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**(54) A DRIVE ASSEMBLY FOR A MARINE DUAL-PROPELLER DRIVE UNIT**

(57) A drive assembly (1) for a marine propeller drive unit, said drive assembly (1) comprising two concentric drive shafts for carrying a respective propeller. A space between the drive shafts is lubricated with liquid lubricant pumped into the space by a pump. The outermost drive shaft (3) is provided with at least one protrusion (20) protruding radially inwards from an inner surface of the

outer drive shaft (3). The inlet (17) of the secondary fluid channel (16) is provided in said at least one protrusion (20) at a first radial level (21) offset radially inwards from the inner surface of the outer drive shaft (3) such that liquid lubricant at said first radial level (21) is able to lubricate bearings (11) between the outermost drive shaft (3) and the innermost drive shaft (6).

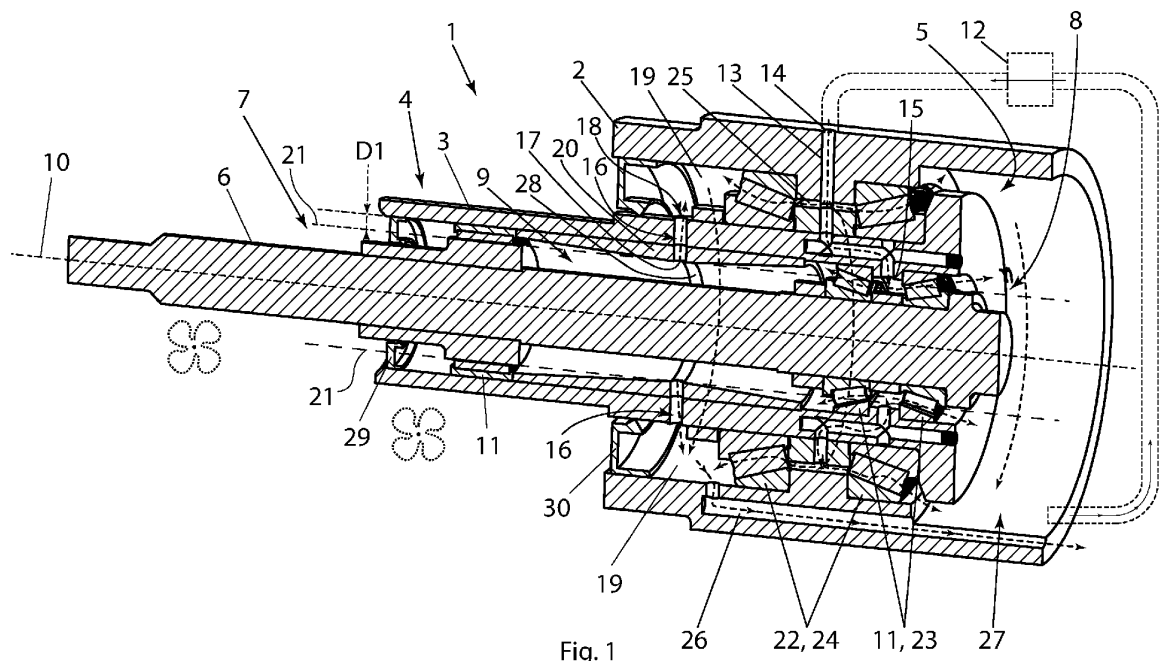


Fig. 1

**EP 4 570 643 A1**

## Description

### TECHNICAL FIELD

5 **[0001]** The present disclosure relates to a drive assembly for a marine dual-propeller drive unit. Specifically, the present disclosure relates to a design of a lubrication system integrated in such drive assemblies.

### BACKGROUND

10 **[0002]** Marine dual-propeller drive units typically comprise two co-axial drive shafts each configured to carry a respective propeller. In use the propellers are typically counter rotating. The inner drive shaft is supported in the outer drive shaft, typically using bearings. A space between the outer drive shaft and the inner drive shaft is typically filled with liquid lubricant for lubrication of the bearings. A general goal of the present disclosure is to reduce friction in the marine dual-propeller drive unit, thereby reducing power consumption.

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### SUMMARY

**[0003]** According to a first aspect of the disclosure, the goal is achieved by a drive assembly for a marine dual-propeller drive unit. The drive assembly comprises:

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a housing,  
an outer drive shaft assembly comprising an outer drive shaft comprising an outer end portion for holding a first propeller and an axially opposite inner end portion for connection to a gear or a motor,  
an inner drive shaft assembly comprising an inner drive shaft comprising an inner end portion for holding a second propeller and an axially opposite inner end portion for connection to a gear or a motor, and a lubrication system.

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**[0004]** The outer drive shaft comprises a through central opening extending along a rotational axis of the outer drive shaft.

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**[0005]** The inner drive shaft extends co-axially with the outer drive shaft, through the central opening of the outer drive shaft.

**[0006]** A plurality of primary bearings are mounted in the central opening for rotationally supporting the inner drive shaft in the outer drive shaft such that the inner drive shaft and the outer drive shaft are rotatable relative to each other about the rotational axis.

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**[0007]** A plurality of secondary bearings are mounted around the outer drive shaft for rotationally supporting the outer drive shaft in the housing such that the outer drive shaft is rotatable relative to the housing about the rotational axis.

**[0008]** The lubrication system comprises a liquid lubricant pump, and a primary fluid channel comprising a primary inlet fluidly connected to the liquid lubricant pump for receiving pressurized liquid lubricant, and at least one primary outlet emanating in the central opening of the outer drive shaft.

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**[0009]** The outer drive shaft comprises at least one secondary fluid channel extending from a secondary inlet facing the central opening to a secondary outlet facing an outer space between the housing and a radial outside of the outer drive shaft.

**[0010]** The outer drive shaft is provided with at least one protrusion protruding radially inwards from an inner surface of the outer drive shaft.

