

DESCRIPTION

VERTICAL PUMP

TECHNICAL FIELD

[0001] The present invention relates to a vertical pump that pumps up liquid such as river water and drainage, and particularly to a vertical pump that improves durability and maintainability of a bearing supporting a rotating shaft, and facilitates replacement of the bearing.

BACKGROUND ART

[0002] Figure 1 is a schematic diagram of a conventional vertical pump. As shown in Figure 1, a vertical pump generally has a pump base 514, and the pump base 514 is installed on a pump installation floor 500 in an upper part of a water tank. A guide casing 506 that accommodates an impeller 504 is suspended from the pump installation floor 500, through a suspension pipe 502. The impeller 504 is fixed to a rotating shaft 509, and the rotating shaft 509 is rotatably supported by an external bearing 510 and a submerged bearing 508.

[0003] Since this type of vertical pump is operated with the impeller 504 and the submerged bearing 508 submerged in water, wear and corrosion gradually occur in these members over time. Hence, it is necessary to inspect the vertical pump periodically to check the state of wear of the bearing part (external bearing 510 and submerged bearing 508) and the impeller 504, and the state of corrosion of the guide casing 506, and repair or replace these members if needed. Among

these members, damage or wear in the submerged bearing 508 will cause abnormal vibration of the pump, and will eventually cause a failure (inoperative state) of the pump. For this reason, inspection of the submerged bearing 508 is one of the important inspection items.

[0004] Known methods of inspecting and maintaining a vertical pump include 1) working with the pump installed, and 2) working by lifting up the pump. Since the inspection method 1) can be carried out without lifting the pump, it is low in cost, and inspection and maintenance require less time. However, when the submerged bearing 508 of the vertical pump is submerged in water, for example, with the aforementioned method 1), it is difficult to appropriately measure or detect the state of wear of the submerged bearing 508, and impossible to replace the submerged bearing 508. Additionally, even if the water tank is drained and dried, the submerged bearing 508 still cannot be inspected, receive maintenance or be replaced, since the submerged bearing 508 is positioned above (on the discharge side of) the impeller 504. That is, even if the water tank is drained to expose the bearing part to the atmosphere, the part cannot be inspected or and maintained sufficiently, because of the installed position of the bearing.

[0005] Against this background, methods have been proposed to measure vibration of the external bearing 510 and the pump base 514 that are measurable above ground, and estimate the state of the submerged bearing 508 in an indirect manner (see Patent Literatures 1 and 2). However, in this method, since the measurement is not made near the submerged bearing 508

which is the vibration source, various attenuation effects from the vibration source to the measurement point hinder measurement of abnormal vibration due to wear or the like of the submerged bearing. Hence, the state of damage or wear cannot be determined appropriately.

[0006] Meanwhile, according to the aforementioned method 2), it is possible to appropriately measure or detect the state of wear of the submerged bearing 508, and replace the submerged bearing 508. For this reason, the aforementioned method 2) has conventionally been used to check wear of the submerged bearing 508 of the vertical pump.

[0007] However, the aforementioned method 2) is high in cost, and inspection and maintenance require longer time. For example, if the vertical pump is to be lifted by an overhead crane, a machinist as an inspection staff, a worker, and a crane operator would be needed, for example, so the lifting would require a considerable amount of work cost. In addition, lifting and re-assembly of the heavy pump are dangerous tasks.

[0008] Moreover, in the lifting and inspection, inspection and maintenance is performed after the lifting, and then steps such as reinstallation, centering, and test operation are required, which take many days. Further, some pump stations are required to constantly drain a required amount of water, even during inspection and maintenance. However, since a pump under inspection cannot be operated during the inspection period, drainage capacity needs to be ensured by installing a temporary pump, for example.

[0009] Against this background, Patent Literature 3

proposes a vertical pump having a structure in which both of a submerged bearing arranged below an impeller, and an external bearing above a pump installation floor support a rotating shaft. According to this structure, since the submerged bearing is positioned below (on the suction side of) the impeller, it is possible to check the state of wear of the submerged bearing from the inlet by visual observation, and easily replace the submerged bearing.

