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(54) **A vessel with a hull and a propulsion unit**

(57) The propulsion unit comprises a hollow strut (21) rotatably attached to the hull of the vessel, a propeller shaft (41) having an axial centre line (X-X) and being positioned and supported in the lower portion of the strut with bearings (51, 52), a propeller (80) being attached to at least one end of the propeller shaft protruding from the lower portion (23) of the strut , and an electric motor (30) driving the propeller shaft. An additional support arrangement (110, 120) is positioned at least in one end portion of the propeller shaft axially outwards from the bearings. The support arrangement comprises a first support surface (110) formed in connection with the propeller shaft and a second support surface (120) mating with the first support surface and being formed in connection with the lower portion of the strut. The second support surface is positioned at a predetermined distance (D1) from the first support surface so that a slot (S1) is formed between the first and second support surface facing towards each other. The bending of the propeller shaft due to external loads acting on the propeller is restricted to a predetermined maximum value with the support surfaces.

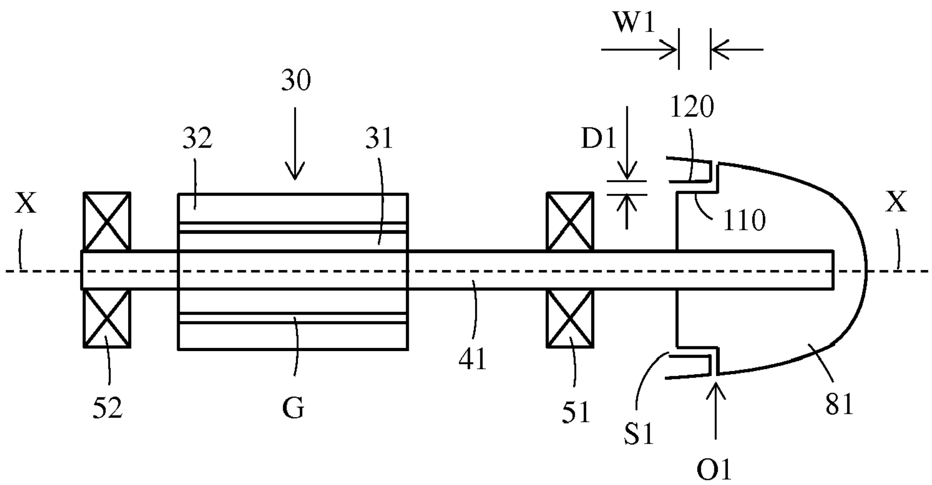

FIG. 3

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Description

FIELD OF THE INVENTION

[0001] The present invention relates to a vessel with a hull and a propulsion unit according to the preamble of claim 1.

BACKGROUND ART

[0002] WO patent publication 2013/039443 discloses a method and a device for protecting an electric motor in a pod unit for propulsion of marine vessels against shaft bending shocks when blades of the pod propeller hit ice blocks or other hard objects. The electric motor has a drive shaft, a rotor and a stator. The shocks tend to momentarily bend the shaft to such an extent that the rotor will come into contact with the stator. The rotor is prevented from coming into detrimental contact with the stator by providing at least two members, which together form a radial plane bearing having mating arcuate bearing surfaces. The bearing surfaces are in normal operation of the electric motor spaced from one another by a gap and come into contact with one another only at extreme loads with short durations. One of the members is an inner member having a circular circumference that constitutes one of the bearing surfaces. The arcuate surface of the inner member is coaxial with the rotor and rotary therewith. Another of the members is an outer member, which is fixed in relation to the stator. The arcuate bearing surface of the outer member is coaxial with the stator.

BRIEF DESCRIPTION OF THE INVENTION

[0003] An object of the present invention is to achieve an improvement in the propulsion unit in a vessel with a hull.

[0004] The vessel with a hull and a propulsion unit according to the invention is characterized by what is stated in the characterizing portion of claim 1.

[0005] The propulsion unit of the vessel with a hull comprises:

a hollow strut with an upper portion and a lower portion, the upper portion being rotatably attached to the hull of the vessel and forming a support arm for the lower portion, the lower portion forming a longitudinal compartment having a first end and a second opposite end,
a propeller shaft having an axial centre line and being positioned within the lower portion of the strut and supported in the lower portion of the strut with bearings positioned at an axial distance from each other,
a propeller being attached to at least one end of the propeller shaft protruding from the lower portion of the strut,
a motor driving the propeller shaft,

[0006] The propulsion unit is characterized in that:

an additional support arrangement is positioned at least in one end portion of the propeller shaft axially outwards from the bearings, said support arrangement comprising:

a first support surface formed in connection with the propeller shaft or in connection with a part attached to the propeller shaft so that the first support surface rotates with the propeller shaft,
a second support surface mating with the first support surface and being formed in connection with the lower portion of the strut or in connection with a part attached to the lower portion of the strut so that the second support surface is stationary in relation to the rotating propeller shaft, the second support surface being positioned at a predetermined distance from the first support surface so that a slot is formed between the first support surface and the second support surface facing towards each other, whereby
the bending of the propeller shaft due to external loads acting on the propeller is restricted to a predetermined maximum value with the support surfaces.

[0007] The radial forces acting on the propeller at the end of the propeller shaft can cause the propeller shaft to bend. Also axial forces acting on a propeller side can cause the propeller shaft to bend. The propeller shaft is subjected to heavy bending forces e.g. when the vessel is turned in an S-like manner at full speed either deliberately in tests according to the International Convention for the safety of Life at Sea (SOLAS) or at sea in trying to avoid accidents. These bending forces are due to the forces acting on the propeller in these turns. The propeller shaft is also subjected to heavy bending shocks when the propeller hits ice blocks or other hard objects.

[0008] The use of a first support surface attached to the rotating propeller shaft and a second support surface attached to the stationary strut so that said support surfaces are at a predetermined distance from each other provides an efficient means for limiting the bending of the propeller shaft.

[0009] The support surfaces can advantageously be positioned in connection with the propeller hub. The propeller hub is attached to an outer end of the propeller shaft and the propeller blades are attached to the propeller hub. The support surfaces will restrict the bending of the outer end of the propeller shaft caused by the forces acting through the propeller on the outer end of the propeller shaft. The axial position of the support surfaces will be very near the axial position of the point where the bending forces act on the propeller shaft.

[0010] The propeller hub has a bigger diameter compared to the propeller shaft. The support surfaces can thus be positioned radially further from the propeller shaft, which enables the use of bigger support surface areas i.e. bigger load carrying areas in the support surfaces. The support surfaces can easily be made big enough to withstand bigger forces. This is especially advantageous in cases where one of the support surfaces is of a softer bearing material compared to the opposite support surface. The use of softer bearing materials may require that the surface pressure in a contact between the first support surface and the second support surface is limited to a value under e.g. 30 MPa.