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**[0011]** The secondary inlet of the secondary fluid channel is provided in said at least one protrusion at a first radial level offset radially inwards from the inner surface of the outer drive shaft such that liquid lubricant at said first radial level is able to lubricate at least some of the primary bearings.

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**[0012]** In use, liquid lubricant, such as a suitable oil, is forced by the pump into the central opening of the outer drive shaft through the primary fluid channel. Inside the central opening the liquid lubricant is forced radially outwards by centrifugal force thereby spreading the liquid lubricant in the central opening space along the length of the outer drive shaft. As more liquid lubricant is pumped into the central opening, the radial thickness of the layer of liquid lubricant formed inside the central opening increases and eventually the thickness of the layer of liquid lubricant will be enough to provide proper lubrication to the primary bearings. Also, depending on the location(s) at which liquid lubricant emanated from the first fluid channel into the central opening, the liquid lubricant will also be forced through one or more primary bearings. Also, any tapered roller bearings will, depending on their orientation, provide an additional force moving liquid lubricant through the tapered bearing. The pressure of the liquid lubricant may also be used to force liquid lubricant through the secondary bearings supporting the outer drive shaft in the housing.

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**[0013]** The secondary fluid channel enables liquid lubricant to escape the central opening such that the space between the outer drive shaft and the inner drive shaft is not filled with liquid lubricant, thereby enabling the inner shaft to rotate

surrounded by gas rather than liquid, such that friction between the inner drive shaft and the surrounding fluid is mitigated.

**[0014]** The provision of the at least one protrusion offset radially inwards from the inner surface of the outer drive shaft establishes a minimum thickness of the layer of liquid lubricant, thus ensuring proper lubrication of primary bearings.

**[0015]** Optionally in some examples, including in at least one preferred example, the housing may be provided with a return channel fluidly connecting a lower portion of the outer space to a sump. The sump may be vented to atmospheric pressure and said liquid lubricant pump fluidly connected to the sump to pump liquid lubricant from the sump.

**[0016]** As liquid lubricant passes through the secondary fluid channel, the liquid lubricant will eventually reach the housing and flow to the sump by the force of gravity. The pump picks up liquid lubricant from the sump and forces it back into the first fluid channel. Accordingly, liquid lubricant is circulated in the drive assembly without filling up the central opening of the outer drive shaft.

**[0017]** Optionally in some examples, including in at least one preferred example, the sump is fluidly connected to ambient air at atmospheric pressure.

**[0018]** By fluidly connecting the sump to ambient air, pressure increase in the sump is mitigated and oil can be pumped into the central opening without risking pressure increase in the housing.

**[0019]** Optionally in some examples, including in at least one preferred example, the protrusion comprises a ridge extending circumferentially about the rotational axis.

**[0020]** The circumferential extension of the ridge promotes improved spread of liquid lubricant as liquid lubricant fills up on the side of the ridge from which liquid lubricant is supplied from the pump and flows over the ridge to the other axial side of the ridge.

**[0021]** Optionally in some examples, including in at least one preferred example, said protrusion is formed by an insert mounted to the outer drive shaft.

**[0022]** The insert allows the inner drive shaft to be inserted into the central opening of the outer drive shaft before the insert is mounted. Hence, the protrusion will not obstruct mounting of the inner drive shaft and the primary bearings.

**[0023]** Optionally in some examples, including in at least one preferred example, the outer drive shaft comprises a plurality of said secondary fluid channels.

**[0024]** The provision of a plurality of secondary fluid channels promotes an even distribution of the thickness of the layer of liquid lubricant inside the outer drive shaft and reduces the risk of failure due to clogging of the secondary fluid channel. Also, improved balancing of the outer drive shaft is enabled since the positions of the secondary fluid channels may be varied at production of the outer drive shaft. Further, the cross-sectional size of each secondary fluid channel may be decreased without reducing the total cross-sectional size of the secondary fluid channels, hence promoting a more even spread of stress through the material of the outer drive shaft.

**[0025]** Optionally in some examples, including in at least one preferred example, the plurality of secondary fluid channels are circumferentially distributed about the rotational axis such that the outer drive shaft is balanced about the rotational axis.

**[0026]** Optionally in some examples, including in at least one preferred example, the primary fluid channel extends through the housing to a confined space between the outer drive shaft and the housing, and through one or more fluid channels in the outer drive shaft from the confined space to said one or more primary outlets.

**[0027]** As liquid lubricant is pumped into the confined space, the space is filled with liquid lubricant. As more liquid lubricant is pumped into the confined space, liquid lubricant leaves the confined space via the one or more fluid channels to the one or more primary outlets. The confined space provides a fluid path from the pump to the primary outlets independently of the relative rotation between the outer drive shaft and the housing, hence enabling continuous lubrication also when the outer drive shaft is rotating relatively the housing.

**[0028]** Optionally in some examples, including in at least one preferred example, the primary bearings comprise two tapered roller bearings provided at the inner end portion of the inner drive shaft. The tapered roller bearings are spaced-apart and oriented to withstand axial force in opposite axial directions. Also, the primary fluid channel comprises a primary outlet emanating between the tapered roller bearings of the primary bearings.

**[0029]** The tapered roller bearings rotatably support the inner drive shaft and co-operate to withstand axial loading of the inner drive shaft caused by force from a propeller mounted on the inner drive shaft. The provision of a primary outlet between the tapered roller bearings enabled liquid lubricant to be forced through the tapered roller bearings, thus ensuring proper lubrication also for the tapered roller bearing closest to inner end portion of the inner drive shaft. Hence, some liquid lubricant may move directly from the central opening to the sump through one of the tapered roller bearings, whilst some liquid lubricant will move through the other tapered roller bearing and subsequently form the layer of liquid lubricant and eventually exit through the secondary fluid channel(s).

