allows individual propellers to be driven at different speeds or operation of one propeller only.

[0022] According to a further example at least one electric motor is permanently connected to the drive shaft, while the remaining electric motors are freewheeling motors. Under certain operating conditions the propulsion unit can be arranged to drive the at least one propeller with at least one electric motor. The electric motors not being operated can be allowed to free-wheel in order to improve efficiency. At least one electrical motor is permanently in driving connection with its crown gear in order to allow one or more propellers to be reversed. One operating condition can be that the demanded or required power output from the propulsion unit can be achieved by operating fewer than the total number of available electric motors. The electric motors can drive the propellers together, independently or in variable combinations in response to different torque and power demands in order to improve the efficiency of the propulsion unit. The effect of the hypoid gear is to allow the use of high-speed electric motors with a corresponding reduced output torque. In this way the cost is of the propulsion unit is lowered, while the electric motors can be operated in a high-efficiency area.

[0023] A further operating condition can be a so-called limp-home mode the propulsion unit is arranged to drive the at least one propeller when at least one or only one electric motor is operable. This arrangement provides a redundancy for the propulsion unit and ensures that the vessel can be operated even if one or more electric motors are inoperable.

[0024] According to a second aspect of the invention, the invention relates to a marine vessel provided with a marine propulsion unit as described in the above examples.

[0025] The propulsion unit according to the invention solves the problem of providing a stern drive with electric propulsion without requiring significant modifications of existing units. In most cases the outdrive can be advantageously be provided with a stern drive housing having the same or approximately the same shape and size as conventional stern drive housings. Further, the interface for mounting a stern drive and its steering gear connections can be maintained. As the inboard drive unit can be eliminated there is no need for an opening through the transom or for an associated sealing means for a drive shaft. The electric motors can drive the propellers together, independently or in variable combinations in response to different torque and power demands whereby the efficiency of the propulsion unit is improved. By allowing independent operation of at least a single motor the arrangement provides a redundancy for the propulsion unit and ensures that the vessel can be operated even if one or more electric motors are inoperable. The use of hypoid gearings in a power transmission provides a more efficient gearing than a conventional worm or bevel gearing. Hypoid gears are considerably stronger in that any load is conveyed through multiple teeth simultaneously, which also makes it more silent compared to worm or bevel gearings.

[0026] Further advantages and advantageous features of the invention are disclosed in the following description and in the dependent claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027] 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 side view of a schematically illustrated vessel comprising a marine propulsion unit according to the invention;

Fig.2 shows a schematic side view of a propulsion unit according to a first example;

Fig.3 shows a schematic side view of a propulsion unit according to a second example;

Fig.4 shows a schematic side view of a propulsion unit according to a third example;

Fig.5 shows a schematic side view of a propulsion unit according to a fourth example;

Fig.6 shows a schematic plan view of a propulsion unit according to a fifth example;

Fig.7 shows a schematic plan view of a propulsion unit according to a sixth example;

Fig.8 shows a schematic plan view of a propulsion unit according to a seventh example; and

Fig.9 shows a schematic perspective view of a hypoid gear suitable for use in the propulsion unit.

DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS OF THE INVENTION

[0028] Figure 1 shows a side view of a schematically illustrated marine vessel 100 comprising a marine propulsion unit 103 according to the invention. The marine propulsion unit 103 is mounted to a transom 102 on the vessel 100. Electric motors (see Fig.2) in the marine propulsion unit 103 are connected to an inboard battery pack 104 via suitable wiring 105. The battery pack 104 is indicated schematically in Figure 1 and is preferably located below the waterline of the vessel hull 101 where it can act as ballast and contribute to the stability of the vessel 100.

[0029] The marine propulsion unit 103 is controllable by a control means such as a throttle lever 110 located at an operating position. The throttle lever 110 is connected to an electronic control unit (ECU) 111 via suitable wiring 112, which ECU 111 is connected to the battery pack 104 via additional wiring 113. The battery pack also comprises a power electronic controller (PEC) and an electronic controller for calibrating and charging the battery pack. Electronic controllers of this type are known in the art and will not be described in further detail here.

[0030] Figure 2 shows a schematic side view of a propulsion unit according to a first example. Figure 2 shows a stern drive 200 suitable for mounting to a transom of a marine vessel (see Fig.1; "102"). In Figure 2 the transom would be located at the left-hand side of the stern drive 200, which is defined as the front end of the stern drive. Similarly, the propellers are located at the opposite, rear end of the stern drive. The stern drive 200 comprises an upper unit 201 enclosed in a stern drive housing 203 and a lower unit 202 enclosed in a gearbox housing 204. The gearbox housing 204 contains a gearbox 205 arranged to drive a pair of coaxial shafts connected to counter rotating propellers 206, 207 rotatable about a first axis X_1. The propulsion unit in this example comprises two electric motors 211, 212 arranged one above the other in the stern drive housing 203. The electric motors 211, 212 are mounted horizontally with their output shafts 213, 214 extending towards a respective crown gear 217, 218. Each output shaft 213, 214 comprises a pinion gear 215, 216 operatively connected to annular sets of gear teeth 227, 228 on its respective crown gear 217, 218, which crown gears 217, 218 are mounted fixed against rotation and axially separated on a vertical drive shaft 210. The vertical drive shaft 210 is rotatable about a second axis X_2 and is operatively connected to the gearbox 205.

[0031] The example in Figure 2 shows two electric motors 211, 212 arranged axially separated in the vertical direction on the same side of and to the rear of the vertical drive shaft 210 relative to a plane through the second axis X_2 and at right angles to the first axis X_1. Figure 2 shows crown gears 217, 218 with annular sets of gear teeth 227, 228 facing in the same direction. In Figure 2 the annular sets of gear teeth 227, 228 face upwards, but downwards facing teeth are also an option. An advantage with the arrangement shown in Figure 2 is that the downwards force applied to the crown gears by the respective pinion gear can be taken up and supported by a bevel gear arrangement in the gearbox 205. The pinion gears 215, 216 and crown gears 217, 218 in Figure 2 are preferably hypoid gears. A hypoid gear has the axis of the pinion gear offset to the axis of the crown gear. Hence, the electric motors 211, 212 in Figure 2 can be arranged parallel and offset in the horizontal plane, or in the plane of the respective crown gear 217, 218. An example of such an arrangement is schematically indicated in Figure 6 below.

[0032] Within the scope of the invention, the propulsion unit can alternatively comprise two electric motors arranged on the same side of and front of the vertical drive shaft, or on opposite sides of the vertical drive shaft 210 relative to a plane through the second axis X_2 and at right angles to the first axis X_1. Additional electric motors can be provided level with and in parallel to the electric motors shown in Figure 2. The number of motors is selected depending on the desired power output of the stern drive.

[0033] The gearbox 211 comprises bevel gears arranged to drive a first and a second drive shaft, respectively, to drive the pair of counter rotating propellers 206, 207. By mounting the electric motors 211, 212 with their rotary axes in a horizontal direction and selecting high speed motors having a suitable size, the motors can be fitted within a stern drive housing 203. The interface for mounting the stern drive 200 to the transom and the connection to its steering gear (not shown) can be the same as the outdrive for a conventional stern drive.

