Seal arrangement for a propeller shaft

The propeller shaft (31) supported with at least one bearing (41) extends through an opening (O1) in the hull of the vessel to the propeller (32). The seal arrangement comprises a water seal (100) positioned on the propeller shaft (31) adjacent to the opening (O1) and a first oil seal (200) positioned on the propeller shaft (31) at an axial (X-X) distance from the water seal (100) adjacent to the bearing (41). An intermediate compartment (300) surrounds the water seal (100) and the first oil seal (200).

A first pressure sensor (91) measures the pressure of the sea water acting on the propeller shaft (31) and a second pressure sensor (92) measures the pressure within the intermediate compartment (300). An air pressure system (500) produces an air pressure into the intermediate compartment (300), whereby the air pressure within the intermediate compartment (300) is kept at a lower level compared to the pressure of the sea water acting on the propeller shaft (31).
The present invention relates to a seal arrangement for a propeller shaft according to the preamble of claim 1.

BACKGROUND ART

US patent 4,174,672 discloses a propeller shaft seal assembly. The sealing assembly is intended for a propeller shaft in the stern frame of the ship aft of the rearmost bearing assembly. The arrangement prevents ingress of sea water into the bearing assembly. The sealing arrangement comprises three housing units. The first unit at the propeller forms a water seal housing, the third unit at the bearing forms an oil seal housing and the second unit positioned between the first unit and the second unit forms a chamber housing. The sealing arrangement prevents on the other hand egress of bearing lubricant from the bearing assembly to the sea water. The water seal comprises one seal ring and an oil seal comprises two seal rings. There is a lubrication oil seal chamber between the two seal rings in the oil seal. There is further an annular void chamber formed into the chamber housing between the water seal and the oil seal. The annular chamber is provided with an outlet passage leading to a bilge tank. Any leakage from the water or the oil seal can then readily be observed from inboard.

WO publication 2009/130368 discloses an arrangement for sealing the propeller shaft of a vessel. The vessel comprises a propulsion unit mounted into a hollow strut. The propulsion unit comprises a motor connected to a shaft and a propeller connected to an outer end of the shaft outside the strut. The shaft is supported at the shell of the strut with a bearing positioned between the propeller and the motor. The outer surface of the shell of the strut is in contact with the surrounding sea water. There is a closed intermediate compartment between the bearing and the propeller. The intermediate compartment is bound by a vertical first wall at the propeller side and a vertical second wall at the bearing. The outer circumference of the intermediate compartment is formed by the circumference of the shell of the strut between the first vertical wall and the second vertical wall. The shaft is sealed with a water seal at the first vertical wall and with a first oil seal at the second vertical wall. The inner circumference of the intermediate space is formed by the outer circumferences of the water seal and the first oil seal and by the outer circumference of the shaft between the water seal and the first oil seal.

WO publication 2012/085325 discloses an arrangement and a method for sealing the propeller shaft of a ship. There is an intermediate compartment between the propeller and the shaft bearing. The sealing comprises a water seal and an oil seal positioned at an axial distance from each other within the intermediate compartment. The water seal comprises four lip seals forming a seal chamber between each pair of adjacent lip seals. Lubrication oil is provided from a lubrication oil container with a first pump through a heat exchanger to the second seal chamber calculated from the propeller side. The lubrication oil is further directed from the second seal chamber through a fixed throttle to the third seal chamber and back to the lubrication oil container. The pressure in the first seal chamber is close to the pressure of the surrounding water at the propeller shaft level. The pressure in the third seal chamber is kept at a constant pressure level below the pressure in the first seal chamber. The pressure in the second seal chamber can be adjusted by regulating the rotation speed of the first pump to a value between the pressure values of the first seal chamber and the third seal chamber. The pressure differential over each seal lip is in the arrangement kept at a low level in order to reduce excessive wear of the seal lips.

BRIEF DESCRIPTION OF THE INVENTION

An object of the present invention is to achieve an improved seal arrangement for a propeller shaft.