**[0030]** Optionally in some examples, including in at least one preferred example, the secondary bearings comprise two tapered roller bearings provided at the inner end portion of the outer drive shaft, said tapered roller bearings being spaced-apart and oriented to withstand axial force in opposite axial directions, and said confined space being provided between the tapered roller bearings of the secondary bearings.

**[0031]** The tapered roller bearings rotatably support the outer drive shaft and co-operate to withstand axial loading of the

outer drive shaft caused by force from a propeller mounted on the outer drive shaft. The provision of a primary outlet between the tapered roller bearings enabled liquid lubricant to be forced through the tapered roller bearings, thus ensuring proper lubrication also for the tapered roller bearing closest to inner end portion of the outer drive shaft. Hence, some liquid lubricant will move directly from the confined space to the sump through the respective tapered roller bearings, whilst some liquid lubricant will move to the one or more primary outlets.

[0032] Optionally in some examples, including in at least one preferred example, the primary bearings further comprise at least one bearing provided at the outer end portion of the inner drive shaft.

[0033] The bearing provided at the outer end portion of the inner drive shaft cooperates with the other secondary bearings to withstand radial forces and associated momentum on the inner drive shaft.

[0034] Optionally in some examples, including in at least one preferred example, the primary bearing provided at the outer end portion of the inner drive shaft is a needle bearing.

[0035] Optionally in some examples, including in at least one preferred example, a first seal is provided between the inner drive shaft and the outer drive shaft at the outer end portion, and a second seal is provided between the outer drive shaft and the housing at the outer end portion of the outer drive shaft.

[0036] The seals keep liquid lubricant inside the housing and thus lowers consumption of liquid lubricant thus enabling use of a lower-capacity pump with lower energy consumption.

[0037] According to a second aspect of the disclosure, a propeller drive unit is provided, said propeller drive unit comprising the drive shaft assembly described above, a motor and a planetary gear. The planetary gear comprises a ring gear, a planetary carrier and a sun gear. The ring gear may be connected to the outer drive shaft, and the planetary carrier may be connected to the inner drive shaft or integrated with the inner drive shaft. Also, the sun gear is operatively connected to the motor.

[0038] The planetary gear provides a simple and robust means of rotating the outer drive shaft and the inner drive shaft in different rotational directions with respect to the rotational axis.

[0039] According to a second aspect of the disclosure, a marine vessel is provided, said marine vessel comprising the above-described propeller drive unit. The marine vessel may for example be a boat or a ship.

[0040] The disclosed aspects, examples (including any preferred examples), and/or accompanying claims may be suitably combined with each other as would be apparent to anyone of ordinary skill in the art. Additional features and advantages are disclosed in the following description, claims, and drawings, and in part will be readily apparent therefrom to those skilled in the art or recognized by practicing the disclosure as described herein.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0041]

Fig. 1 shows a cross-sectional perspective view of a first embodiment of a drive assembly according to the present disclosure.

Fig. 2 shows a cross-sectional perspective view corresponding to the one of the drive assembly also shown in fig. 1, however also provided with a planetary gear and a shaft for driving sun gears of the planetary gear.

## DETAILED DESCRIPTION

[0042] The detailed description set forth below provides information and examples of the disclosed technology with sufficient detail to enable those skilled in the art to practice the disclosure.

[0043] A problem to be solved by the present disclosure is how to reduce friction in a marine dual-propeller drive unit, thereby reducing power consumption. This problem is solved by a drive assembly 1 for a marine dual-propeller drive unit. A first embodiment of the drive assembly 1 is shown in fig. 1. The drive assembly 1 comprises:

a housing 2, an outer drive shaft assembly comprising an outer drive shaft 3 comprising an outer end portion 4 for holding a first propeller (not shown) and an axially opposite inner end portion 5 for connection to a gear (fig. 2) or a motor, an inner drive shaft assembly comprising an inner drive shaft 6 comprising and outer end portion 7 for holding a second propeller (not shown) and an axially opposite inner end portion 8 for connection to a gear (fig. 2) or a motor, and a lubrication system.

[0044] The outer drive shaft 3 comprises a through central opening 9 extending along a rotational axis 10 of the outer drive shaft 3.

[0045] The inner drive shaft 6 extends co-axially with the outer drive shaft 3, through the central opening 9 of the outer drive shaft 3.

[0046] A plurality of primary bearings 11 are mounted in the central opening 9 for rotationally supporting the inner drive shaft 6 in the outer drive shaft 3 such that the inner drive shaft 6 and the outer drive shaft 3 are rotatable relatively each other about the rotational axis 10. The respective end portions for receiving a propeller are indicated by the propeller symbols in Fig. 1.

In other embodiments, the number of primary bearings 11 may be higher or lower and the type of bearings of the primary bearings 11 may differ from the ones of this embodiment.

**[0047]** A plurality of secondary bearings 22 are mounted around the outer drive shaft 3 for rotatably supporting the outer drive shaft 3 in the housing 2 such that the outer drive shaft 3 is rotatable relatively the housing 2 about the rotational axis 10.

In other embodiments, the number of secondary bearings 22 may be higher or lower and the type of bearings of the secondary bearings 22 may differ from the ones of this embodiment.

**[0048]** The lubrication system comprises a liquid lubricant pump 12, and a primary fluid channel 13 comprising a primary inlet 14 fluidly connected to the liquid lubricant pump 12 for receiving pressurized liquid lubricant, and at least one primary outlet 15 emanating in the central opening 9 of the outer drive shaft 3.

**[0049]** The outer drive shaft 3 comprises at least one secondary fluid channel 16 extending from a secondary inlet 17 facing the central opening 9 to a secondary outlet 18 facing an outer space 19 between the housing 2 and a radial outside of the outer drive shaft 3.

**[0050]** The outer drive shaft 3 is provided with at least one protrusion 20 protruding radially inwards from an inner surface of the outer drive shaft 3.