[0034] Figure 3 shows a schematic side view of a propulsion unit according to a second example. Figure 3 shows a stern drive 300 suitable for mounting to a transom of a marine vessel (see Fig.1; "102"). In Figure 3 the transom would be located at the left-hand side of the stern drive 300, which is defined as the front end of the stern drive. Similarly, the propellers are located at the opposite, rear end of the stern drive. The stern drive 300 comprises an upper unit 301 enclosed in a stern drive housing 303 and a lower unit 302 enclosed in a gearbox housing 304. The gearbox housing 304 contains a gearbox 305 arranged to drive a pair of coaxial shafts connected to counter rotating propellers 306, 307 rotatable about a first axis X_1. The propulsion unit in this example comprises two electric motors 311, 312 arranged one above the other in the stern drive housing 303. The electric motors 311, 312 are mounted horizontally with their output shafts 313, 314 extending towards a respective crown gear 317, 318. Each output shaft 313, 314 comprises a pinion gear 315, 316 operatively connected to annular sets of gear teeth 327, 328 on its respective crown gear 317, 318, which crown gears 317, 318 are mounted fixed against rotation and axially separated on a vertical drive shaft 310. The vertical drive shaft 310 is rotatable about a second axis X_2 and is operatively connected to the gearbox 305.

[0035] The example in Figure 3 shows two electric motors 311, 312 arranged axially separated in the vertical direction on the same side of and to the rear of the vertical drive shaft 310 relative to a plane through the second axis X_2 and at right angles to the first axis X_1. Figure 3 shows crown gears 317, 318 with annular sets of gear teeth 327, 328 facing in opposite directions. An advantage with the arrangement shown in Figure 3 is that the opposing forces applied to the crown gears by the pinion gears can be balanced. The pinion gears 315, 316 and crown gears 317, 318 in Figure 3 are preferably hypoid gears. A hypoid gear has the axis of the pinion gear offset to the axis of the crown gear. Hence, the electric motors 311, 312 in Figure 3 can be arranged parallel and offset in the horizontal plane, or in the plane of the respective crown gear 317, 318. An example of such an arrangement is schematically indicated in Figure 6 below.

[0036] Within the scope of the invention, the propulsion unit can alternatively comprise two electric motors arranged on the same side of and front of the vertical drive shaft, or on opposite sides of the vertical drive shaft 310 relative to a plane through the second axis X_2 and at right angles to the first axis X_1. Additional electric motors can be provided level with and in parallel to the electric motors shown in Figure 3. The number of motors is selected depending on the desired power output of the stern drive.

[0037] The gearbox 311 comprises bevel gears arranged to drive a first and a second drive shaft, respectively, to drive the pair of counter rotating propellers 306, 307. By mounting the electric motors 311, 312 with their rotary axes in a horizontal direction and selecting high speed motors having a suitable size, the motors can be fitted within a stern drive housing 303. The interface for mounting the stern drive 300 to the transom and the connection to its steering gear (not shown) can be the same as the outdrive for a conventional stern drive.

[0038] Figure 4 shows a schematic side view of a propulsion unit according to a third example. Figure 4 shows a stern drive 400 suitable for mounting to a transom of a marine vessel (see Fig.1; "102"). In Figure 4 the transom would be located at the left-hand side of the stern drive 400, which is defined as the front end of the stern drive. Similarly, the propellers are located at the opposite, rear end of the stern drive. The stern drive 400 comprises an upper unit 401 enclosed in a stern drive housing 403 and a lower unit 402 enclosed in a gearbox housing 404. The gearbox housing 404 contains a gearbox 405 arranged to drive a pair of coaxial shafts connected to counter rotating propellers 406, 407 rotatable about a first axis X_1. The propulsion unit in this example comprises two electric motors 411, 412 arranged one above the other in the stern drive housing 403. The electric motors 411, 412 are mounted horizontally with their output shafts 413, 414 extending towards a double-sided crown gear 417, 418. Each output shaft 413, 414 comprises a pinion gear 415, 416 operatively connected to annular sets of axially separated gear teeth 427, 428 on its respective side of double-sided crown gear 417, 418. The double-sided crown gear 417, 418 can therefore be defined as axially separated crown gear 417 and 418. The double-sided crown gear 417, 418 is mounted fixed against rotation on a vertical drive shaft 410.

[0039] The vertical drive shaft 410 is rotatable about a second axis X_2 and is operatively connected to the gearbox 405.

[0040] The example in Figure 4 shows two electric motors 411, 412 arranged axially separated in the vertical direction on the same side of and to the rear of the vertical drive shaft 410 relative to a plane through the second axis X_2 and at right angles to the first axis X_1. Figure 4 shows a double-sided crown gear 417, 418 with annular sets of gear teeth 427, 428 facing in opposite directions. An advantage with the arrangement shown in Figure 4 is that the opposing forces applied to the double-sided crown gear by the pinion gears can be balanced. The pinion gears 415, 416 and the double-sided crown gear 417, 418 in Figure 4 are preferably hypoid gears. A hypoid gear has the axis of the pinion gear offset to the axis of the crown gear. Hence, the electric motors 411, 412 in Figure 4 can be arranged parallel and offset in the horizontal plane, or in the plane of the respective crown gear 417, 418. An example of such an arrangement is schematically indicated in Figure 6 below.

[0041] Within the scope of the invention, the propulsion unit can alternatively comprise two electric motors arranged on the same side of and front of the vertical drive shaft, or on opposite sides of the vertical drive shaft 410 relative to a plane through the second axis X_2 and at right angles to the first axis X_1. Additional electric motors can be provided level with and in parallel to the electric motors shown in Figure 4. The number of motors is selected depending on the desired power output of the stern drive.

[0042] The gearbox 411 comprises bevel gears arranged to drive a first and a second drive shaft, respectively, to drive the pair of counter rotating propellers 406, 407. By mounting the electric motors 411, 412 with their rotary axes in a horizontal direction and selecting high speed motors having a suitable size, the motors can be fitted within a stern drive housing 403. The interface for mounting the stern drive 400 to the transom and the connection to its steering gear (not shown) can be the same as the outdrive for a conventional stern drive.

[0043] Figure 5 shows a schematic side view of a propulsion unit according to a fourth example. Figure 5 shows a stern drive 500 suitable for mounting to a transom of a marine vessel (see Fig.1; "102"). In Figure 5 the transom would be located at the left-hand side of the stern drive 500, which is defined as the front end of the stern drive. Similarly, the propellers are located at the opposite, rear end of the stern drive. The stern drive 500 comprises an upper unit 501 enclosed in a stern drive housing 503 and a lower unit 502 enclosed in a gearbox housing 504. The gearbox housing 504 contains a gearbox 505 arranged to drive a pair of coaxial shafts connected to counter rotating propellers 506, 507 rotatable about a first axis X_1. The propulsion unit in this example comprises two electric motors 511, 512 arranged one above the other in the stern drive housing 503. The electric motors 511, 512 are mounted with their output shafts 513, 514 at an angle α out of the plane of its respective crown gear 517, 518 with their output shafts 513, 514 extending downwards to a respective crown gear 517, 518. The angle α can be selected up to and including 30°. Each output shaft 513, 514 comprises a pinion gear 515, 516 operatively connected to annular sets of gear teeth 527, 528 on its respective crown gear 517, 518, which crown gears 517, 518 are mounted fixed against rotation and axially separated on a vertical drive shaft 510. The vertical drive shaft 510 is rotatable about a second axis X_2 and is operatively connected to the gearbox 505.