[0011] The depth of the slot between the support surfaces can be dimensioned so that detrimental bending of the propeller shaft is eliminated. The bending of the propeller shaft is detrimental in a propulsion unit where the propeller shaft passes through the electric motor driving the propeller. The bending of the propeller shaft is also detrimental in a propulsion unit where the propeller shaft is driven by a second shaft through a transmission and the second shaft is driven by an electric motor or a combustion engine.

[0012] In a propulsion unit where the propeller shaft passes through the electric motor, the outer surface of the rotating rotor may come into contact with the inner surface of the stationary stator, when the propeller shaft bends too much. A contact between the rotor and the stator of the electric motor would lead to severe damages and cannot therefore be accepted. The bending of the propeller shaft could also lead to a contact between the stator and the rotor in the excitation machine when a synchronous electric motor is used. The bending of the propeller shaft could further lead to a contact in the seals positioned on the propeller shaft. The bending of the propeller shaft reduces also the load capacity of the bearings, especially the thrust bearing of the propeller shaft.

[0013] In a propulsion unit in which the propeller shaft passes through the electric motor, the air gap between the rotor and the stator in the electric motor must be big enough in order to eliminate contact between the rotor and the stator in these extreme situations when the propeller shaft bends. A big air gap between the rotor and the stator will on the other hand reduce the efficiency especially of an induction motor in the size range of 1 to 10 MW.

[0014] Synchronous electric motors provided with an Excitation Unit are on the other hand often used in the size range of at least 10 MW. The air gap between the rotor and the stator in the Excitation Unit must be big enough in order to avoid contact when the propeller shaft bends. A big air gap between the rotor and the stator in the Excitation Unit will reduce the efficiency of the Excitation Unit. A smaller air gap in the Excitation Unit makes it possible to use a smaller voltage in the Excitation Unit or to use a shorter Excitation Unit or to increase the power output of an existing Excitation Unit. It could also be possible to use an Excitation Unit with a smaller diameter when the diameter of the propeller shaft can be reduced.

[0015] In a propulsion unit where the propeller shaft is driven by a second shaft through a transmission and the second shaft is driven by an electric motor or a combustion engine, the bending of the propeller shaft will cause uneven loading of the transmission between the propeller shaft and the second shaft. The uneven loading of the transmission might also lead to a bending of the second shaft, which will these cause problems to the electric motor driving the second shaft if the second shaft passes through the electric motor. The bending of the second shaft might also cause problems to a possible transmission at the upper end of the second shaft.

[0016] The classification societies require that the propulsion unit must withstand the forces in e.g. a Blade Brake situation and in turns according to the SOLAS regulations. The strength of the propeller shaft is usually over dimensioned in order to withstand these forces without bending too much.

[0017] The support surfaces will also reduce the radial forces acting on the radial bearing of the propeller shaft that is positioned nearest to the propeller hub. This radial bearing has to be dimensioned in ice going vessels to withstand the extreme loads caused by ice shocks on the propeller. The support surfaces will thus make it possible to use a smaller size for the bearing nearest to the propeller hub compared to a situation where the support surfaces are not in use.

[0018] The use of the support surfaces will also contribute to a proper function of the thrust bearing taking the axial loads of the propeller shaft. Reducing the maximum bending of the shaft line, will in high impact cases help the thrust bearing to withstand higher loads with a similar safety factor. This is useful especially when thrust bearing units based on roller bearings are used and when hybrid bearing units including a slide thrust bearing are used. The pads of the thrust bearing will wear and deform plastically faster due to an uneven load when the bending/misalignment of the propeller shaft is great. The durability of the propeller bearing is longer when the misalignment of the propeller shaft is kept on a small level.

[0019] The use of the support surfaces will also have a positive impact on the seals on the propeller shaft. Standard seals can be used on the propeller shaft. There is thus no need to use special versions of the seals, which would be able to withstand a large bending of the propeller shaft causing wide radial movements in the seal structures.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] In the following the invention will be described in greater detail by means of preferred embodiments with reference to the attached drawings, in which:

Figure 1 shows a cross section of a propulsion unit of a vessel in which the invention can be applied,
Figure 2 shows a cross section of another propulsion unit of a vessel in which the invention can be applied,
Figure 3 shows a first embodiment of an arrangement according to the invention,

Figure 4 shows a second embodiment of an arrangement according to the invention,

Figure 5 shows a third embodiment of an arrangement according to the invention,

Figure 6 shows a detail of a possible arrangement according to the invention,

Figure 7 shows a detail of another possible arrangement according to the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0021] Figure 1 shows a cross section of a propulsion unit in a vessel in which the invention can be applied. The propulsion 20 unit comprises a hollow strut 21 having an upper portion 22 and a lower portion 23, a propeller shaft 41, a propeller 80 and an electric motor 30. The propulsion unit 20 has a pulling propeller 80, which means that the forward travelling direction of the vessel 10 is in a first direction L1. The propulsion unit 20 could instead have a pushing propeller 80, which means that the forward travelling direction of the vessel 10 is in a second direction L2 opposite to the first direction L1.

[0022] The upper portion 22 of the strut 21 forms a support arm supporting the lower portion 23 of the strut. The lower portion 23 of the strut 21 forms a longitudinal compartment having a first end 23A and a second opposite end 23B. The propulsion unit 20 is rotatably attached via a gearwheel 25 to the vessel 10 via the upper portion 22 of the strut 21 so that it can turn 360 degrees around a centre axis Y-Y of rotation. There is normally a slewing bearing under the gearwheel and a slewing seal under the slewing bearing (not shown in the figure). The slewing bearing makes the rotation of the propulsion unit 20 around the centre axis Y-Y possible and the slewing seal seals the opening through which the upper portion 22 of the strut passes through the hull 11 of the vessel 10.

[0023] The electric motor 30 comprising a rotor 31, a stator 32 and an air gap G between the rotor 31 and the stator 32 is positioned in the lower portion 23 of the strut 21.

[0024] The propeller shaft 41 passes through the electric motor 30 and is rotatably supported with bearings 51, 52 at the lower portion 23 of the strut 21. The propeller shaft 41 comprises a first end 41A and a second opposite end 42B protruding from a second end 23B of the lower portion 23 of the strut 21. The propeller shaft 41 can be a one piece shaft or it can be divided into several parts.