**[0051]** The secondary inlet 17 of the secondary fluid channel 16 is provided in said at least one protrusion 20 at a first radial level 21 offset radially inwards from the inner surface of the outer drive shaft 3 such that liquid lubricant at said first radial level 21 is able to lubricate at least some of the primary bearings 11.

**[0052]** In use, liquid lubricant, such as a suitable oil, is forced by the pump 12 into the central opening 9 of the outer drive shaft 3 through the primary fluid channel 13. Inside the central opening 9, the liquid lubricant is forced radially outwards by centrifugal force thereby spreading the liquid lubricant in the central opening 9 along the length of the outer drive shaft 3. As more liquid lubricant is pumped into the central opening 9, the radial thickness D1 of the layer of liquid lubricant formed inside the central opening 9 increases and eventually the thickness of the layer of liquid lubricant will be enough to provide proper lubrication to the primary bearings 11. Also, depending on the location(s) at which liquid lubricant emanated from the first fluid channel into the central opening 9, the liquid lubricant will also be forced through one or more primary bearings 11. Also, any tapered roller bearings 23, 24 will, depending on its orientation, provide an additional force moving liquid lubricant through the tapered roller bearing 23, 24. The pressure of the liquid lubricant may also be used to force liquid lubricant through the secondary bearings 22 supporting the outer drive shaft 3 in the housing 2.

**[0053]** The secondary fluid channel 16 enables liquid lubricant to escape the central opening 9 such that the space between the outer drive shaft 3 and the inner drive shaft 6 is not filled with liquid lubricant, thereby enabling the inner shaft to rotate surrounded by gas rather than liquid, such that friction between the inner drive shaft 6 and the surrounding fluid is mitigated.

**[0054]** The provision of the at least one protrusion 20 offset radially inwards from the inner surface of the outer drive shaft 3 establishes a minimum thickness of the layer of liquid lubricant, thus ensuring proper lubrication of primary bearings 11.

**[0055]** As shown in the lower portion of Fig. 1, the housing 2 is provided with a return channel 26 fluidly connecting a lower portion of the outer space to a sump 27. The sump (27) may be vented to atmospheric pressure and said liquid lubricant pump 12 fluidly connected to the sump 27 to pump liquid lubricant from the sump 27. The position, size and extent of the return channel 26 is preferably such that liquid lubricant is able to flow through the return channel 26 by the force of gravity. In other embodiments, the return channel 26 may have any other suitable position, size and extent.

**[0056]** As liquid lubricant passes through the secondary fluid channel 16, the liquid lubricant will eventually reach the housing 2 and flow to the sump 27 by the force of gravity. The pump 12 picks up liquid lubricant from the sump 27 and forces it back into the first fluid channel. Accordingly, liquid lubricant is circulated in the drive assembly 1 without filling up the central opening 9 of the outer drive shaft 3.

**[0057]** The sump 27 is fluidly connected to ambient air at atmospheric pressure but may in other embodiments be isolated from ambient air.

**[0058]** By fluidly connecting the sump 27 to ambient air, pressure increase in the sump 27 is mitigated and oil can be pumped into the central opening 9 without risking pressure increase in the housing 2.

**[0059]** The at least one protrusion 20 protruding radially inwards from an inner surface of the outer drive shaft 3 comprises a ridge 28 extending circumferentially about the rotational axis 10. In other embodiments the protrusion 20 may have any other suitable shape, for example without a ridge 28. However, the protrusion 20 of the embodiment illustrated in Fig. 1 may be produced in a cost-effective manner by turning.

**[0060]** The circumferential extension of the ridge 28 promotes improved spread of liquid lubricant as liquid lubricant fills up on the side of the ridge 28 from which liquid lubricant is supplied from the pump 12 and flows over the ridge 28 to the other axial side of the ridge 28.

**[0061]** The protrusion 20 is formed by an insert mounted to the outer drive shaft 3 but may in other embodiments alternatively be integrally formed with the outer drive shaft 3.

**[0062]** The insert allows the inner drive shaft 6 to be inserted into the central opening 9 of the outer drive shaft 3 before the insert is mounted. Hence, the protrusion 20 will not obstruct mounting of the inner drive shaft 6 and the primary bearings 11.

**[0063]** In this embodiment, the outer drive shaft 3 comprises two of said secondary fluid channels 16. In other embodiments, the outer drive shaft 3 may alternatively comprise only one secondary fluid channel 16, or more than two secondary fluid channels 16.

**[0064]** The provision of a plurality of secondary fluid channels 16 promotes an even distribution of the thickness of the layer of liquid lubricant inside the outer drive shaft 3 and reduces the risk of failure due to clogging of the secondary fluid channel 16. Also, improved balancing of the outer drive shaft 3 is enabled since the positions of the secondary fluid channels 16 may be varied at production of the outer drive shaft 3. Further, the cross-sectional size of each secondary fluid channel 16 may be decreased without reducing the total cross-sectional size of the secondary fluid channels 16, hence promoting a more even spread of stress through the material of the outer drive shaft 3.

**[0065]** The plurality of secondary fluid channels 16 are circumferentially distributed about the rotational axis 10 such that the outer drive shaft 3 is balanced about the rotational axis 10. In other embodiments, the plurality of secondary fluid channels 16 may alternatively be otherwise distributed and positioned in other positions than the ones shown in Fig. 1. For example, a plurality of secondary fluid channels 16 may have different axial positions with respect to the rotational axis 10.