[0044] The example in Figure 5 shows two electric motors 511, 512 arranged axially separated in the vertical direction on the same side of and to the rear of the vertical drive shaft 510 relative to a plane through the second axis X_2 and at right angles to the first axis X_1. Figure 5 shows crown gears 517, 518 with annular sets of gear teeth 527, 528 facing in the same direction. In Figure 5 the annular sets of gear teeth 527, 528 face upwards, but downwards facing teeth are also an option. An advantage with the arrangement shown in Figure 5 is that the downwards force applied to the crown gears by the respective pinion gear can be taken up and supported by a bevel gear arrangement in the gearbox 505. The pinion gears 515, 516 and crown gears 517, 518 in Figure 5 are preferably hypoid gears. A hypoid gear has the axis of the pinion gear offset to the axis of the crown gear. Hence, the electric motors 511, 512 in Figure 5 can be arranged parallel and offset in the horizontal plane, or in the plane of the respective crown gear 517, 518. An example of such an arrangement is schematically indicated in Figure 6 below.

[0045] Within the scope of the invention, the propulsion unit can alternatively comprise two electric motors arranged on the same side of and front of the vertical drive shaft, or on opposite sides of the vertical drive shaft 510 relative to a plane through the second axis X_2 and at right angles to the first axis X_1. Additional electric motors can be provided level with and in parallel to the electric motors shown in Figure 5. The number of motors is selected depending on the desired power output of the stern drive.

[0046] The gearbox 511 comprises bevel gears arranged to drive a first and a second drive shaft, respectively, to drive the pair of counter rotating propellers 506, 507. By mounting the electric motors 511, 512 with their rotary axes in a horizontal direction and selecting high speed motors having a suitable size, the motors can be fitted within a stern drive housing 503. The interface for mounting the stern drive 500 to the transom and the connection to its steering gear (not shown) can be the same as the outdrive for a conventional stern drive.

[0047] Figure 6 shows a schematic plan view of a propulsion unit according to a fifth example. Figure 6 shows a stern drive 600 suitable for mounting to a transom 620 (indicated by a dashed line) of a marine vessel (not shown). The transom 620 would be located at the upper part of the stern drive 600 as shown in Figure 6, which is defined as the front end of the stern drive. The stern drive 600 comprises an upper unit 601 enclosed in a stern drive housing 603 and a lower unit enclosed in a gearbox housing (see Figure 2; "204"). The gearbox housing contains a gearbox arranged to drive a pair of coaxial shafts connected to counter rotating propellers, as described in connection with Figure 2. The propellers are rotatable about a first axis X_1. The propulsion unit in this example comprises two electric motors 611, 612 arranged on opposite sides of and parallel to a vertical plane through the first axis X_1. The electric motors 611, 612 are further arranged one above the other in the stern drive housing 603 in the same way as schematically indicated in Figures 2-4. The electric motors 611, 612 in this example are mounted with their output shafts 613, 614 extending towards a respective first and second crown gear 617, 618. Each output shaft 613, 614 comprises a pinion gear 615, 616 operatively connected to annular sets of gear teeth 627, 628 on its respective crown gear 617, 618. The lower set of gear teeth 628 (indicated by dashed lines) is not visible as it is located below the uppermost crown gear 617. The crown gears 617, 618 are mounted fixed against rotation and axially separated on a vertical drive shaft 610. The vertical drive shaft 610 is rotatable about a second axis X_2 and is operatively connected to the gearbox. The output shafts 613, 614 are rotatable about their respective axes X_3 (one shown) which axes are parallel to the plane of the crown gears 617, 618. The pinion gear 615, 616 are arranged with an offset O relative to the second axis X_2 of the crown gears 617, 618.

[0048] Figure 7 shows a schematic plan view of a propulsion unit according to a sixth example. Figure 7 shows a stern drive 700 suitable for mounting to a transom 720 (indicated by a dashed line) of a marine vessel (not shown). The transom would be located at the upper part of the stern drive 700 as shown in Figure 7, which is defined as the front end of the stern drive. The stern drive 700 comprises an upper unit 701 enclosed in a stern drive housing 703 and a lower unit enclosed in a gearbox housing (see Figure 2; "204"). The gearbox housing contains a gearbox arranged to drive a pair of coaxial shafts connected to counter rotating propellers, as described in connection with Figure 2. The propellers are rotatable about a first axis X_1. The propulsion unit in this example comprises four electric motors 711, 712, 721, 722. A first pair of electric motors 711, 712 are arranged in parallel on opposite sides of a first vertical plane through the first axis X_1 and to one side of a second vertical plane through the second axis X_2 and at right angles to the first vertical plane. A second pair of electric motors 721, 722 are arranged facing the first pair of electric motors 711, 712. The second pair of electric motors 721, 722 are also arranged in parallel on opposite sides of a first vertical plane through the first axis X_1 but on the opposite side of the second vertical plane through the second axis X_2 and at right angles to the first vertical plane. The first pair of electric motors 711, 712 are further arranged above the second pair of electric motors 721, 722 in the vertical direction of the stern drive housing 703 with an axial spacing similar to the arrangement of electric motors schematically indicated in Figure 2-4. In Figure 7 the first pair of electric motors 711, 712 are mounted horizontally with their output shafts 713, 714 extending forwards towards a first crown gear 717. Each output shaft 713, 714 comprises a pinion gear 715, 716 operatively connected to an annular set of gear teeth 727 on its crown gear 717. The second pair of electric motors 721, 722 are mounted horizontally with their output shafts 723, 724 extending rearwards towards a second crown gear 718. The lower, second crown gear 718 (not visible) is located below first crown gear 717 and is indicated by dashed lines in Figure 7. Each output shaft 723, 724 comprises a pinion gear 725, 726 operatively connected to an annular set of gear teeth 728 on its crown gear 718. The lower set of pinion gears 725, 726 and their associated gear teeth 728 are not visible as it is located below the uppermost crown gear 717. These components are indicated by arrows in Figure 7. The crown gears 717, 718 are mounted fixed against rotation and axially separated on a vertical drive shaft 710. The vertical drive shaft 710 is rotatable about a second axis X_2 and is operatively connected to the gearbox. The output shafts 713, 714, 723, 724 are rotatable about their respective axes X_3 (one shown) which axes are parallel to the plane of their respective crown gear 717, 718. The pinion gears 715, 716, 725, 726 are arranged with an offset O relative to the second axis X_2 of the crown gears 717, 718.

[0049] Figure 8 shows a schematic plan view of a propulsion unit according to a seventh example. Figure 8 shows a stern drive 800 suitable for mounting to a transom 820 (indicated by a dashed line) of a marine vessel (not shown). The transom 820 would be located at the upper part of the stern drive 800 as shown in Figure 8, which is defined as the front end of the stern drive. The stern drive 800 comprises an upper unit 801 enclosed in a stern drive housing 803 and a lower unit enclosed in a gearbox housing (see Figure 2; "204"). The gearbox housing contains a gearbox arranged to drive a pair of coaxial shafts connected to counter rotating propellers, as described in connection with Figure 2. The propellers are rotatable about a first axis X_1. The propulsion unit in this example comprises two electric motors 811, 812 arranged to extend through a vertical plane through the first axis X_1. The electric motors 811, 812 have output shafts 813, 814 operatively connected with a respective crown gear 817, 818 mounted on a vertical drive shaft 810 rotatable about a second axis X_2. The vertical drive shaft 810 is operatively connected to the gearbox. The pinion gears 815, 816 are rotatable about a respective third axis X_3 which axes X_3 are arranged with an offset O relative to the second axis X_2 of the crown gears 817, 818. The pinion gear 815, 816 of each output shaft 813, 814 is operatively connected to annular sets of gear teeth 827, 828 on its respective crown gear 817, 818. The lower set gear of teeth associated with the pinion gear 816 is not visible as it is located below the uppermost crown gear 817. The electric motors 811, 812 are further arranged one above the other in the stern drive housing 803 similar to the arrangements schematically indicated in Figure 2-5.