[0025] The propeller 80 comprising a propeller hub 81 and propeller blades 82 is connected to the second end 41 B of the propeller shaft 41 outside the second end 23B of the lower portion 23 of the strut 21. The axial centre line X-X of the shaft 41 forms a shaft line. The propeller hub 81 and the propeller blades 82 can be formed as one entity or as separate entities.

[0026] The bearings 51, 52 of the propeller shaft 41 are positioned on axially X-X opposite sides of the electric motor 30. The first bearing 51 at the second end 23B of the lower portion 23 of the strut 21 is advantageously a radial bearing. The second bearing 52 at the second end 23A of the lower portion 23 of the strut 21 is advantageously a hybrid bearing comprising a radial bearing and a slide thrust bearing or it can consist of various types and amounts of roller bearings. The slide thrust bearing or a combination of various roller bearings will take the axial loads of the propeller shaft 41.

[0027] Figure 2 shows a cross section of another propulsion unit of a vessel in which the invention can be applied. This propulsion unit 20 is a thruster comprising a hollow strut 21 having a upper portion 22 and a lower portion 23, a propeller shaft 41, a second shaft 61, a transmission 44, 64, a propeller 80, an annular nozzle 90 and an electric motor 30. The propulsion unit 20 has a pushing propeller 80, which means that the forward travelling direction of the vessel 10 is in a first direction L1. The propulsion unit 20 could instead have a pulling propeller 80, which means that the forward travelling direction of the vessel 10 is in a second direction L2 opposite to the first direction L1.

[0028] The upper portion 22 of the strut 21 forms a support arm supporting the lower portion 23 of the strut 21. The lower portion 23 of the strut 21 forms a longitudinal compartment having a first end 23A and a second opposite end 23B. The propulsion unit 20 is rotatably attached via a gearwheel 25 to the vessel 10 via the upper portion 22 of the strut 21 so that it can turn 360 degrees around a centre axis Y-Y of rotation.

[0029] The propeller shaft 41 is rotatably supported with bearings 51, 52 within the lower portion 23 of the strut 21. The propeller shaft 41 comprises a first end 41A and a second opposite end 42B protruding from a second end 23B of the lower portion 23 of the strut 21. A propeller 80 comprising a propeller hub 81 and propeller blades 82 is connected to the second end 41 B of the propeller shaft 41 outside the second end 23B of the lower portion 23 of the strut 21. The axial centre line X-X of the propeller shaft 41 forms a shaft line.

[0030] The bearings 51, 52 of the propeller shaft 41 are positioned axially X-X at a distance from each other. The first bearing 51 at the second end 23B of the lower portion 23 of the strut 21 is advantageously a radial bearing. The second bearing 52 at the first end 23A of the lower portion 23 of the strut 21 is advantageously a hybrid bearing comprising a radial bearing and a slide thrust bearing or it can consist of various types and amounts of roller bearings taking the axial and the radial forces e.g. a so called pressure bearing. The slide thrust bearing or a combination of roller bearings will take the axial loads of the propeller shaft 41.

[0031] The second shaft 61 has a first end 61 A and a second opposite end 61 B. The second shaft 61 extends vertically within the first portion 22 of the strut 21 and has a centre line Y-Y coinciding with the centre axis Y-Y of rotation of the strut 21. The second shaft 61 is rotatably supported with bearings 71, 72 within the upper portion 22 of the strut 21.

[0032] The transmission 44, 64 connects the lower first end 61A of the second shaft 61 to the propeller shaft 41. The transmission 44, 64 is formed of a first pinion 44 attached to the propeller shaft 41 and a second pinion 64 attached to the first end 61A of the second shaft 61. The cogs on the periphery of the pinions 44, 64 are in contact with each other so that the rotation of the second shaft 61 also rotates the propeller shaft 41. The electric motor 30 rotates the second shaft 61 at a first rotation speed and the propeller shaft 41 rotates with a second different rotation speed determined by the transmission 44, 64 i.e. the pitch diameters of the pinions 44, 64. The second rotation speed will be lower than the first rotation speed. The propeller 80 is thus driven by the electric motor 30 at a speed which is lower than the rotation speed of the electric motor 30.

[0033] The propeller 80 comprising a propeller hub 81 provided with propeller blades 82 is attached to the outer second end 41 B of the propeller shaft 41 outside the second end 23B of the lower portion 23 of the strut 21. The propeller 80 may also be a monoblock type propeller in which the propeller hub 81 and the propeller blades 82 are integrated into a monoblock construction. The propeller 80 rotates with the propeller shaft 41.

[0034] The annular nozzle 90 is fixedly supported on the strut 21. The axial centre line X-X of the propeller shaft 41 forms also an axial centre line of the annular nozzle 90. The annular nozzle 90 surrounds an outer perimeter of the propeller 80 and forms a duct 95 with an axial flow path for water flowing through the interior of the annular nozzle 90. The annular nozzle 90 is attached to the strut 21 with a first support part 93 and a second support part 94. The rotating propeller 80 causes water to flow through the central duct 95 from the first end 91 of the central duct 95 to the second end 92 of the central duct 95 in a second direction S2, which is opposed to the first direction S1. The thrust produced by the propeller 80 is amplified by the annular nozzle 90 at low speeds.

[0035] The electric motor 30 is positioned within the upper portion 22 of the strut 21. The electric motor 30 comprises a rotor 31, a stator 32 surrounding the rotor 31 and an air gap G between the rotor 31 and the stator 32. The rotor 31 of the electric motor 30 extends along the centre line Y-Y of the second shaft 61. The rotor 31 of the electric motor 30 is attached to the second shaft 61 passing through the electric motor 30 so that the second shaft 61 rotates with the rotor 31 of the electric motor 30. The rotation of the rotor 31 of the electric motor 30 is thus transferred to rotation of the second shaft 61. The rotation of the rotor 31 of the electric motor 30 is thus transferred via the second shaft 61, the transmission 44, 64 and the propeller shaft 41 to the propeller 80. The electric motor 30 drives the propeller 80.

[0036] The electric motor 30 could alternatively be positioned within the hull 11 of the vessel 10. In case the electric motor 30 is within the hull 11 of the vessel 10, it could be replaced by a combustion engine. The combustion engine would have a vertical shaft, which means that the second shaft 61 would be connected through a transmission within the hull 11 of the vessel 10 to the horizontal shaft of the combustion engine. In case the electric motor 30 is within the hull 11 of the vessel 10, it could be positioned horizontally instead of vertically. The electric motor 30 would have a vertical shaft, which means that the second shaft 61 would be connected through a transmission within the hull 11 of the vessel 10 to the horizontal shaft of the electric motor 30.