**[0066]** The primary fluid channel 13 extends through the housing 2 to a confined space 25 between the outer drive shaft 3 and the housing 2, and through one or more fluid channels in the outer drive shaft 3 from the confined space 25 to said one or more primary outlets 15. The fluid channel through the outer drive shaft 3 may be achieved using any suitable production method, but in the present embodiment it is produced by drilling a hole from the inner end portion 5 of the outer drive shaft 3 substantially parallel to the rotational axis 10 and by radially drilling two other holes such that a first radially drilled hole connects to the confined space 25, and such that a second radially drilled hole forms one of said at least one primary outlets 15 and fluidly connects to the axially drilled hole. As indicated by the black colored area at the inlet of the axially drilled hole, an outer opening of the axially drilled hole is subsequently plugged, or otherwise closed, to prevent liquid lubricant from exiting the primary fluid channel 13 through an inner end of the outer drive shaft 3. The confined space 25 may be achieved in any suitable way, such as by providing a radial spacing between the outer drive shaft 3 and the housing 2, and axially surrounding the confined space 25 using bearings and/or ridges extending from the housing 2 or extending from the outer drive shaft 3. In the present embodiment, two bearings 11, 23 axially confined the confined space 25 but in other embodiments, a close fit between the housing 2 and an outer surface of the outer drive shaft 3 may sufficiently prevent/limit fluid leak from the confined space 25 radially outside the outer drive shaft 3. Further, one or more seals may be provided between the housing 2 and the outer drive shaft 3 to axially confine the confined space 25.

**[0067]** As liquid lubricant is pumped into the confined space 25, the space is filled with liquid lubricant. As more liquid lubricant is pumped into the confined space 25, liquid lubricant leaves the confined space 25 via the one or more fluid channels to the one or more primary outlets 15. The confined space 25 provides a fluid path from the pump 12 to the primary outlets 15 independently of the relative rotation between the outer drive shaft 3 and the housing 2, hence enabling continuous lubrication also when the outer drive shaft 3 is rotating relatively the housing 2.

**[0068]** As shown in fig. 1, the primary bearings 11 in this embodiment comprises two tapered roller bearings 23 provided at the inner end portion 8 of the inner drive shaft 6. The tapered roller bearings 23 are spaced-apart and oriented to withstand axial force in opposite axial directions. Also, the primary fluid channel 13 comprises a primary outlet 15 emanating between the tapered roller bearings 23 of the primary bearings 11. In other embodiments, the primary outlets 15 may be provided at other positions, not necessarily between the tapered roller bearings 23, as long as the liquid lubricant is able to move through, or past, the bearings to reach and sufficiently lubricate all bearings. For example, an axially extending groove may be provided on an inside surface of the outer drive shaft 3 to enable increased flow of liquid lubricant past one or more primary bearings 11.

**[0069]** The tapered roller bearings 23 rotatably support the inner drive shaft 6 and co-operate to withstand axial loading of the inner drive shaft 6 caused by force from a propeller mounted on the inner drive shaft 6. The provision of a primary outlet 15 between the tapered roller bearings 23 enabled liquid lubricant to be forced through the tapered roller bearings 23, thus ensuring proper lubrication also for the tapered roller bearing closest to inner end portion 8 of the inner drive shaft 6. Hence, some liquid lubricant may move directly from the central opening 9 to the sump 27 through one of the tapered roller bearings 23, whilst some liquid lubricant will move through the other tapered roller bearing and subsequently form the layer of liquid lubricant and eventually exit through the secondary fluid channels 16.

**[0070]** The secondary bearings 22 comprise two tapered roller bearings 24 provided at the inner end portion 5 of the outer drive shaft 3, said tapered roller bearings 24 being spaced-apart and oriented to withstand axial force in opposite axial directions, and said confined space 25 being provided between the tapered roller bearings 24 of the secondary bearings 22. In other embodiments, other types of bearings may alternatively be provided adjacent the confined space 25, or no primary bearings 11 may be provided adjacent the confined space 25, as discussed above.

**[0071]** The tapered roller bearings 24 rotatably support the outer drive shaft 3 and co-operate to withstand axial loading of the outer drive shaft 3 caused by force from a propeller mounted on the outer drive shaft 3. The provision of a primary outlet 15 between the tapered roller bearings 24 enabled liquid lubricant to be forced through the tapered roller bearings 24, thus ensuring proper lubrication also for the tapered roller bearing closest to inner end portion 5 of the outer drive shaft 3. Hence, some liquid lubricant will move directly from the confined space 25 to the sump 27 through the respective tapered

roller bearings 24, whilst some liquid lubricant will move to the one or more primary outlets 15.

**[0072]** The primary bearings 11 further comprise at least one bearing provided at the outer end portion 7 of the inner drive shaft 6. In other embodiments, this bearing may alternatively be omitted or otherwise positioned, depending on the calculated stress and need of off-loading other primary bearings 11.

**[0073]** The bearing provided at the outer end portion 7 of the inner drive shaft 6 cooperates with the other secondary bearings 22 to withstand radial forces and associated momentum on the inner drive shaft 6.

**[0074]** The primary bearing 11 provided at the outer end portion 7 of the inner drive shaft 6 is a needle bearing but may in other embodiments alternatively be any other suitable type of bearing.

**[0075]** As shown in Fig. 1, a first seal 29 is provided between the inner drive shaft 6 and the outer drive shaft 3 at the outer end portion 7, and a second seal 30 is provided between the outer drive shaft 3 and the housing 2 at the outer end portion 4 of the outer drive shaft 3. In other embodiments, the number of seals and positions of the seals may be suitably varied. Alternatively, the seals may be omitted although that would lead to increased use of liquid lubricant.

**[0076]** The seals keep liquid lubricant inside the housing 2 and thus lowers consumption of liquid lubricant thus enabling use of a lower-capacity pump 12 with lower energy consumption.

**[0077]** According to a second aspect of the disclosure, a propeller drive unit is provided (the propeller drive unit is not shown in Fig. 1). The propeller drive unit comprises the drive assembly 1 described above, a planetary gear and preferably a motor. As shown in fig. 2, the planetary gear comprises a ring gear 31, a planetary carrier 32 and a sun gear 33. The ring gear 31 may be connected to the outer drive shaft 3, and the planetary carrier 32 may be connected to the inner drive shaft 6 or integrated with the inner drive shaft 6. Also, the sun gear 33 is operatively connected to, or connectable to, said motor. In other embodiments, the planetary gear may be omitted and torque provided to the respective drive shaft in any other suitable way, such as from a respective motor. The motor may be a combustion engine or an electric motor, or a hybrid-electric motor.