The seal arrangement for a propeller shaft according to the invention is characterized by what is stated in the characterizing portion of claim 1.

The present invention is characterized by what is stated in the characterizing portion of claim 1.

The propeller shaft is supported within the hull to a propeller outside the hull of the vessel, said seal arrangement comprising:

a water seal positioned on the propeller shaft adjacent to the opening in the hull in order to seal the propeller shaft in the opening in the hull, a first oil seal positioned on the propeller shaft adjacent to the bearing at an axial distance from the water seal in order to prevent lubrication oil leakage from the bearing to the sea, an intermediate compartment surrounding the water seal and the first oil seal, a first pressure sensor for measuring the pressure of the sea water acting at the propeller shaft, a second pressure sensor for measuring the pressure within the intermediate compartment, an air pressure system for producing an air pressure into the intermediate compartment, whereby the air pressure within the intermediate compartment is kept at a lower level compared to the pressure of the sea water acting on the propeller shaft.

The seal arrangement makes it possible to use any commercially available water lubricated seal as the water seal. The water seal could be a face type seal or a lip type seal. Also the first oil seal could be a face type...
or a lip type seal.

[0010] The seal arrangement makes it possible to use a pneumatically activated emergency seal in connection with the water seal. This is due to the fact that a water seal having a simple construction can be used in the seal arrangement, whereby space if left space for a pneumatically activated emergency seal. The seawater channels leading to the seal chamber in the water seal can be closed in order to eliminate seawater from penetrating into the seal chamber in the water seal during seal replacement. The replacement of the seal rings in the water seal and the first oil seal can be done from within the vessel. Access can be provided through a service opening to the intermediate compartment from within the vessel.

[0011] The seal arrangement makes it possible to use a simple and cost efficient solution in the water seal. A lip type water seal comprising only two lip seal rings with a seal chamber between the seal rings can be used in the arrangement. Sea water can be circulated in the seal chamber in order to lubricate and cool the seal rings. There is no need to pressurize the lubrication water directed into the seal chamber. The air pressure in the intermediate compartment will act on the back side of the second seal ring so that a suitable pressure difference between the front side and the back side of the second seal ring can be maintained.

[0012] The seal arrangement reduces the number of components needed in the seals compared to prior art solutions. The pump, the electric motor with the frequency converter and the cooling element can be eliminated. Only two seal rings are needed in a water seal based on lip seals in this seal arrangement compared to four seal rings in prior art solutions.

[0013] The seal arrangement minimizes pumping phenomenon caused by vibrations especially in ice breakers.

[0014] The seal arrangement contributes to a fast replacement of the water seal. The most critical seal ring in a lip type water seal is the second seal ring. If the second seal ring would be defective, it would be easy to replace only this second seal ring during a normal harbour stop.

[0015] The seal arrangement makes it possible to postpone the replacement of the water seal in an emergency situation. A defected second seal ring in the water seal could lead to a situation where the whole interior of the intermediate compartment would be flooded. The propulsion unit could still be operated with full power in such a situation until the water seal can be replaced in a harbour. In the case a first oil seal based on a lip type seal with two seal rings is used, the seal chamber between the two seal rings could be manually pressurized over the pressure of the sea water in order to eliminate penetration of sea water into the bearing.

[0016] The seal arrangement makes it easy to have redundancy of critical components. The intermediate compartment should always be pressurized to a pressure below the pressure of the sea water. The components used to pressurize the intermediate compartment can easily be made redundant. The volume of the intermediate compartment can be made fairly large i.e. in the range of 500 to 3000 litres, which means that a short brake in air supply does not affect the system.

[0017] The seal arrangement is in overall cheaper compared to prior art solutions due to the simplicity of the arrangement.