[0037] The propulsion unit 20 could also be modified so that the annular nozzle 90 would be left out.

[0038] Figure 3 shows a first embodiment according to the invention. The figure shows the electric motor 30, the shaft 41, the propeller hub 81, and the bearings 51, 52. The additional support arrangement of the shaft 41 is realized with two support surfaces 110, 120 arranged in connection with the propeller hub 81. The first support surface 110 is formed of a cylindrical inner bearing surface on the propeller hub 81. The first support surface 110 rotates with the propeller hub 81. The second support surface 120 forms a cylindrical outer bearing surface on the frame of the strut 21. The second support surface 120 is stationary in relation to the rotating propeller hub 81. There is a radial slot D1 between the first support surface 110 and the second support surface 120. Sea water can pass through the opening O1 between the propeller hub 81 and the strut 21 into the radial slot S1 between the first support surface 110 and the second support surface 120 and thereby lubricate the first support surface 110 and the second support surface 120.

[0039] Figure 4 shows a second embodiment of an arrangement according to the invention. This second embodiment differs from the first embodiment in that the additional support arrangement comprises support surfaces 110A, 110B, 120A, 120B at each end of the propeller shaft 41. This is due to the fact that there is a propeller at each end of the propeller shaft 41 i.e. at each end of the lower portion 23 of the strut 21. Each propeller hub 81A, 81 B is provided with a first support surface 110A, 110B and a second support surface 120A, 120B in the same way as in the first embodiment. There is a radial slot S1 between the support surfaces 110A, 120A, 110B, 120B having a width W1 in the axial X-X direction and a height D1 in the radial direction.

[0040] Figure 5 shows a third embodiment of an arrangement according to the invention. This third embodiment differs from the first embodiment in that the additional support arrangement comprises support surfaces 110, 120 at a first end 41A of the propeller shaft 41. The first support surface 110 is provided on a cylindrical part 42 being attached to the first end 41 A of the propeller shaft 41. The second support surface 120 surrounds the first support surface 110 and is attached to the lower portion 23 of the strut 21. There is a radial slot S1 between the support surfaces 110, 120 having a width W1 in the axial X-X direction and a depth D1 in the radial direction. The radial slot S1 could be empty i.e. filled with air or lubricated with water or lubricated with oil or lubricated with crease or lubricated with some other lubrication medium.

[0041] The third embodiment could naturally be modified so that the support arrangement would comprise support surfaces 110, 120 also at the first end 41 A of the propeller shaft 41. The support surfaces 110, 120 at the first end 41A of the propeller shaft 41 would be realized in connection with the propeller hub 81 in the same way as in the first embodiment.

[0042] The support surfaces 110, 120 at the first end 41A of the propeller shaft 41 are in the embodiments shown in the figures 2-4 situated in connection with the propeller hub 81. The support surfaces 110, 120 could instead be situated in connection with the propeller shaft 41 in an axial X-X position between the first bearing 51 and the propeller hub 81. The first support surface 110 could be arranged on the outer surface of a cylinder which is attached to the propeller shaft 41 and the second support surface 120 could surround the first support surface 110 and be attached to the lower portion 23 of the strut 21.

[0043] Figure 6 shows a detail of one possible arrangement according to the invention. A cylindrical first support surface 110 is arranged on the rotating propeller hub 81 and a cylindrical second support surface 120 is arranged on the stationary strut 21. The first support surface 110 and the second support surface 120 are both concentric with the centre axis X-X of the propeller shaft 41. A ring shaped slot S1 is thus formed between the two cylindrical support surfaces 110, 120. The slot S1 has a depth D1 in the radial direction, which is formed by the radial distance between the first support surface 110 and the second support surface 120. The slot S1 has further a width W1 in the axial direction X-X. The first support surface 110 is formed directly on the propeller hub 81 i.e. there is no separate part forming the first support surface 110. The second support surface 120 is formed by a cylindrical first support member 130 having a flange 131 at an outer end of the support member 130. The first support member 130 is attached with axial X-X bolts 150 from the flange 131 to the strut 21, which means that the first support member 130 is replaceable. The depth D1 of the slot S1 in the radial direction is determined so that the bending of the propeller shaft 41 is restricted to a predetermined value. The first support surface 110 will come into contact with the second support surface 120 when the predetermined value of the bending of the propeller shaft 41 is reached. The propeller shaft 41 cannot bend beyond the predetermined value. A rope clipper or cutter 170 can also be integrated into this arrangement. The rope clipper 170 cuts any ropes twisting into the opening between the strut 21 and the propeller hub 81. The axial width of the opening O1 is bigger than the axial movement of the propeller shaft 41 in order to avoid contact between the radial surfaces restricting the opening O1. The axial X-X movement of the propeller shaft 41 has not been restricted in this arrangement.

[0044] The second support surface 120 could be slightly conical expanding axially X-X outwardly. This would increase the axial width W1 of the first support surface 110 that comes into contact with the second support surface 120 when the propeller shaft 41 is bent. The angle of the cone could be in the order of 0.5 to 1 degrees.

[0045] Figure 7 shows a detail of another possible arrangement according to the invention. A radially directed first support surface 110 is arranged on the rotating propeller hub 81 and a radially directed second support surface 120 is arranged on the stationary strut 21. The first support surface 110 and the second support surface 120 are positioned in parallel radial planes. A ring shaped slot S1 is thus formed between the two radially directed support surfaces 110, 120. The slot S1 has a depth D1 in the axial direction, which is determined by the axial X-X distance between the first support surface 110 and the second support surface 120. The slot S1 has further a width W1 in the radial direction. The first support surface 110 is formed by a ring shaped second support member 140 having a planar radial first support surface 110. The second support member 140 is attached to the hub 81 with radial bolts 160, which means that the first support member 130 is replaceable. The second support surface 120 is formed directly on the strut 21, i.e. there is no separate part forming the second support surface 120. The depth D1 of the slot S1 in the axial X-X direction is determined so that the bending of the propeller shaft 41 is restricted to a predetermined value. The first support surface 110 will come into contact with the second support surface 120 when the predetermined value of the bending of the propeller shaft 41 is reached. Also the axial displacement of the propeller shaft 41 has to be taken into account when dimensioning the axial depth D1 of the slot S1. The propeller shaft 41 cannot bend beyond the predetermined value. The cylindrical surface of the hub 81 will not in any case attach the corresponding cylindrical surface of the lower portion 23 of the strut 21. The second support member 140 could be attached to the hub 81 with axially directed bolts instead of radial bolts 160 as shown in the figure.