**[0078]** The planetary gear provides a simple and robust means of rotating the outer drive shaft 3 and the inner drive shaft 6 in different rotational directions with respect to the rotational axis 10.

**[0079]** These terms are only used to distinguish one element from another. For example, a first element could be termed a second element, and, similarly, a second element could be termed a first element without departing from the scope of the present disclosure.

**[0080]** Relative terms such as "below" or "above" or "upper" or "lower" or "horizontal" or "vertical" may be used herein to describe a relationship of one element to another element as illustrated in the Figures. It will be understood that these terms and those discussed above are intended to encompass different orientations of the device in addition to the orientation depicted in the Figures. It will be understood that when an element is referred to as being "connected" or "coupled" to another element, it can be directly connected or coupled to the other element, or intervening elements may be present. In contrast, when an element is referred to as being "directly connected" or "directly coupled" to another element, there are no intervening elements present.

**[0081]** Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure belongs. It will be further understood that terms used herein should be interpreted as having a meaning consistent with their meaning in the context of this specification and the relevant art and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

**[0082]** It is to be understood that the present disclosure is not limited to the aspects 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 present disclosure and appended claims. In the drawings and specification, there have been disclosed aspects for purposes of illustration only and not for purposes of limitation, the scope of the disclosure being set forth in the following claims.

*Table of reference numerals*

|   |                                        |
|---|----------------------------------------|
| 1 | drive assembly                         |
| 2 | housing                                |
| 3 | outer drive shaft                      |
| 4 | outer end portion of outer drive shaft |
| 5 | inner end portion of outer drive shaft |
| 6 | inner drive shaft                      |
| 7 | outer end portion of inner drive shaft |
| 8 | inner end portion of inner drive shaft |

(continued)

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|    |                                                                     |
|----|---------------------------------------------------------------------|
| 9  | through central opening                                             |
| 10 | rotational axis                                                     |
| 11 | primary bearings                                                    |
| 12 | liquid lubricant pump                                               |
| 13 | primary fluid channel                                               |
| 14 | primary inlet (of primary fluid channel)                            |
| 15 | primary outlet (of primary fluid channel)                           |
| 16 | secondary fluid channel                                             |
| 17 | secondary inlet of secondary fluid channel                          |
| 18 | secondary outlet of secondary fluid channel                         |
| 19 | outer space between housing and radial outside of outer drive shaft |
| 20 | protrusion inside outer drive shaft                                 |
| 21 | first radial level                                                  |
| 22 | secondary bearings                                                  |
| 23 | tapered roller bearings of primary bearings                         |
| 24 | tapered roller bearings of secondary bearings                       |
| 25 | confined space                                                      |
| 26 | return channel                                                      |
| 27 | sump                                                                |
| 28 | ridge of protrusion                                                 |
| 29 | first seal                                                          |
| 30 | second seal                                                         |
| 31 | ring gear                                                           |
| 32 | planetary carrier                                                   |
| 33 | sun gear                                                            |
| D1 | radial thickness of layer of liquid lubricant                       |

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## Claims

1. A drive assembly (1) for a marine dual-propeller drive unit, said drive assembly (1) comprising:

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a housing (2),  
 an outer drive shaft assembly comprising an outer drive shaft (3) comprising an outer end portion (4) for holding a first propeller and an axially opposite inner end portion (5) for connection to a gear or a motor,  
 an inner drive shaft assembly comprising an inner drive shaft (6) comprising an outer end portion (7) for holding a second propeller and an axially opposite inner end portion (8) for connection to a gear or a motor, and  
 a lubrication system,  
 said outer drive shaft (3) comprising a through central opening (9) extending along a rotational axis (10) of the outer drive shaft (3),  
 said inner drive shaft (6) extending co-axially with the outer drive shaft (3), through the central opening (9) of the outer drive shaft (3),  
 wherein a plurality of primary bearings (11) are mounted in the central opening (9) for rotationally supporting the inner drive shaft (6) in the outer drive shaft (3) such that the inner drive shaft (6) and the outer drive shaft (3) are rotatable relatively each other about the rotational axis (10),  
 wherein a plurality of secondary bearings (22) are mounted around the outer drive shaft (3) for rotatably

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supporting the outer drive shaft (3) in the housing (2) such that the outer drive shaft (3) is rotatable relatively the housing (2) about the rotational axis (10),  
 said lubrication system comprising a liquid lubricant pump (12), and a primary fluid channel (13) comprising a primary inlet (14) fluidly connected to the liquid lubricant pump (12) for receiving pressurized liquid lubricant, and  
 at least one primary outlet (15) emanating in the central opening (9) of the outer drive shaft (3),  
 said outer drive shaft (3) comprising at least one secondary fluid channel (16) extending from a secondary inlet (17) facing the central opening (9) to a secondary outlet (18) facing an outer space (19) between the housing (2) and a radial outside of the outer drive shaft (3),  
 said outer drive shaft (3) being provided with at least one protrusion (20) protruding radially inwards from an inner surface of the outer drive shaft (3),  
 said secondary inlet (17) of the secondary fluid channel (16) being provided in said at least one protrusion (20) at a first radial level (21) offset radially inwards from the inner surface of the outer drive shaft (3) such that liquid lubricant at said first radial level (21) is able to lubricate at least some of the primary bearings (11).

2. The drive assembly (1) according to any one of the preceding claims, wherein the housing (2) is provided with a return channel (26) fluidly connecting a lower portion of the outer space to a sump (27), said sump (27) being vented to atmospheric pressure and said liquid lubricant pump (12) being fluidly connected to the sump (27) to pump liquid lubricant from the sump (27).