[0018] The water seal is purely water lubricated. This means that no leakage of lubrication oil from the water seal to the sea can occur. It is naturally possible to use biodegradable oils as lubrication oils in water seals, but the use of biodegradable oils will reduce the expected lifetime of the shaft seal. The lifetime of a shaft seal lubricated with mineral oil is in the order of 5 years and the lifetime of a shaft seal lubricated with biodegradable oil is in the order of 2.5 years.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] 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,
- Figure 2 shows an enlargement of a lower end portion of the propulsion unit of figure 1,
- Figure 3 shows a cross section of a seal ring for a propeller shaft,
- Figure 4 shows a cross section of a prior art seal arrangement for a propeller shaft,
- Figure 5 shows the principle construction of a prior art seal arrangement and a control system for a propeller shaft,
- Figure 6 shows a cross section of a seal arrangement and a control system for a propeller shaft according to one embodiment of the invention,
- Figure 7 shows the principle construction of the seal arrangement and the control system of figure 6,
- Figure 8 shows a cross section of a seal arrangement and a control system for a propeller shaft according to another embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0020] Figure 1 shows a cross section of a propulsion unit in a vessel. The propulsion 20 unit comprises a hollow strut 21 with an upper portion 22 and a lower portion 23. 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 lower portion 23 of the strut contains a driving unit 30, 31, 32. The driving unit comprises in this embodiment a first electric motor 30, a first shaft 31 and a propeller 32 positioned outside the second end 23B of the lower portion 23 of the strut 21. A first end 31A of the first
shaft 31 is connected to the first electric motor 30 and a second end 31B of the first shaft 31 protrudes from the second end 23B of the lower portion 23 of the strut 21. The propeller 32 is attached 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. The propulsion unit 20 is rotatably attached with bearings 41, 42 within the lower portion 23 of the strut 21. The second end 31B of the first shaft 31 is sealed with a water seal 100 in the opening O1 from which the first shaft 31 protrudes out from the second end 23B of the lower portion 23 of the strut 21. The bearing 41 at the second end 31B of the first shaft 31 is at the side facing towards the water seal 100 sealed a first oil seal 200 and at the outer side sealed with a second oil seal 400. The oil seals 200, 400 prevent leakage of oil from the bearing 41 into the lower portion 23 of the strut and into the sea surrounding the lower portion 23 of the strut 21.

[0021] Figure 2 shows an enlargement of a lower end portion of the propulsion unit of figure 1. The enlargement shows the second end 23B of the lower portion 23 of the strut 21. The figure shows the first electric motor 30, the shaft 31, the propeller 32, the bearing 41, the water seal 100, the first oil seal 200 and the second oil seal 400. The propulsion unit comprises an intermediate compartment 300 between the propeller 32 and the bearing 41. The intermediate compartment 300 is bound in the axial X-X direction by a vertical first wall 26 at the propeller 32 and a vertical second wall 27 being formed of the support structure of the bearing 41. The outer circumference of the intermediate compartment 300 is formed by the portion of the outer circumference 28 of the lower portion 23 of the strut 21, which extends in the axial X-X direction between said first wall 26 and said second wall 27. The inner circumference of the intermediate compartment 300 is bound by the outer circumference of the water seal 100, the outer circumference of the first oil seal 200 and the outer circumference of the shaft 31 between the water seal 100 and the first oil seal 200. The first wall 26 and the second wall 27 are at an axial X-X distance A1 from each other. The shaft 31 passes through the intermediate compartment 300.