[0050] The output shafts 813, 814 are mounted with their rotatable axes X_3 (one shown) arranged at equal and opposite angles β out of a vertical plane through the first axis X_1 and in a plane parallel to the plane of the respective crown gears 817, 818. The angle β can be selected up to and including 45° out of the vertical plane through the first axis if it is desired to provide a drive unit assembly that can allows the size of the stern drive housing to be maintained. Angles up to 90° are of course possible, but larger angle will result in an increase in width of the stern drive housing. It can be desirable to select an angle in the lower portion of the range as a larger angle can increase the offset O and causes the body of the electric motor to protrude in the transverse direction of the stern drive housing. A larger offset will also result in a reduction of mechanical efficiency and a consequent increase in the power requirement. However, the angle selection is balanced against the fact that a higher offset allows the gear to transmit higher torque.

[0051] The plan view in Figure 8 can illustrate two different examples. According to a first example, the output shafts 813, 814 of the electric motors 811, 812 are rotatable about their respective axes X_3 (one shown) which axes are arranged parallel to the plane of the respective crown gear 817, 818. This example applies to the embodiments shown in Figures 2 and 5, where the gearing comprises two axially separated crown gears 217, 218; 517, 518 having gear teeth 227, 228; 257, 258 facing in the same direction and the embodiment shown in Figure 3, where the gearing comprises two axially separated crown gears 317, 318 having gear teeth 327, 328 facing in opposite directions. According to a second example, the output shafts 813, 814 of the electric motors 811, 812 are rotatable about their respective axes X_3 (one shown) which axes are arranged at an angle (see Figure 5; "α") out of the plane of the of the respective crown gear 817, 818. The output shaft axes of the electric motors can be angled up to 30° out of the plane of its respective crown gear. This example is applicable to a modification of the embodiment shown in Figure 4, where the gearing comprises a pair of separate crown gears 417, 418 having gear teeth 427, 428 on opposite sides of a double-sided crown gear. In this case the axes can be angled to avoid mechanical interference between the electric motors. This arrangement of the electric motors as described in the above examples can contribute to minimizing the width of the stern drive housing 803.

[0052] Figure 9 shows a schematic perspective view of a hypoid gear suitable for use in the propulsion unit. A hypoid gear is a type of spiral bevel gear whose axis does not intersect with the axis of the meshing gear. The hypoid gear in Figure 9 comprises a ring-shaped crown gear 901 having a planar pitch surface and a planar root surface, both of which are perpendicular to the axis of rotation about the axis X_2. The hypoid gear comprises a pinion gear 902 arranged on an output shaft 903 from a suitable motor (not shown). The output shaft 903 is rotatable about an axis X_3 placed with an offset O relative to the axis X_2 of the crown gear 901 which allows the pinion gear 902 to be larger in diameter and have more contact area compared to a conventional spur gear in al bevel gearing.

[0053] 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. A marine propulsion unit comprising a stern drive (200) with a front end for mounting to a transom, which stern drive comprises an upper unit (201) enclosed in a stern drive housing (203) and a lower unit (202) enclosed in a gearbox housing (204); where the gearbox housing contains a gearbox (205) arranged to drive at least one propeller (206, 207) rotatable about a first axis (X_1) and where the stern drive housing contains at least two electric motors (211, 212), which electric motors are in driving connection with a vertical drive shaft (210) rotatable about a second axis (X_2) and connected to the gearbox; wherein:

   - each electric motor (211, 212) has an output shaft (213, 214) comprising a pinion gear (215,216),
   - the pinion gear (215, 216) of each output shaft (213, 214) is operably connected with a crown gear (217, 218) on the drive shaft (210);
   -- the output shafts (213, 214) are arranged with their axes of rotation (X_3) at an offset (O) from the axes of rotation (X_2) of the drive shaft (210); and
   - the drive shaft (210) comprises at least two crown gears (217, 218).

2. Marine propulsion unit according to claim 1, wherein the crown gears are hypoid gears.

3. Marine propulsion unit according to claim 1 or 2, wherein the drive shaft comprises at least two separate crown gears (217, 218) which are axially separated.

4. Marine propulsion unit according to claim 3, wherein the at least two axially separated crown gears (217, 218) have gear teeth (227, 228) facing in the same direction.

5. Marine propulsion unit according to claim 3, wherein the at least two axially separated crown gears (317, 318) have gear teeth (327, 328) facing in opposite directions.

6. Marine propulsion unit according to claim 1 or 2, wherein the drive shaft comprises at least one pair of separate crown gears (417, 418) arranged on opposite sides of a double-sided crown gear.

7. Marine propulsion unit according to any one of claims 1-6, wherein at least two electric motors are arranged on the same side of the vertical drive shaft relative to a plane through the second axis (X_2) and at right angles to the first axis (X_1).

8. Marine propulsion unit according to any one of claims 1-6, wherein at least two electric motors are arranged on opposite sides of the vertical drive shaft relative to a plane through the second axis (X_2) and at right angles to the first axis (X_1).

9. Marine propulsion unit according to any one of claims 1-8, wherein the output shaft (213, 214) of at least one electric motor has an axis (X_3) parallel to the first axis (X_1).

10. Marine propulsion unit according to any one of claims

1-9, wherein the output shaft of at least one electric motor has an axis (X_3) arranged at an angle out of a vertical plane through the first axis (X_1) and in a plane parallel to the plane of the crown gear.

11. Marine propulsion unit according to any one of claims 10, wherein the output shaft (813, 814) of at least one electric motor (811, 812) has an axis (X_3) arranged at an angle up to 45°.

12. Marine propulsion unit according to any one of claims 1-11, wherein the output shaft (513, 514) of at least one electric motor (511, 512) has an axis angled up to 30° out of the plane of its crown gear.

13. Marine propulsion unit according to any one of claims 1-12, wherein the vertical drive shaft comprises a pair of concentric shafts (309, 310) connected to different electric motors (311, 312) via separate crown gears (317, 318).

14. Marine propulsion unit according to any one of claims 1-13, wherein at least one electric motor is permanently connected to the drive shaft, while the remaining electric motors are freewheeling motors.