[0046] The first support surface 110 and the second support surface 120 could be cylindrical in the embodiments described in connection with figures 3-6. The first support surface 110 and the second support surface 120 could on the other hand be radial planes in the embodiment described in connection with figure 7.

[0047] Another possibility would be to use a conical surface in the embodiments described in connection with figures 3-6. The conical second support surface 120 would contract axially X-X inwardly. This would increase the axial width W1 of the first support surface 110 that comes into contact with the second support surface 120 when the propeller shaft 41 is bent. The cone angle could be in the order of 0.5 to 1 degrees. The depth D1 of the slot S1 between the support surfaces 110, 120 will vary along the axial width W1 of the slot S1 in a situation where one of the support surfaces 110, 120 is cylindrical and the other support surface 110, 120 is conical.

[0048] The same principle could be applied to the embodiment described in connection with figure 7. The second support surface 120 could be slightly inclined from the radial plane. The inclination would be to the left in the figure 7. This would in the same way increase the radial width W1 of the first support surface 110 that comes into contact with the second support surface 120 when the propeller shaft 41 is bent. The inclination could be in the order of 0.5 to 1 degrees. The depth D1 of the slot S1 between the support surfaces 110, 120 will vary along the radial width W1 of the slot S1 in a situation where one of the support surfaces 110, 120 is inclined in relation to the radial plane and the other support surface 110, 120 is in the radial plane.

[0049] The propeller shaft 41 is in the figures supported with two axially X-X displaced bearings 51, 52 within the strut 21. The first bearing 51 is in the figures 1-4 positioned on the propeller shaft 41 between the electric motor 30 and the hub 81 and the second bearing 52 is positioned on the propeller shaft 41 at the axially X-X opposite side of the electric motor 30. The use of two bearings 51, 52 is an economical and simple solution in a propulsion unit. The two support surfaces 110, 120 could naturally also be used in a case where the propeller shaft 41 is supported with more than two bearings.

[0050] The first support surface 110 and the second support surface 120 are situated axially X-X outwardly in relation to the first bearing 51 and/or the second bearing 52 of the propeller shaft 41.

[0051] The first support surface 110 and the second support surface 120 could be arranged so that at least one of the support surfaces 110, 120 is formed on a support member 130, 140. The support member 130, 140 could be made of a softer material compared to the opposite support surface 110, 120. The support member 130, 140 could be made of a water lubricated bearing material e.g. Vesconite Hilube. Vesconite Hilub is a long life, low maintenance plain bearing material, which also gives outstanding performance when lubricated. Vesconite Hilube is compounded from advanced engineering thermoplastic incorporating a PTFE internal lubricant. Vesconite Hilube has low dynamic friction and an even lower dynamic friction. The depth D1 of the slot S1 could be dimensioned to be so tight that the bending of the propeller shaft 41 is restricted already in heavy operational situations. This would make it possible to have a smaller gap G between the rotor 31 and the stator 32 in the electric motor 30 as well as in the Exciting Unit. This could be a solution in a vessel operating in open water in order to increase the propulsion efficiency. Instead of reducing the gap G between the rotor 31 and the stator 32, it would be possible to reduce the size of the propeller shaft 41 and the bearings 51, 52, especially the first bearing 51 being closest to the hub 81.

[0052] The first support surface 110 and the second support surface 120 could on the other hand be arranged so that both the support surfaces 110, 120 are formed of steel or some other base metal used in structures. The depth D1 of the slot S1 could be dimensioned to be so large that the bending of the propeller shaft 41 is restricted and contact between the support surfaces will occur only in extreme situations. This arrangement could be used e.g. in vessels operating in artic seas. There is a heavy load bending the propeller shaft when the propeller hits ice or some other hard object, e.g. is grounded. The support surfaces 110, 120 would restrict the bending of the propeller shaft 41 only in such extreme situations. The first support surface 110 and the second support surface 120 could be formed as integral parts of the strut 21 and the hub 81. The other possibility is to form at least one of the support surfaces 110, 120 as a separate support part attached to the strut 21 and/or to the hub 81 and/or to the propeller shaft 41.

[0053] It is advantageous to position the support surfaces 110, 120 in connexion with the hub propeller 81. The diameter of the propeller hub 81 is bigger compared to the diameter of the propeller shaft 41. The support surfaces 110, 120 can thus be arranged on a bigger diameter in order to withstand bigger forces. The support surfaces 110, 120 are positioned radially outwards from the outer surface of the propeller shaft 41.

[0054] The support surfaces 110, 120 could have a cylindrical form. Another possibility is that at least one of the support surfaces 110, 120 is slightly conical. Still another possibility is that the support surfaces 110, 120 are planar surfaces formed in the radial plane. The support surfaces 110, 120 may be formed as continuous support surfaces or they may be formed of several segments that can be replaceable parts.

[0055] The support surfaces 110, 120 may be of the same metal or of different metal having a different hardness. Another possibility is to have one support surface 110, 120 of metal and the other support surface 110, 120 of water lubricated bearing material. One or both support surfaces 110, 120 could also be coated with a suitable coating in order to reduce the friction between the support surfaces 110, 120.

[0056] The support surfaces 110, 120 may also be arranged so that the depth D1 between the support surfaces 110, 120 is adjustable. This could e.g. be achieved by using cylinders of different thickness for the support surfaces 110, 120 in the embodiments shown in the figures 2-5.

[0057] The support surfaces 110, 120 may be arranged so that one or both of them is formed on a separate part that is replaceable. The other possibility is that one or both of the support surfaces 110, 120 is formed as an integral part into the propeller shaft 41 or into a part attached to the propeller shaft 41 or into the frame of the strut 21 or into a part attached to the frame of the strut 21.

[0058] The radial slot S1 between the first support surface 110 and the second support surface 120 could be empty i.e. filled with air or lubricated with water or lubricated with oil or lubricated with crease or lubricated with some other lubrication medium.

[0059] It would naturally also be possible that both support surfaces 110, 120 are slightly conical or slightly inclined instead of having only one of the support surfaces

110, 120 slightly conical or slightly inclined.

[0060] The material and the stiffness of the support surfaces 110, 120 could adapted according to different requirements. The support surfaces 110, 120 could act as inelastic walls or they could provide a softer support when they come into contact with each other.

[0061] The criteria for dimensioning the depth D1 of the slot S1 are naturally different in a propulsion unit 20 according to figure 1 and in a propulsion unit 20 according to figure 2. The starting point in figure 1 is the air gap G between the rotor 31 and the stator 32 in the electric motor 30. The starting point in figure 2 is the play in the transmission 44, 64 between the propeller shaft 41 and the second shaft 61.