[0022] Figure 3 shows a cross section of a seal ring for a propeller shaft seal. The seal ring 110 is formed of a lip seal and comprises a first lip portion 111 and a second support portion 112. The support portion 112 is fitted into a support frame 113 supporting the seal ring 110. The lip portion 111 is acting against the outer surface of the shaft 31 or on the outer surface of a liner that is fitted on the shaft 31. The lip portion 111 is pressed by a spring 114 against the liner. The sea water acting on the front side FS of the lip portion 111 is further pressing the lip portion 111 against the liner. The pressure of the sea water is depending of the draught of the shaft line X-X of the propulsion unit 20. The shaft seals in a propulsion unit can be designed e.g. for shaft line X-X draughts in the range of 4 to 10 meters. The idea is to keep a small pressure difference between the front side FS of the lip portion 111 and the back side BS of the lip portion 111. A target pressure difference over the lip portion 111 in order to keep the lip portion 111 tightly closed against the liner is in the range of 0.1 to 0.5 bar, advantageously 0.3 bar. A decrease in this pressure difference will increase the risk for leakage and a too big pressure difference will increase the wear of the lip too much. Strong shaft movements in the axial direction or in the radial direction will also increase the risk for leakage. The lip portion 111 is further lubricated with a lubrication medium comprising e.g. water and oil. The lubrication medium is directed to the back side BS of the lip portion 111. The pressure difference is thus maintained between the sea water and the lubrication medium.

[0023] Figure 4 shows a cross section of a prior art seal arrangement for a propeller shaft. The figure shows a water seal 100 comprising four water seal rings 110, 120, 130, 140 and three seal chambers 115, 125, 135 formed between the four water seal rings 110, 120, 130, 140. There is a liner 33 on the shaft 31 and the lip portions of the seal rings 110, 120, 130, 140 are thus acting on the outer surface of the liner 33. All lip portions in the seal rings 110, 120, 130, 140 are facing towards the sea water. The pressure difference over the lip portions of each seal ring 110, 120, 130, 140 is kept at a minimum value in order to reduce wear of the seal rings 110, 120, 130, 140. The lip portion 111 of the seal rings 110, 120, 130, 140 is tightened against the liner 33 by the spring 114, which is integrated into the lip portion 111 and by the pressure of the lubrication medium e.g. water and oil pressure in the seal chambers 115, 125, 135.

[0024] The sea water pressure depends on the draught. A draught of e.g. 4 meters equals to a pressure of about 0.4 bar acting on the first seal ring 110. The pressure that is present in the first seal chamber 115 depends on the condition of the first seal ring 110. The basic function of the first seal ring 110 is to act as a "dirt seal" and it is normal that the first seal ring 110 lets the pressure stabilize between the sea water and the first seal chamber 115 after some time of operation. A brand new first seal ring 110 keeps anyway very tight contact with the liner 33. The pressure in the first seal chamber 115 can thus be lower than the pressure of the sea water when the first seal ring 110 is new. The pressure in the first seal chamber 115 will, however, after some time of operation be the same as the pressure of the sea water at the shaft line X-X.

[0025] Figure 5 shows the principle construction of a prior art seal arrangement and a control system for a propeller shaft. This seal arrangement is disclosed in the previously mentioned prior art publication WO 2012/085325.

[0026] The figure shows the water seal 100 with four
that surrounds the propulsion unit 20.

The outlet of the first pump 62 is connected with a second supply pipe 73 to an inlet of a heat exchanger 63. The heat exchanger 63 could be connected according to one embodiment of the invention.

A lubrication oil tank 70 can be filled with lubrication oil. There is further a drain pipe 78 connected via a valve 80 to the second connection pipe 77. There is further a return pipe 78 from the third seal chamber 135 back to the lubrication oil tank 70. There is also a filling pipe 71 leading into the interior of the vessel through which the lubrication oil tank 70 can be filled with lubrication oil. There is further a drain pipe 81 connected via a valve 80 to the second connection pipe 77. The heat exchanger 63 could be connected directly to the hull of the propulsion unit 20 so that cooling of the heat exchanger 63 is achieved with the sea water that surrounds the propulsion unit 20.

[0027] Lubrication oil is thus pumped from the lubrication oil tank 70 with the first pump 62 into the second seal chamber 125 and further through the fixed throttle 76 to the third seal chamber 135 and further back to the lubrication oil tank 70.

[0028] The first pump 62 is driven by a second electric motor 61 and the second electric motor 62 is controlled by a frequency converter 56.