3. The drive assembly (1) according to claim 2, wherein the sump (27) is fluidly connected to ambient air at atmospheric pressure.

4. The drive assembly (1) according to claim 1, wherein the protrusion (20) comprises a ridge (28) extending circumferentially about the rotational axis (10).

5. The drive assembly (1) according to any one of the preceding claims, wherein said protrusion (20) is formed by an insert mounted to the outer drive shaft (3).

6. The drive assembly (1) according to any one of the preceding claims, wherein the outer drive shaft (3) comprises a plurality of said secondary fluid channels (16).

7. The drive assembly (1) according to any one of the preceding claims, wherein the plurality of secondary fluid channels (16) are circumferentially distributed about the rotational axis (10) such that the outer drive shaft (3) is balanced about the rotational axis (10).

8. The drive assembly (1) according to any one of the preceding claims, wherein the primary fluid channel (13) extends through the housing (2) to a confined space (25) between the outer drive shaft (3) and the housing (2), and through one or more fluid channels in the outer drive shaft (3) from the confined space (25) to said one or more primary outlets (15).

9. The drive assembly (1) according to any one of the preceding claims, wherein the primary bearings (11) comprise two tapered roller bearings (23) provided at the inner end portion (8) of the inner drive shaft (6),

said tapered roller bearings (23) being spaced-apart and oriented to withstand axial force in opposite axial directions, and

said primary fluid channel (13) comprising a primary outlet (15) emanating between the tapered roller bearings (23) of the primary bearings (11).

10. The drive assembly (1) according to any one of the preceding claims, wherein the secondary bearings (22) comprise two tapered roller bearings (24) provided at the inner end portion (5) of the outer drive shaft (3),

said tapered roller bearings (24) being spaced-apart and oriented to withstand axial force in opposite axial directions, and

said confined space (25) being provided between the tapered roller bearings (24) of the secondary bearings (22).

11. The drive assembly (1) according to any one of the preceding claims, wherein the primary bearings (11) further comprise at least one bearing provided at the outer end portion (7) of the inner drive shaft (6).

12. The drive assembly (1) according to any one of the preceding claims, wherein the primary bearing (11) provided at the

outer end portion (7) of the inner drive shaft (6) is a needle bearing.

5      **13.** The drive assembly (1) according to any one of the preceding claims, wherein a first seal (29) is provided between the inner drive shaft (6) and the outer drive shaft (3) at the outer end portion (7), and wherein a second seal (30) is provided between the outer drive shaft (3) and the housing (2) at the outer end portion (4) of the outer drive shaft (3).

10      **14.** A propeller drive unit comprising the drive assembly (1) according to any one of the preceding claims, a motor and a planetary gear, said planetary gear comprising a ring gear (31), a planetary carrier (32) and a sun gear (33), said ring gear being connected to the outer drive shaft (3), and said planetary carrier (32) being connected to the inner drive shaft (6) or integrated with the inner drive shaft (6), wherein the sun gear (33) is operatively connected to the motor.