15. Vessel comprising a transmission with a marine propulsion unit according to claim 1.

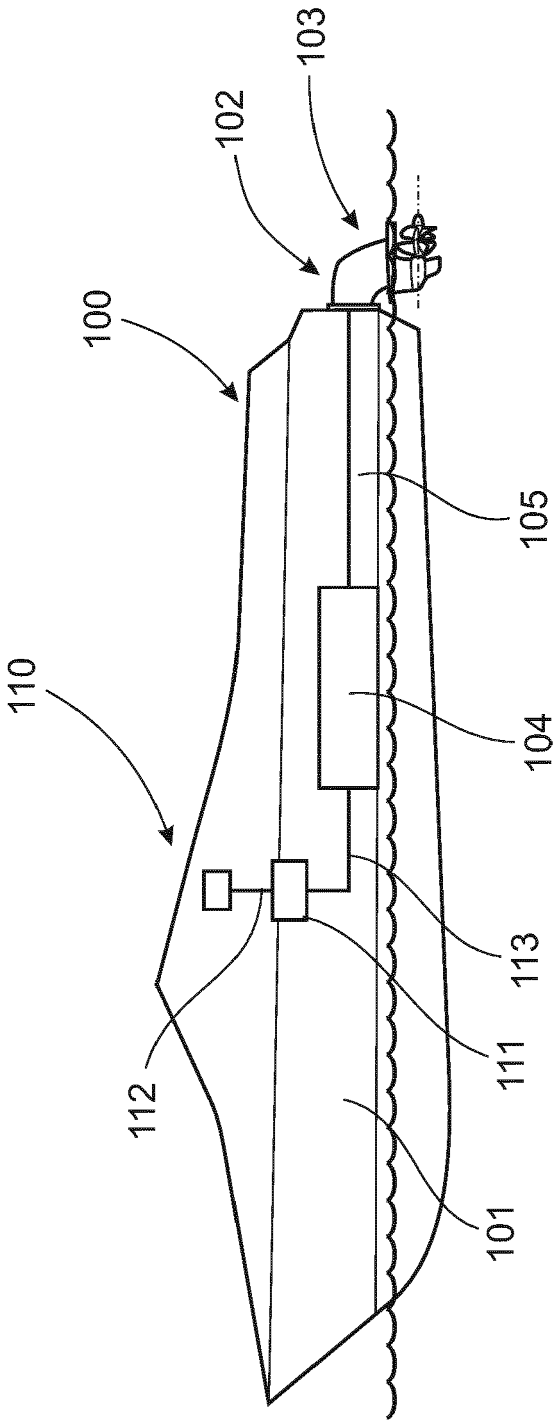
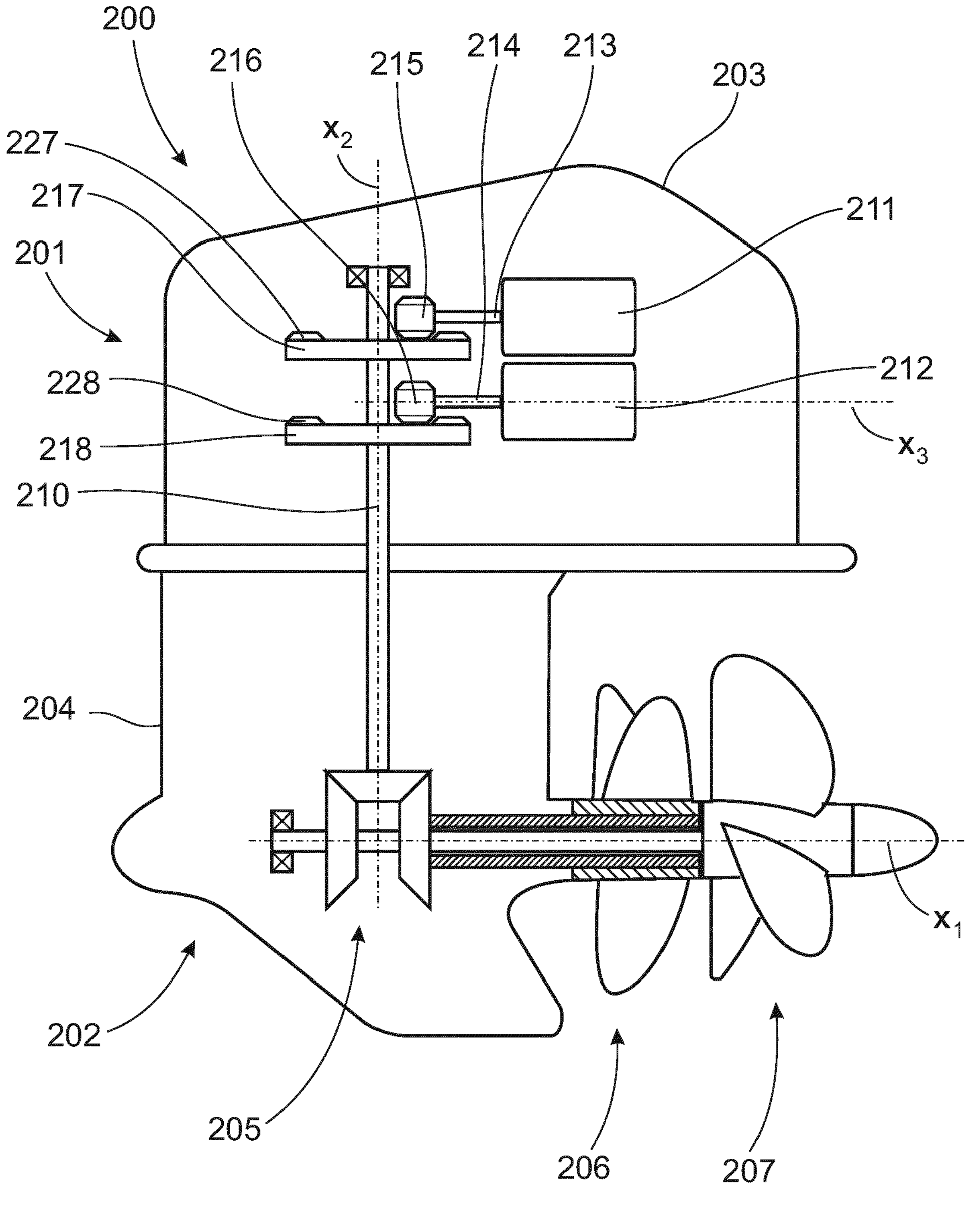