[0029] A first pressure sensor 51 measures the pressure in the first seal chamber 115 and transmits the measurement signal to a first control unit 53. The first control unit 53 is connected via an adder 54 and further via a PI control circuit 55 to the frequency converter 56. A second pressure sensor 52 measures the pressure in the second seal chamber 125 and transmits the measurement signal to the adder 54.

[0030] The balance of the lubrication oil in the system is maintained by controlling the rotation speed of the second electric motor 61 and thereby also the rotation speed of the first pump 62, which is connected to the first electric motor 61. The rotation speed of the first pump 62 corresponds to the amount of oil that it pumps to the water seal 100. The pressure difference over the second seal ring 120 is maintained in a predetermined range by regulating the rotation speed of the first pump 62. If e.g. the pressure of the sea water at the shaft level X-X is 1.0 bar then the pressure in the second seal chamber 125 is regulated by the rotation speed of the first pump 62 so that it is e.g. 0.45 bar. The fixed throttle 76 reduces the pressure of the lubrication oil when it enters to the third seal chamber 135. The pressure of the lubrication oil in the third seal chamber 135 is determined by the hydrostatic pressure caused by the height difference H1 between the shaft line X-X and the lubrication oil tank 70.

The pressure of the lubrication oil in the third seal chamber 135 is typically 0.1 bar. The idea is thus to keep the pressure in the second seal chamber 125 at a level between the pressure of the sea water at the shaft level X-X and the pressure in the third seal chamber 135. The pressure difference that exists over the second seal ring 120 and the third seal ring 130 is thus evened out with this arrangement. The lubrication oil passes through the heat exchanger 63 in which the lubrication oil is cooled. The cooled lubrication oil will cool the water seal 100.

[0031] The first oil seal 200 comprises two seal rings 210, 220 and one seal chamber 215. The first oil seal 200 prevents leakage of lubrication oil from the bearing 41 to the sea. The bearing 41 is continuously lubricated with lubrication oil, which lubrication oil will also lubricate the first seal ring 210 in the first oil seal 200. A part of the bearing lubrication oil can also be directed through the seal chamber 215 in order to lubricate and cool also the second seal ring 220 in the first oil seal 200.

[0032] Figure 6 shows a cross section of a seal arrangement and control system for a propeller shaft according to one embodiment of the invention.

[0033] The water seal 100 is a lip type seal comprising two seal rings 110, 120 and a seal chamber 115 formed between the two seal rings 110, 120. The seal rings 110, 120 are based on lip seals. There is further an emergency seal ring 105 at the outermost edge of the water seal 100 towards the seawater. The water seal 100 is lubricated with sea water SW passing through the seal chamber 115. The basic function of the first seal ring 110 is to act as a “dirt seal” and it is normal that the first seal ring 110 lets the pressure stabilize between the sea water and the first water seal chamber 115 after some time of operation.

[0034] The oil seal is composed of two symmetrical oil seals 200, 400 on opposite sides of the bearing 41. The first oil seal 200 i.e. the oil seal on the right hand side of the bearing 41 is a lip type seal comprising two seal rings 210, 220 and a seal chamber 215 formed between the two seal rings 210, 220. The first oil seal 200 is lubricated with lubrication oil being circulated from a lubrication oil tank 70 to the seal chamber 215. Also the second oil seal 400 i.e. the oil seal on the left hand side of the bearing 41 is a lip type seal comprising two seal rings 410, 420 and a seal chamber 415 between the two seal rings 410, 420.