[0062] The invention and its embodiments are not limited to the examples described above but may vary within the scope of the claims.

Claims

1. A vessel (10) with a hull (11) and a propulsion unit (20), the propulsion unit (20) comprising:

   a hollow strut (21) with an upper portion (22) and a lower portion (23), the upper portion (22) being rotatably attached to the hull (11) of the vessel (100) and forming a support arm for the lower portion (23), the lower portion (23) forming a longitudinal compartment having a first end (23A) and a second opposite end (23B),
   a propeller shaft (41) having an axial centre line (X-X) and being positioned within the lower portion (23) of the strut (21) and supported in the lower portion (23) of the strut (21) with bearings (51, 52) positioned at an axial (X-X) distance from each other,
   a propeller (80) being attached to at least one end of the propeller shaft (41) protruding from the lower portion (23) of the strut (21),
   a motor (30) driving the propeller shaft (41),
   characterized in that:

      an additional support arrangement (110, 120) is positioned at least in one end portion of the propeller shaft (41) axially (X-X) outwards from the bearings (51, 52), said support arrangement (110, 120) comprising:

   a first support surface (110) formed in connection with the propeller shaft (41) or in connection with a part attached to the propeller shaft (41) so that the first support surface (110) rotates with the propeller shaft (41),
   a second support surface (120) mating with the first support surface (110) and being formed in connection with the lower portion (23) of the strut (21) or in connection with a part attached to the lower portion (23) of the strut (21) so that the second support surface (120) is stationary in relation to the rotating propeller shaft (41),
   the second support surface (120) being positioned at a predetermined distance (D1) from the first support surface (110) so that a slot (S1) is formed between the first support surface (110) and the second support surface (120) facing towards each other, whereby
   the bending of the propeller shaft (41) due to external loads acting on the propeller (80) is restricted to a predetermined maximum value with the support surfaces (110, 120).

2. A vessel according to claim 1, **characterized in that** the slot (S1) is open to sea water so that the first support surface (110) and the second support surface (120) become water lubricated.

3. A vessel according to claim 1 or 2, **characterized in that** the first support surface (110) is formed on a propeller hub (81) of the propeller (80) and the second support surface (120) is formed on a stationary part attached to the strut (21) opposite to the first support surface (110).

4. A vessel according to claim 1 or 2, **characterized in that** the first support surface (110) is formed in connection with an opposite end of the propeller shaft (41) in relation to the propeller (80), and the second support surface (120) is formed on a stationary part attached to the strut (21) opposite to the first support surface (110).

5. A vessel according to any one of claims 1 to 4, **characterized in that** both support surfaces (110, 120) are cylindrical and coaxial with the axial centre line (X-X) of the shaft (41), whereby the slot (S1) between the support surfaces (110, 120) has a width (W1) in the axial (X-X) direction and a depth (D1) in the radial direction.

6. A vessel according to any one of claims 1 to 4, **characterized in that** one support surfaces (110, 120) is cylindrical and coaxial with the axial centre line (X-X) of the shaft (41) or slightly conical and the other support surface (110, 120) is slightly conical, whereby the slot (S1) between the support surfaces (110, 120) has a width (W1) in the axial (X-X) direction and a varying depth (D1) in the radial direction.

7. A vessel according to any one of claims 1 to 4, **characterized in that** both support surfaces (110, 120) form a ring in the radial plane, whereby the slot (S1) between the support surfaces (110, 120) has a width (W1) in the radial direction and a depth (D1) in the axial (X-X) direction.

8. A vessel according to any one of claims 1 to 4, **characterized in that** both support surfaces (110, 120) form a ring in the radial plane and that one support surface (110, 120) is slightly inclined in relation to the other support surface (110, 120) or that both support surfaces (110, 120) are slightly inclined in the same direction, whereby the slot (S1) between the support surfaces (110, 120) has a width (W1) in the radial direction and a varying depth (D1) in the axial (X-X) direction.

9. A vessel according to any one of claims 1 to 8, **characterized in that** the first support surface (110) and the second support surface (120) are situated axially (X-X) outwardly in relation to the bearing (51) of the propeller shaft (41) that is closest to the propeller hub (81).

10. A vessel according to any one of claims 1 to 9, **characterized in that** the motor (30) is an electric motor (30) positioned in the lower portion (23) of the strut (21), whereby the propeller shaft (41) passes through the electric motor (30).

11. A vessel according to claim 10, **characterized in that** the propeller shaft (41) is supported with two bearings (51, 52) within the strut (21), whereby a first bearing (51) is positioned on the propeller shaft (41) between the electric motor (30) and the propeller hub (81) and a second bearing (52) is positioned on the propeller shaft (41) at the axially (X-X) opposite side of the electric motor (30).

12. A vessel according to claim 11, **characterized in that** the second bearing (52) is a combined radial and thrust bearing.

13. A vessel according to any one of claims 1 to 9, **characterized in that** the motor (30) is and electric motor (30) positioned in the upper portion (22) of the strut (21), whereby a second shaft (61) passes through the electric motor (30), said second shaft (61) being connected via a transmission (44, 64) to the propeller shaft (41).

14. A vessel according to any one of claims 1 to 13, **characterized in that** the support surfaces (110, 120) are positioned radially outwards from the outer surface of the propeller shaft (41).

15. A vessel according to any one of claims 1 to 14, **characterized in that** one of the support surfaces (110, 120) is made of a softer material compared to the other support surface (110, 120).