Fig.1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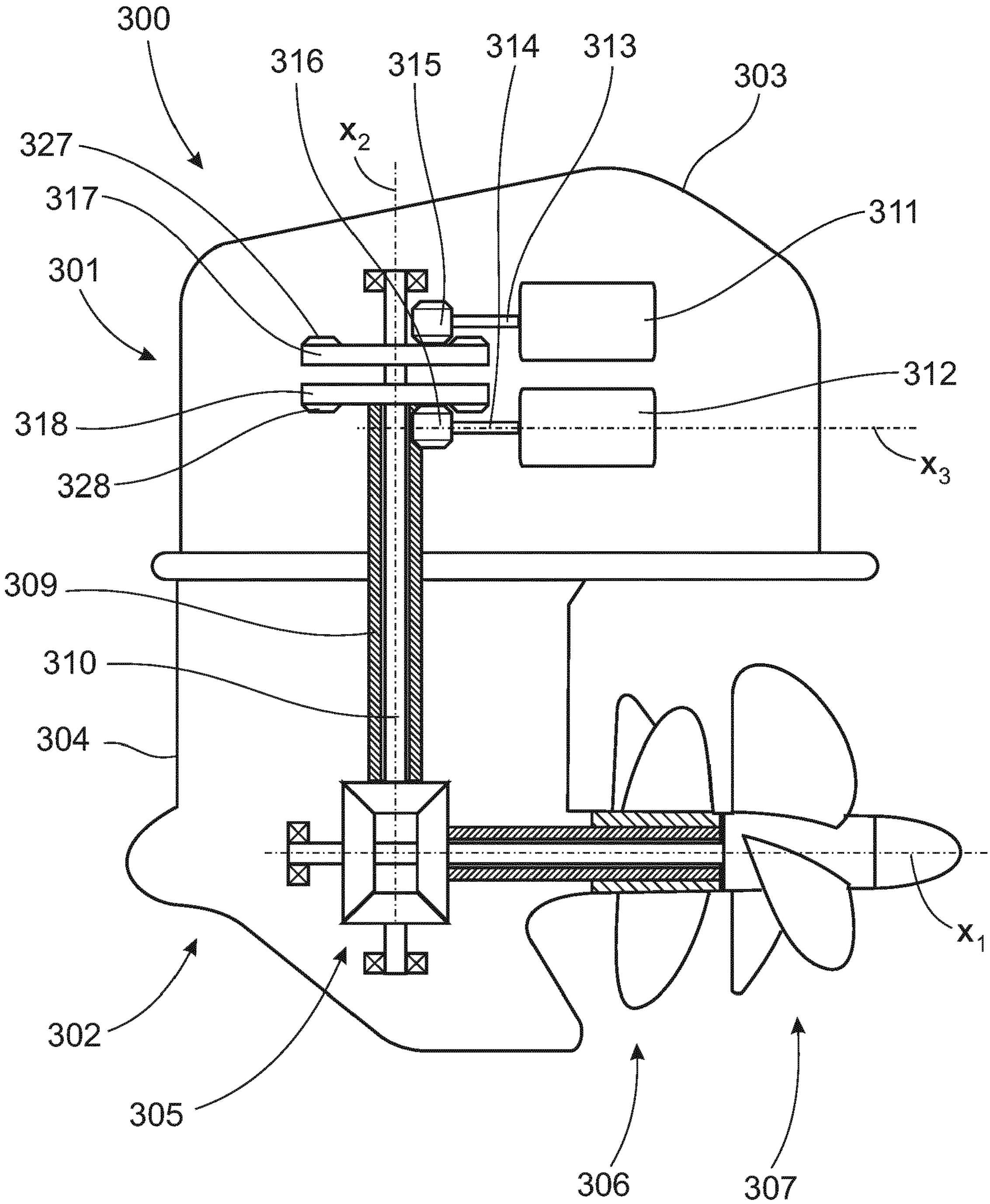
205
206
207

Fig.2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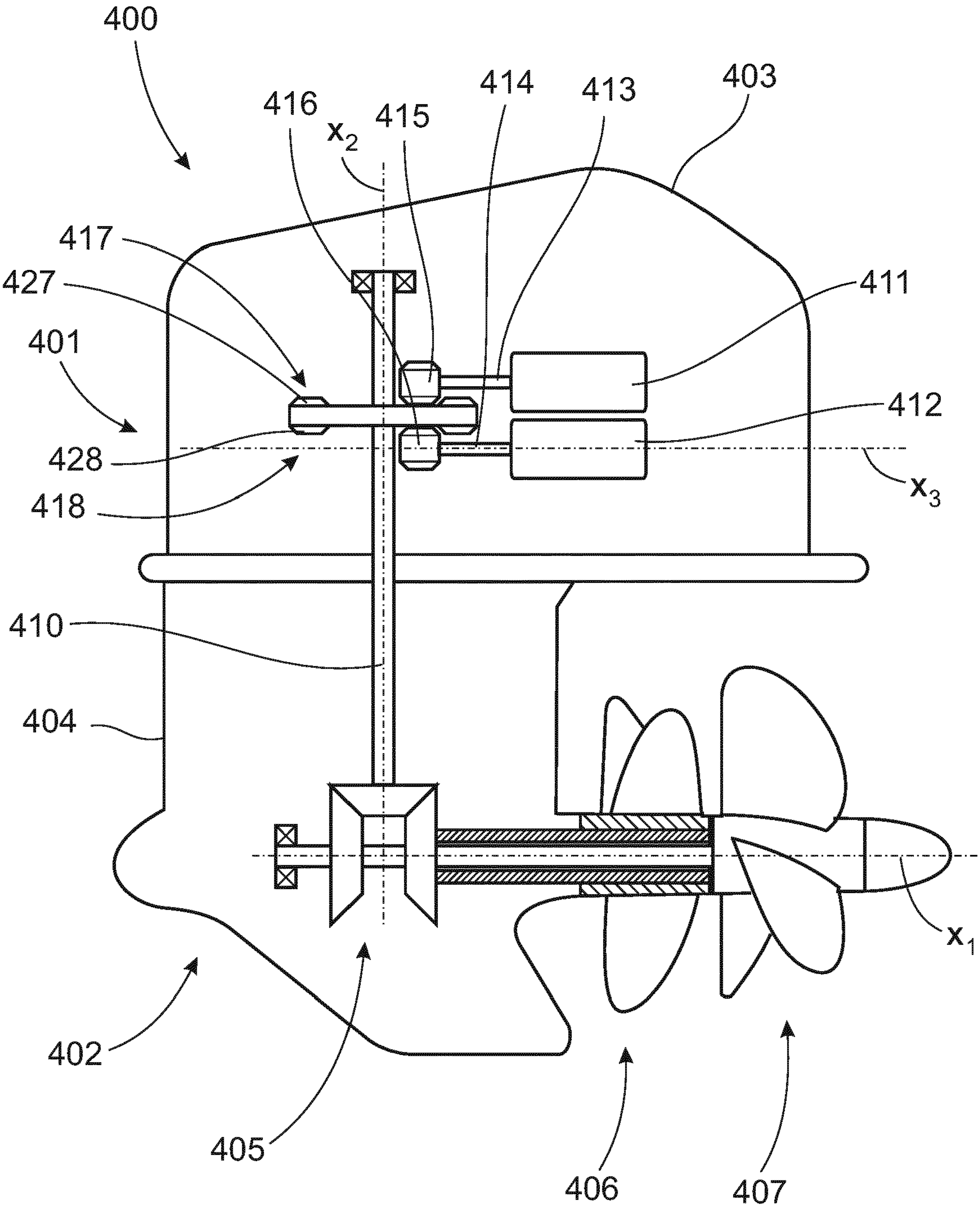
306
307