[0035] The water seal 100 and the first oil seal 200 are enclosed in a common intermediate compartment 300. The intermediate compartment 300 is bound by the first vertical wall 26 and the propeller shaft 32 and the second vertical wall 27 at the bearing 41. The outer circumference of the intermediate compartment 300 is formed by the outer circumference 28 of the shell of the lower portion 23 of the strut 21 between the first vertical wall 26 and the second vertical wall 27. The inner circumference of the intermediate compartment 300 is formed by the water seal 100, the first oil seal 200 and the outer circumference of the shaft 31 between the water seal 100 and the first oil seal 200. There is a first axial distance A1 between the first vertical wall 26 and the second vertical wall 27.
There is further a second axial distance $A_2$ between the water seal 100 and the first oil seal 200. The second vertical wall 27 is provided with a service opening 29 providing access to the intermediate compartment 300 from the interior of the strut 21. An air pressure system 500 controls the air pressure within the intermediate compartment 300. The volume of the intermediate compartment 300 is typically in the range of 500 to 3000 litres.

The second axial distance is needed in order to service and change the water seal 100 and the first oil seal 200. The arrangement can be such that a mechanic passes through the service opening 29 into the intermediate compartment 300 when servicing the water seal 100 and the first oil seal 200. The other possibility is that the service is done through the service opening 29 without the mechanic passing wholly into the intermediate compartment 300. The second axial distance $A_2$ between the water seal 100 and the first oil seal 200 is needed in order to be able to dismantle the old seal and install the new seal. The water seal 100 is dismantled one seal ring 110, 120 at a time beginning from the second seal ring 120. The fastening bolts in the second seal ring 120 are opened and the second seal ring 120 is pulled in the axial direction X-X to the space between the water seal 100 and the first oil seal 200 where the second seal ring 120 can be dismantled. The same procedure is then done to the first seal ring 110. The first oil seal 200 can be dismantled in a similar way. The installation of a new water seal 100 and a new first oil seal 200 is done in the reverse order.

The use of a pressurized intermediate compartment 300 makes it possible to use a simple commercial water seal 100 of any type. The water seal 100 could be a lip seal as shown in the figure or a face type seal. Also the first oil seal could be a lip seal as shown in the figures or a face type seal.

Figure 7 shows the principle construction of the seal arrangement and the control system of figure 6.

The figure shows the water seal 100 with the two seal rings 110, 120 and a seal chamber 115 positioned between the seal rings 210, 220. The seal rings 210, 220 are acting on a second liner 34 positioned on the propeller shaft 31. The first oil seal 200 is lubricated with lubrication oil being circulated from the lubrication oil tank 70. Lubrication oil is circulated through the seal chamber 215. There is a filling pipe 71 leading to the lubrication oil tank 70. The first oil seal 200 prevents lubrication oil from escaping from the bearing 41. The first oil seal 200 prevents on the other hand also sea water from penetrating into the bearing 41 even in an emergency case when the compartment 300 would be flooded.

The seal chamber 215 in the first oil seal 200 is pressurized with the hydrostatic pressure caused by the height difference $H_2$ between the shaft line X-X and the lubrication oil tank 70. A simple mechanical oil circulator could be used to circulate the oil within the seal chamber 215. The oil tank 70 cools down to the temperature of the cooling air used to cool the first electric motor 30 in the lower portion 23 of the strut 21. The sealing ring 210 being nearest to the bearing 41 is cooled by the lubrication oil circulation in the bearing 41. Air pressure produced in the air pressure control system 500 is further directed with a second pipe 95 provided with a second valve 96 to the lubrication oil tank 70. This means that the pressure acting in the seal chamber 215 in the first oil seal 200 is the hydrostatic pressure caused by the height difference $H_2$ between the shaft line X-X and the lubrication oil tank 70 added with the air pressure produced by the air pressure system 500. The air pressure in the intermediate compartment 300 is 0.1 bar below the sea water pressure at the shaft level X-X. The pressure in the seal chamber 215 will thus be 0.1 bar below the sea water pressure at the shaft level X-X added with the hydrostatic pressure caused by the height $H_2$. The height $H_2$ could be e.g. 1 m, which means that the corresponding hydrostatic pressure would be 0.1 bar. The pressure in the seal chamber 215 would thus correspond to the pressure of the sea water at the shaft level X-X. There would thus be a pressure difference of 0.1 bar over the second seal ring 220 in the first oil seal 200. There is
further a drain pipe 81 connected via a valve 80 to the seal chamber 215 in the first oil seal 200.