**15.** A marine vessel comprising a propeller drive unit (1) according to claim 14.

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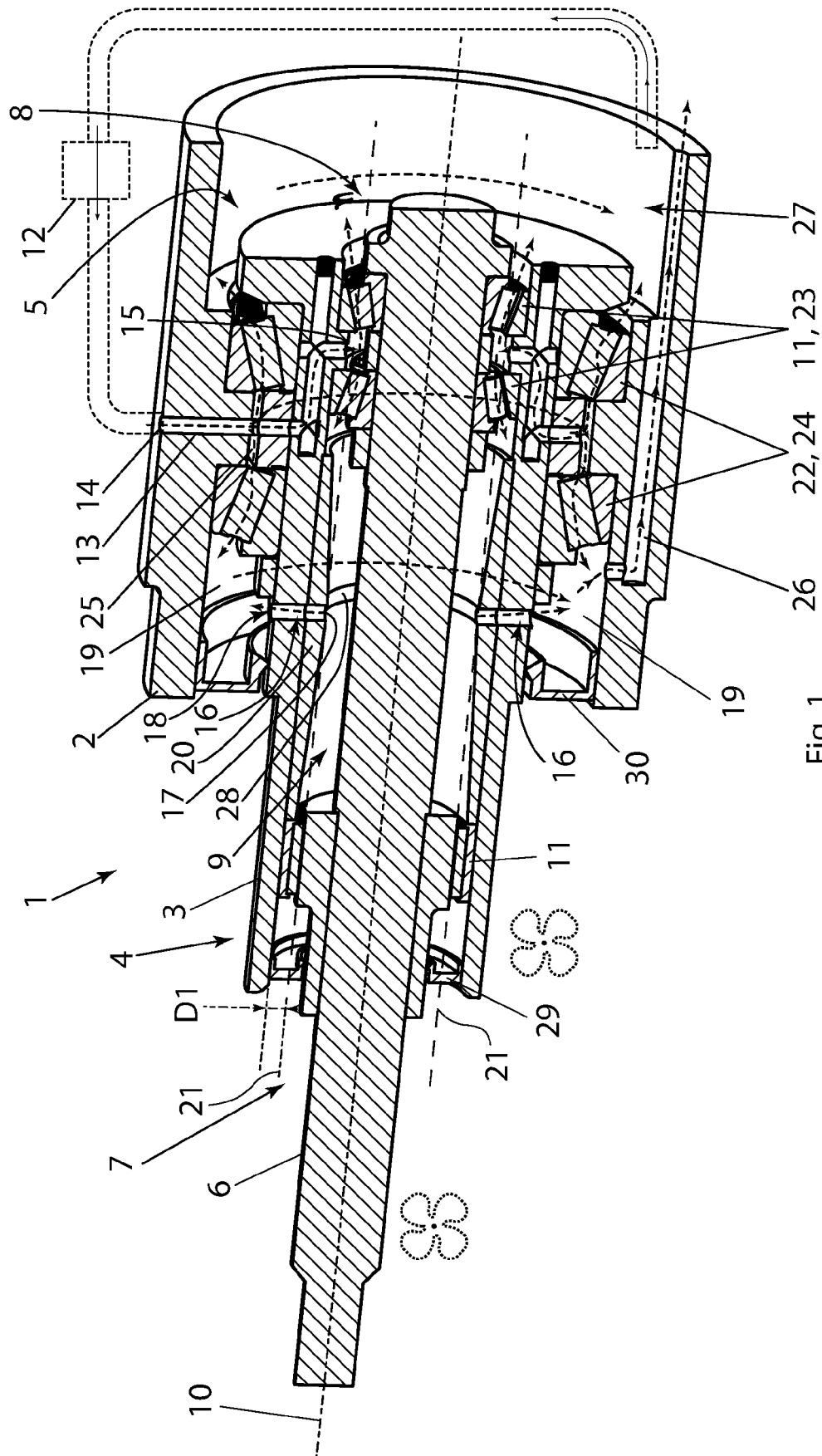
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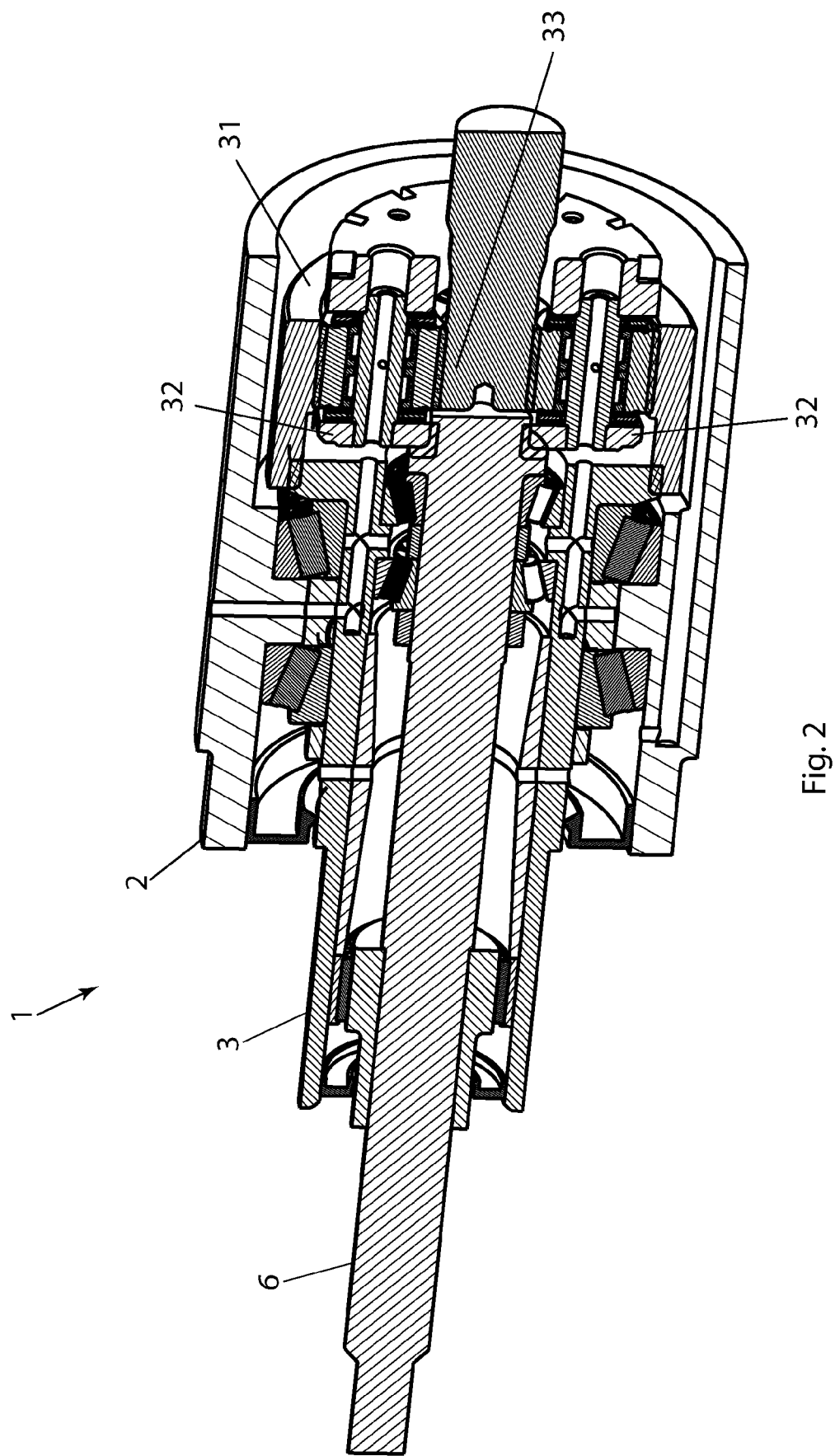


Fig. 2



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Application Number

EP 23 21 5541

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| DOCUMENTS CONSIDERED TO BE RELEVANT                                                                                                                                                                                     |                                                                                             |                                                                                                                                                                                                                                                                              |                                         |
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| Category                                                                                                                                                                                                                | Citation of document with indication, where appropriate, of relevant passages               | Relevant to claim                                                                                                                                                                                                                                                            | CLASSIFICATION OF THE APPLICATION (IPC) |
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| The present search report has been drawn up for all claims                                                                                                                                                              |                                                                                             |                                                                                                                                                                                                                                                                              |                                         |
| Place of search                                                                                                                                                                                                         |                                                                                             | Date of completion of the search                                                                                                                                                                                                                                             | Examiner                                |
| The Hague                                                                                                                                                                                                               |                                                                                             | 25 May 2024                                                                                                                                                                                                                                                                  | Székely, Zsolt                          |
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