Fig.3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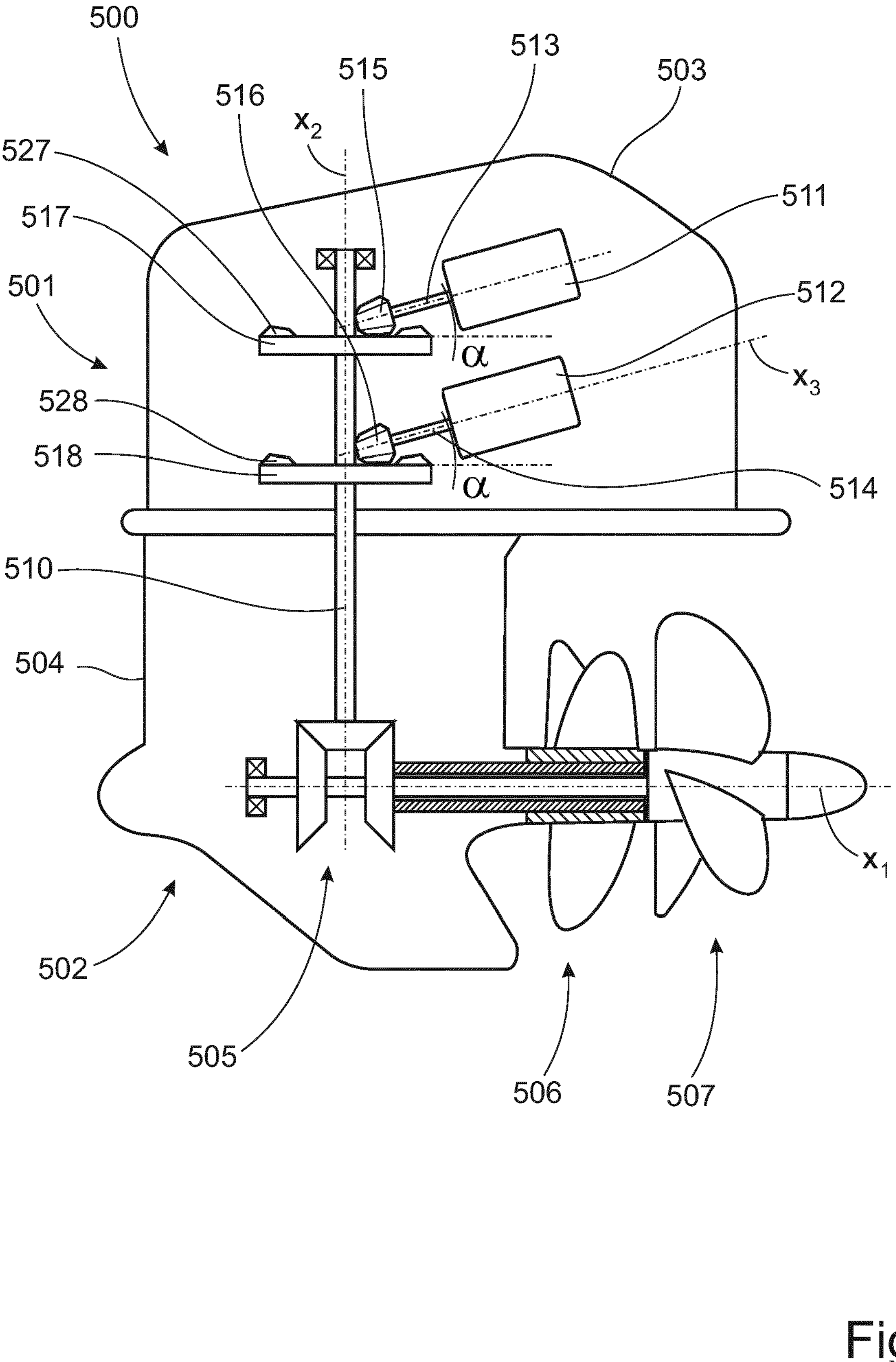
407
x_1

Fig.4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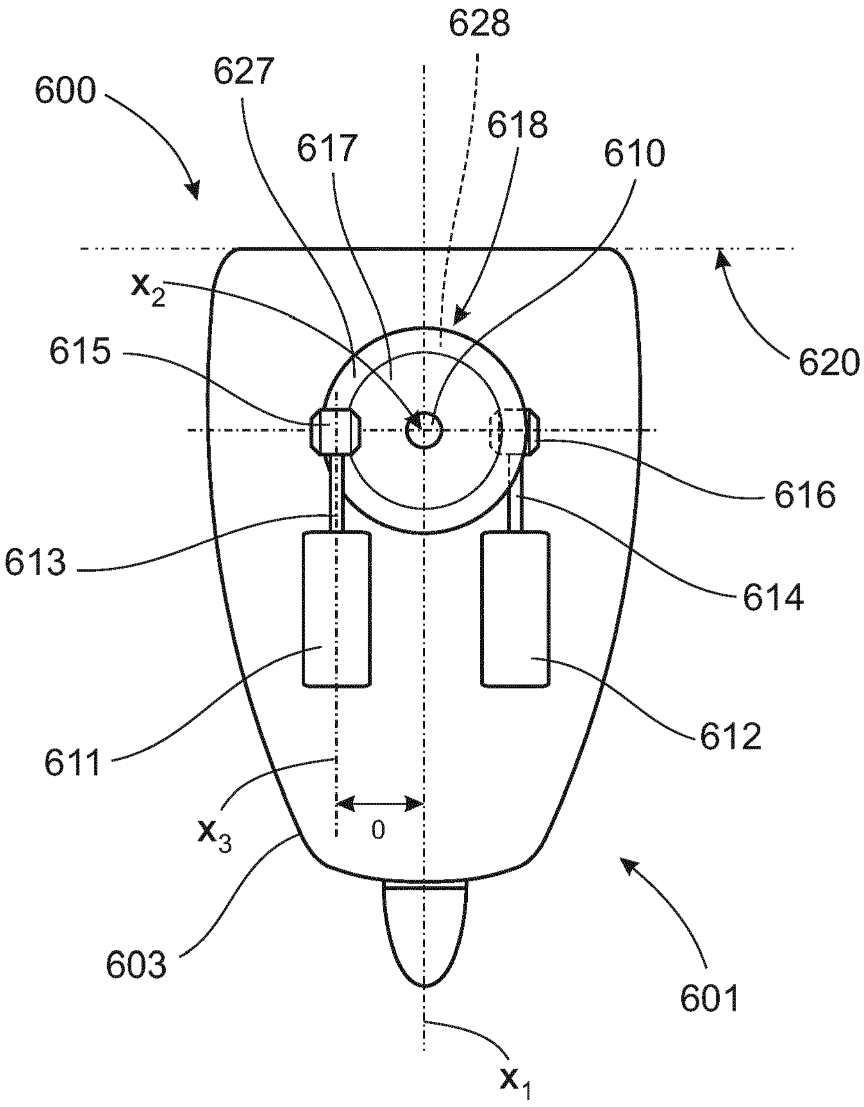
506
507

Fig.5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611
612
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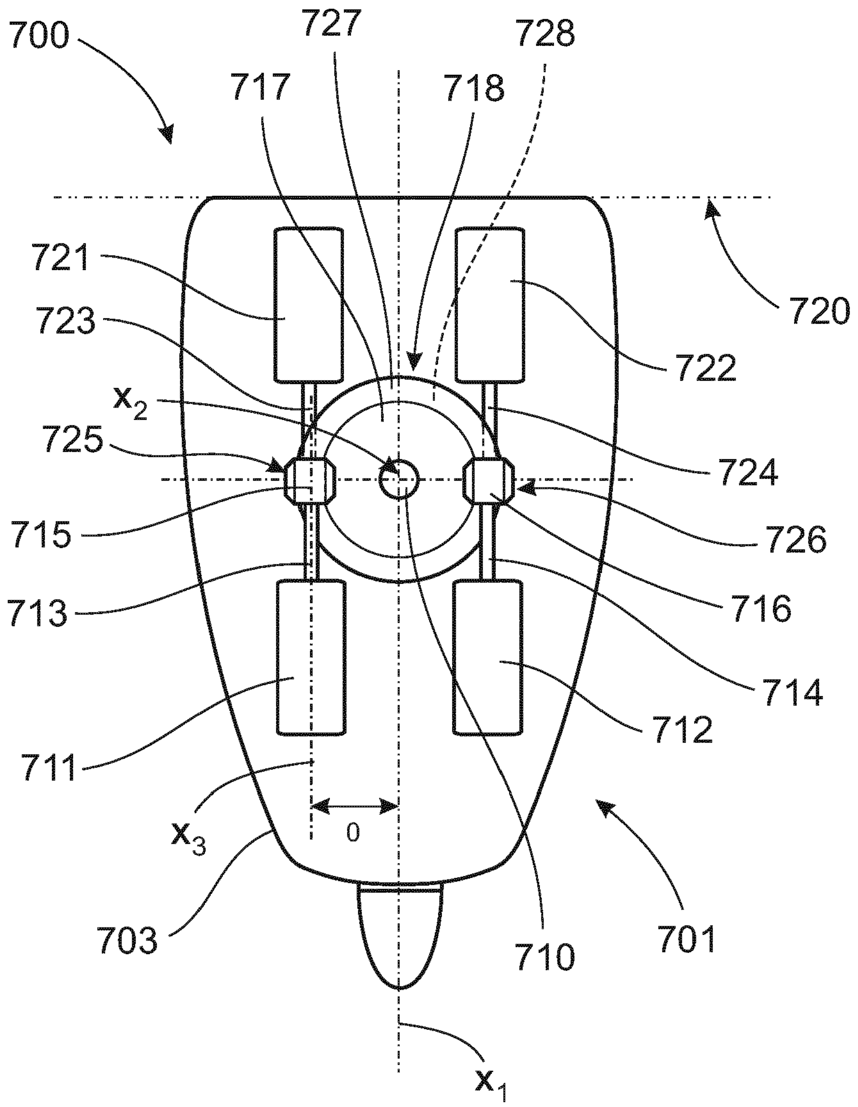
601
x1