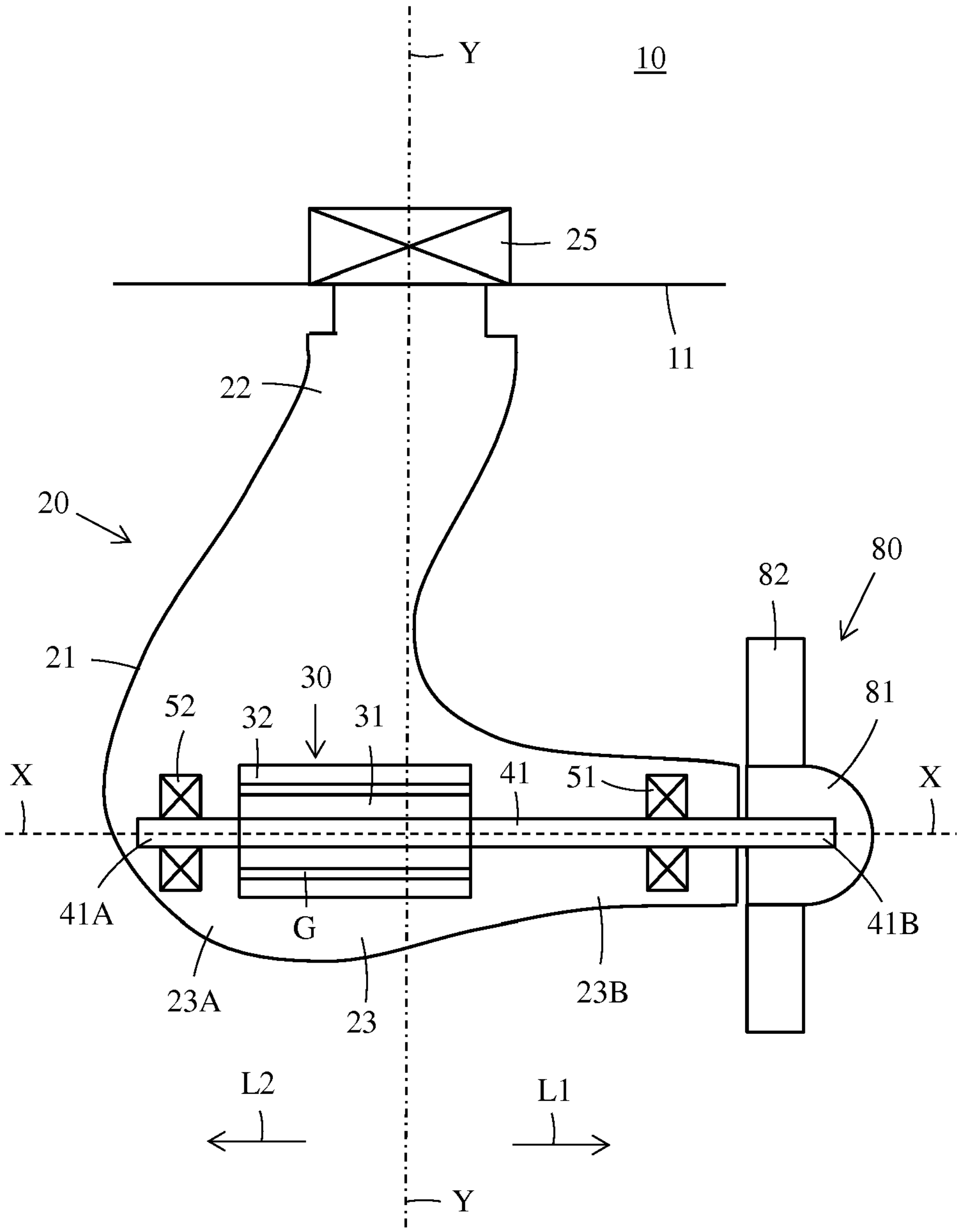
Y
10
25
11
22
20
82
80
21
30
81
52
32
31
X
41
51
X
41A
G
41B
23A
23
23B
L2
L1
Y

FIG. 1

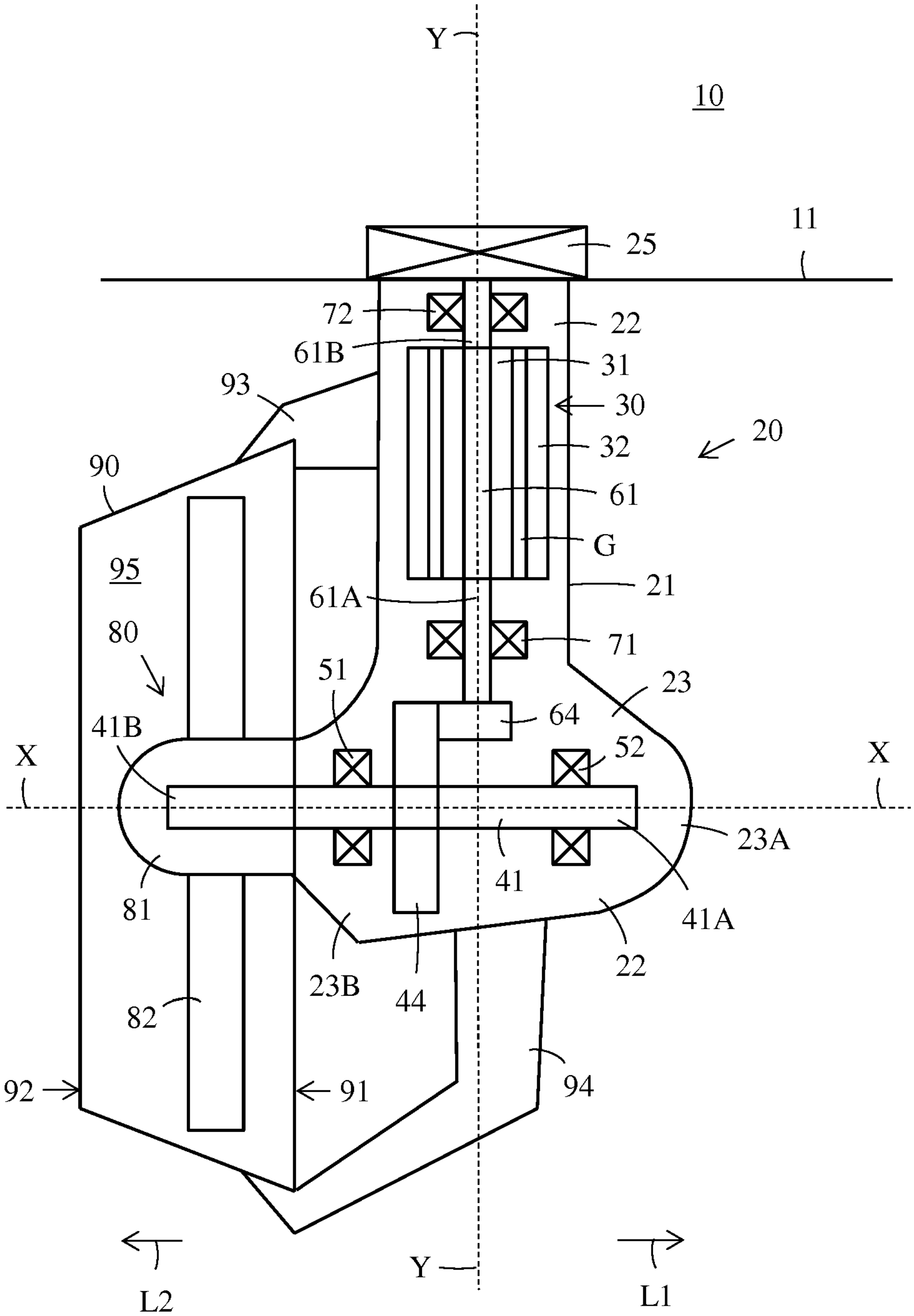
Y
10
11
25
72
22
61B
31
93
30
20
32
90
61
G
95
21
61A
80
71
51
23
41B
64
X
52
X
23A
41
41A
81
22
23B
44
82
94
92
91
L2
Y
L1