[0043] Figure 8 shows a cross section of a seal arrangement and a control system for a propeller shaft according to another embodiment of the invention. The only difference in this embodiment compared to the embodiment shown in figure 7 is in the water seal 100. The water seal 100 is in this embodiment based on a face type seal 150. The shaft 31 is provided with a cylindrical fastening member 35 and the face type seal 150 is attached to the fastening member 35. A vertical face of the water seal 150 is acting against a vertical liner 36 arranged in the first vertical wall 26. This face type seal 150 is formed of a cylindrical portion 152 attached to the fastening member 35 and a circular portion 151 acting against the liner 36. The circular portion 151 acting against the vertical liner 36 could be provided with lips forming the sealing (not shown in the figure). There are different kinds of face type seals 150, but the circular portion 151 possible provided with lips acting against the vertical liner 36 is a common feature for a face type seal 150. The first pressure sensor 91 could measure the pressure of the sea water at the shaft line X-X from the small water seal chamber between the lips in the circular portion 151 or directly from the sea water acting on the outside of the first end wall 26. The seal arrangement and control system corresponds in other respects to that shown in figure 7. The air pressure in the intermediate chamber 300 will act of the face type seal 150 pressing the lips of the circular portion of the face type seal 150 against the vertical liner 36.

[0044] The seal arrangement makes it possible to postpone the replacement of the seal in an emergency situation. A defected seal ring 120 in the water seal 100 could lead to a situation where the whole interior of the intermediate compartment 300 would be flooded. The propulsion unit 20 could still be operated with full power in such a situation until the second seal ring 120 in the water seal 100 can be replaced in a harbour. The seal chamber 215 between the two seal rings 210, 220 in the oil seal 200 could be manually pressurized over the pressure of the sea water in order to eliminate penetration of sea water into the bearing 41. This can be done by closing the first valve 94 and keeping the second valve 96 open. Pressurized air having a pressure higher than the pressure in the flooded intermediate compartment 300 measured with the second pressure sensor 92 can be directed into the lubrication oil tank 70. The pressure in the seal chamber 215 in the first oil seal 200 will thus be higher than the pressure in the flooded intermediate compartment 300, which will prevent sea water from penetrating into the seal chamber 215 in the first oil seal 200.

[0045] The connection of the air pressure from the air pressure system 500 to the lubrication oil tank 70 is not necessary needed in case the draught of the vessel is more or less constant. The lubrication oil tank 70 could in such a case be positioned at a suitable height H2 in order to maintain a suitable hydrostatic pressure in the seal chamber 215 in the first oil seal 200. The pressure in the seal chamber 215 in the first oil seal 200 must be on a higher level than the pressure in the intermediate chamber 300 in order to prevent oil leakage from the bearing 41 to the intermediate chamber 300.

[0046] It would even be possible to do without the lubrication tank 70 for the first oil seal 200. The first oil seal 200 could in such a case comprise only one seal ring 210. This would be possible if the draught of the ship is small and constant, which means that the pressure in the intermediate compartment 300 is small and stable.

[0047] It would also be possible to use a face type seal as the first oil seal 200. A lip type seal is, however, more suitable to be used as the first oil seal 200.

[0048] The emergency seal 105 shown in figure 6 is an optional feature in the seal arrangement. The emergency seal 105 could be inflated with air in a situation where the water seal 100 is to be changed. The emergency seal 105 would prevent water from penetrating into the vessel when the water seal 100 is changed. In a case where an emergency seal 105 is not used a diver is needed to position a temporary inflatable seal between the propeller 32 and the first vertical wall 26 when the water seal 100 is to be changed.

[0049] The emergency seal 105 could naturally also be used in the embodiment of the invention shown in figure 8.