Fig.6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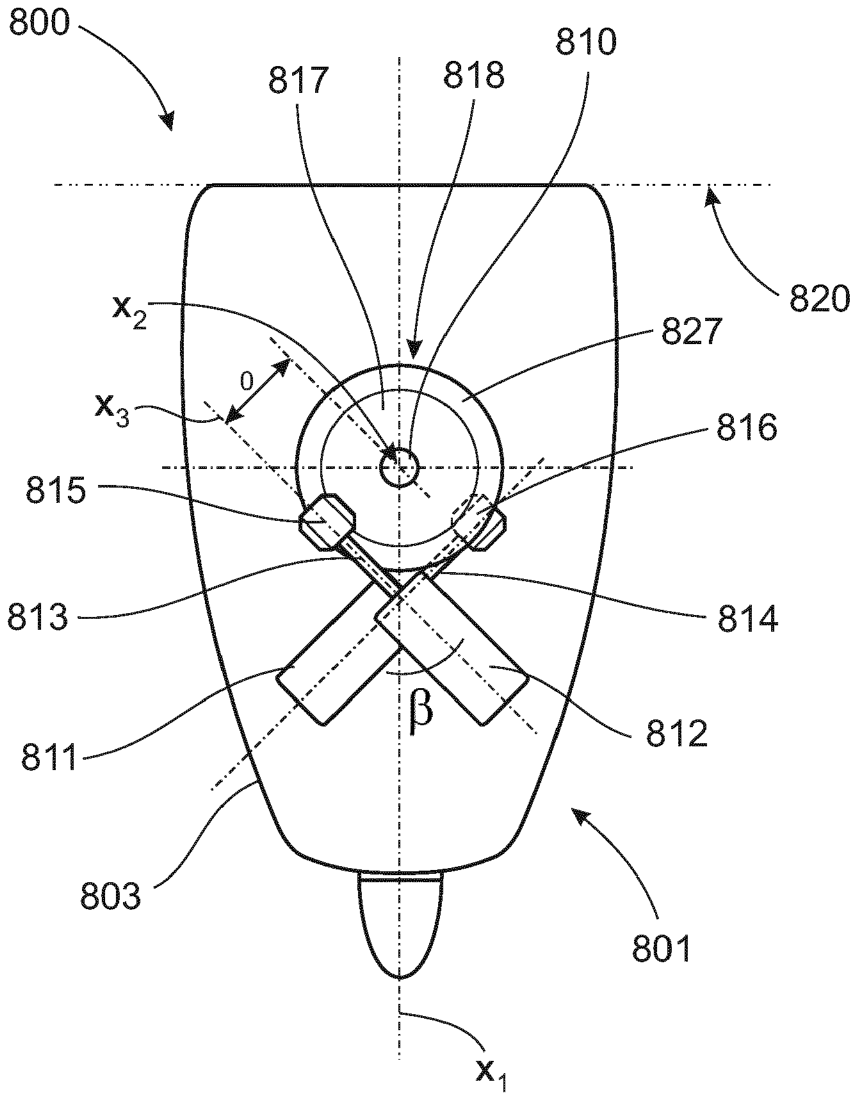
701
x_1

Fig.7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801
x1

Fig.8

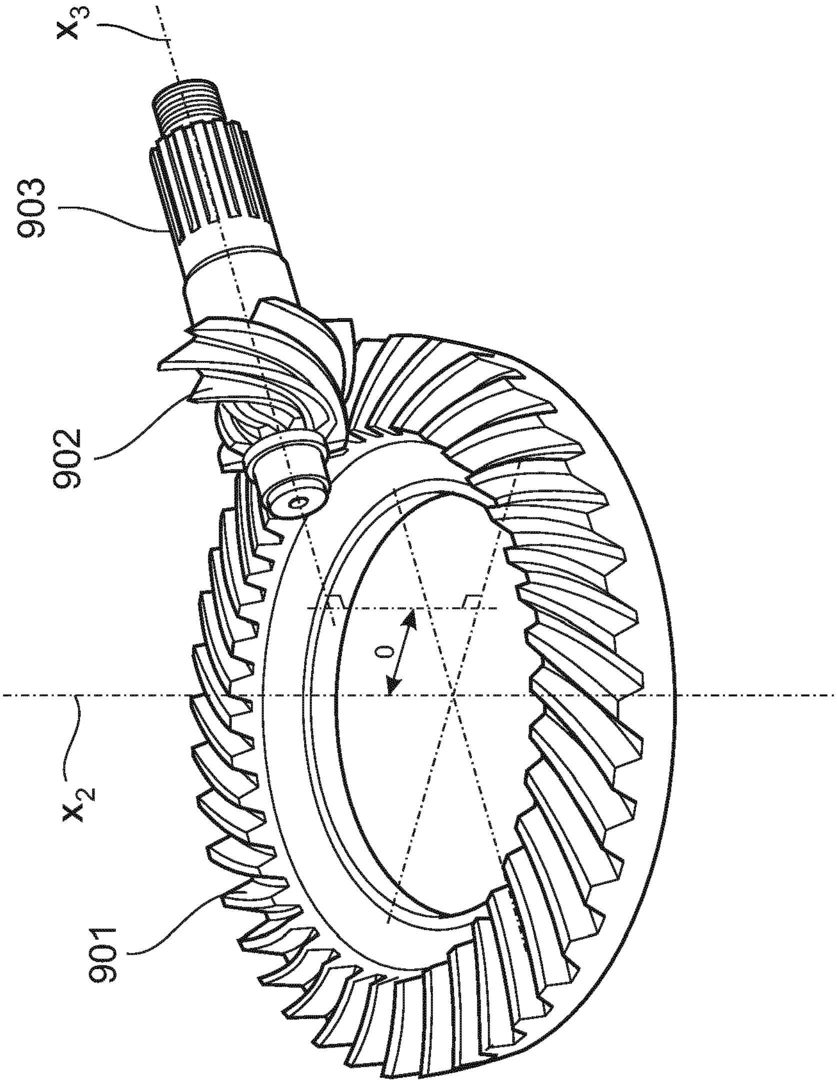

Fig.9

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EUROPEAN SEARCH REPORT

Application Number
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