FIG. 2

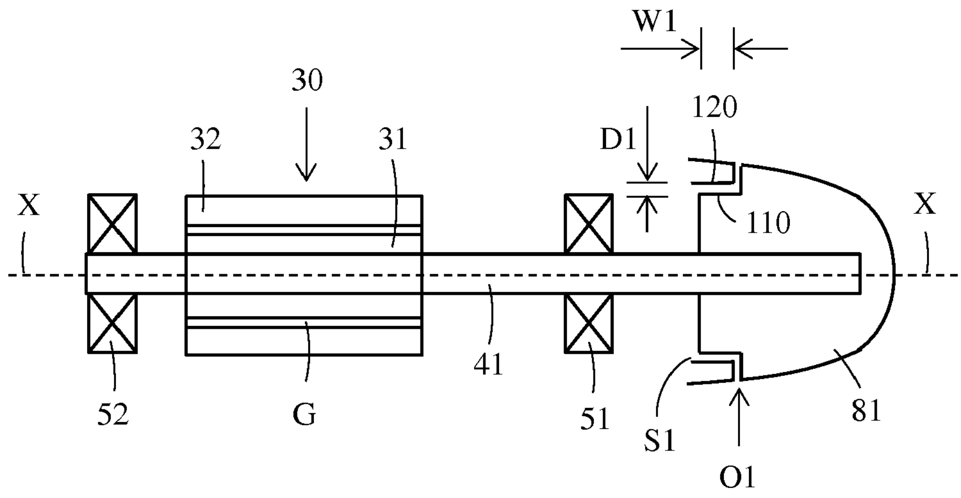
W1
30
120
32
31
D1
X
110
X
52
G
41
51
81
S1
O1

FIG. 3

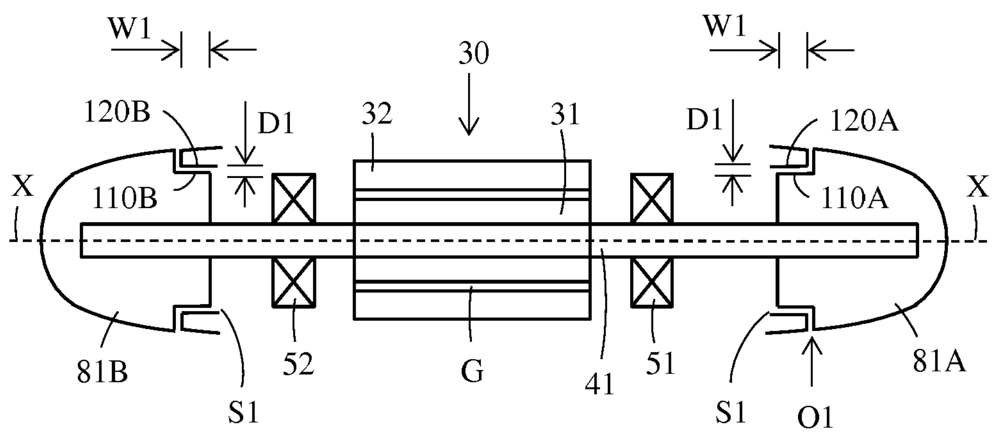
W1
W1
30
120B
D1
32
31
D1
120A
X
110B
110A
X
81B
52
G
41
51
81A
S1
S1
O1

FIG. 4

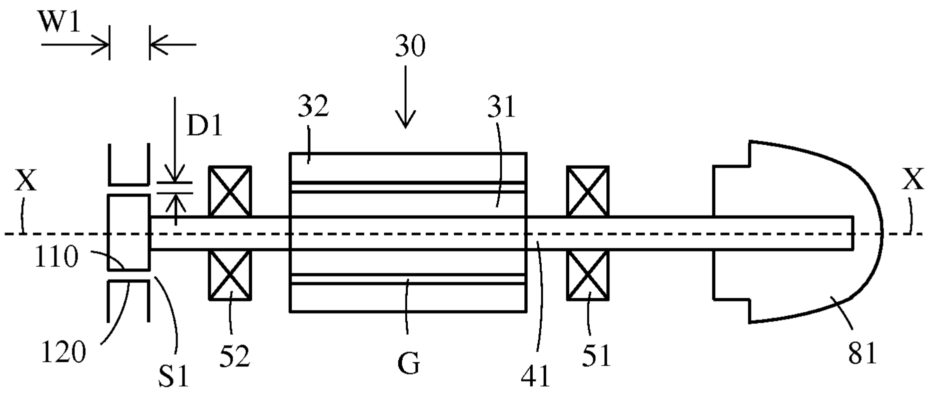

FIG. 5

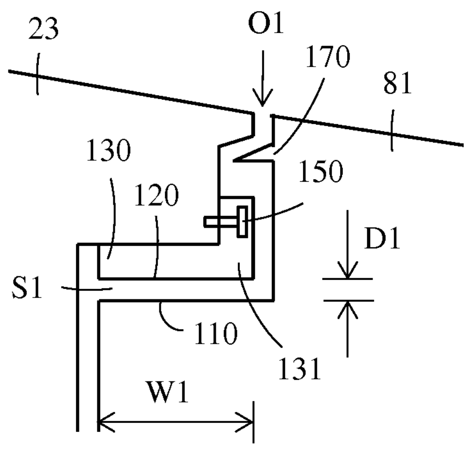

FIG. 6

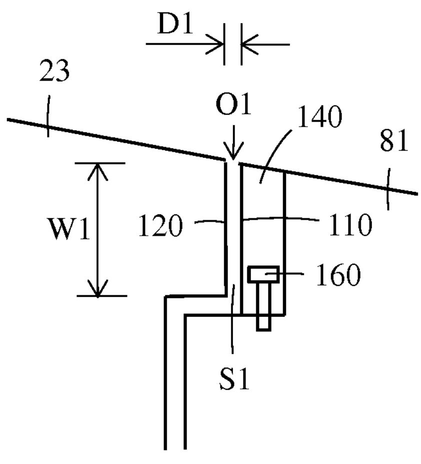

FIG. 7

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EUROPEAN SEARCH REPORT

Application Number
EP 15 15 9997

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B63H

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	21 September 2015	Székely, Zsolt

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21-09-2015

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