[0050] The intermediate compartment 300 is a closed, airtight compartment. Air can escape from the intermediate compartment 300 only through the water seal 100 and the first oils seal 200. The service opening 29 must thus be sealed in order to be air tight when it is closed. There could naturally be several service openings 29 along the circumference of the vertical second wall 27.

[0051] 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 seal arrangement for a propeller shaft (31) in a vessel, the propeller shaft (31) being supported within the hull of the vessel with at least one bearing (41) and extending through an opening (O1) in the hull of the vessel to a propeller (32) outside the hull of the vessel, said seal arrangement comprising:

   - a water seal (100) positioned on the propeller shaft (31) adjacent to the opening (O1) in the hull in order to seal the propeller shaft (31) in the opening (O1) in the hull,
   - a first oil seal (200) positioned on the propeller shaft (31) adjacent to the bearing (41) at an axial (X-X) distance (A2) from the water seal (100) in order to prevent lubrication oil leakage from the bearing (41) to the sea,
   - an intermediate compartment (300) surrounding
the water seal (100) and the first oil seal (200), a first pressure sensor (91) for measuring the pressure of the sea water acting at the propeller shaft (31),

characterized in that the seal arrangement comprises further:

a second pressure sensor (92) for measuring the pressure within the intermediate compartment (300),

an air pressure system (500) for producing an air pressure into the intermediate compartment (300), whereby the air pressure within the intermediate compartment (300) is kept at a lower level compared to the pressure of the sea water acting on the propeller shaft (31).

2. A seal arrangement according to claim 1, characterized in that the water seal (100) is a lip type seal provided with two seal rings (110, 120) and a seal chamber (115) between the two seal rings (110, 120).

3. A seal arrangement according to claim 2, characterized in that the first pressure sensor (91) measures the pressure within the seal chamber (115) of the water seal (100).

4. A seal arrangement according to claim 2 or 3, characterized in that the seal chamber (115) in the water seal (100) is provided with sea water (SW) lubrication.

5. A seal arrangement according to claim 1, characterized in that the water seal (100) is a face type seal (150) provided with a first ring like portion (151) comprising seal lips acting in the axial direction (X-X) on a vertical liner (35).

6. A seal arrangement according to any one of claims 1 to 5, characterized in that the first oil seal (200) is a lip type seal provided with two seal rings (210, 220) and a seal chamber (215) between the two seal rings (210, 220).

7. A seal arrangement according to claim 6, characterized in that the seal chamber (215) in the oil seal (200) is connected to a lubrication oil tank (70) being positioned at a vertical distance (H2) above the oil seal (200) in order to provide lubrication oil to the seal chamber (215) in the oil seal (200).

8. A seal arrangement according to claim 7, characterized in that the air pressure system (500) is connected to the oil tank (70) in order to pressurize the oil tank (70).

9. A seal arrangement according to any one of claims 1 to 8, characterized in that the air pressure system (500) is connected through a first valve (94) to the intermediate compartment (300).

10. A seal arrangement according to any one of claims 1 to 9, characterized in that the air pressure system (500) is connected through a second valve (96) to the oil tank (70) in order to pressurize the oil tank (70).

11. A seal arrangement according to any one of claims 1 to 10, characterized in that the volume of the intermediate compartment (300) is in the range of 500 to 3000 litres.
FIG. 5 (Prior art)
## DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document with indication, where appropriate, of relevant passages</th>
<th>Relevant to claim</th>
<th>CLASSIFICATION OF THE APPLICATION (IPC)</th>
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<tr>
<td>A</td>
<td>GB 1 071 987 A (ROBERT YATES) 14 June 1967 (1967-06-14) * page 2, line 46 - line 53 * figures *</td>
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**TECHNICAL FIELDS SEARCHED (IPC)**
- B63H
- B63B
- F16J

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The present search report has been drawn up for all claims
This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on 22-04-2015.

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REFERENCES CITED IN THE DESCRIPTION

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