[0010] However, in recent years, a pump is required to handle a larger quantity of water and have a higher pump head (larger capacity). The increase in capacity increases load applied on the submerged bearing, which is provided only in the lower part of the pump, and makes the bearing itself larger and heavier. In this case, there is a problem that workability from below the impeller deteriorates.

Additionally, the increase in capacity of the pump widens the diameter of the rotating shaft, whereby the peripheral speed of a bearing contact surface increases. This leads to a problem of acceleration of wear of the bearing.

[0011] Meanwhile, Patent Literature 4 describes a technique for addressing the above problem, in which an additional submerged bearing (middle bearing) is provided between an external bearing and a submerged bearing installed below an impeller of a pump. The middle bearing has a divided structure, so that a worker can enter the pump and replace the bearing. However, the inside of the pump is narrow, and the work needs to be done in a high place, which leaves a problem of workability and safety.

CITATION LIST

PATENT LITERATURE

[0012] Patent Literature 1: Japanese Patent No. 3567140

Patent Literature 2: Japanese Patent Laid-Open No. 2004-218578

Patent Literature 3: Japanese Patent No. 4456579

Patent Literature 4: Japanese Patent Laid-Open No. 2012-137074

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0013] The present invention has been made in view of such problems of conventional techniques, and aims to provide a vertical pump that, even in a large-capacity pump, facilitates replacement of a submerged bearing, with the pump remaining installed, without lifting the pump, and improves reliability of the submerged bearing.

SOLUTION TO PROBLEM

[0014] A vertical pump according to a first aspect of the present invention includes: an impeller; a rotating shaft that extends through the impeller and to which the impeller is fixed; an external bearing that supports the rotating shaft; and a bearing unit that is provided below the impeller, and supports the rotating shaft penetrating the impeller. The rotating shaft extends from the external bearing through the impeller, without passing through any bearing other than the external bearing; and the bearing unit has a first bearing that supports a sliding part of the rotating shaft on a bearing inner circumferential surface, and a second bearing

that supports a sliding part of the rotating shaft on a bearing outer circumferential surface.

[0015] According to a vertical pump of a second aspect of the present invention, in the vertical pump of the first aspect, the bearing unit is detachably attached below the impeller.

[0016] According to a vertical pump of a third aspect of the present invention, in the vertical pump of the first or second aspect, the first bearing and the second bearing are configured in a detachable manner below the impeller.

[0017] According to a vertical pump of a fourth aspect of the present invention, in the vertical pump of any of the first to third aspects, a protection cover is provided below the bearing unit; and the protection cover has a small hole that is directed laterally, and configured to guide water flow toward the bearing unit.

[0018] According to a vertical pump of a fifth aspect of the present invention, in the vertical pump of any of the first to fourth aspects, the first bearing and the second bearing are made of the same material; and the material is made of resin or a resin composite.

ADVANTAGEOUS EFFECTS OF INVENTION

[0019] According to the present invention, a vertical pump includes: a rotating shaft that extends from an external bearing through an impeller without passing through any bearing other than the external bearing, and to which the impeller is fixed; and a bearing unit that receives the rotating shaft below the impeller. The bearing unit has a

first bearing that supports a sliding part of the rotating shaft on a bearing inner circumferential surface, and a second bearing that supports a sliding part of the rotating shaft on a bearing outer circumferential surface. Hence, even in a large pump, stability of a submerged bearing can be improved to enable stable operation of the pump, and the submerged bearing can be downsized. Also, in terms of maintenance such as inspection and replacement, the work can be done easily with high workability and reliability, with the pump remaining installed, without lifting the pump.

BRIEF DESCRIPTION OF DRAWINGS

[0020] Figure 1 is a schematic diagram of a conventional vertical pump.

Figure 2 is a schematic diagram of a vertical pump of an embodiment of the present invention.

Figure 3 is a schematic diagram of a longitudinal section for describing the principle of a bearing unit.

Figure 4 is a cross-sectional view of an XX' section shown in Figure 3.

Figure 5 is a diagram showing a movement of the bearing unit during dry operation.

Figure 6 is a diagram showing a movement of the bearing unit during drainage operation.

Figure 7 is a diagram in which the vibration velocity of the vertical pump including the bearing unit during dry operation is compared with that of a conventional bearing device.

Figure 8 is a diagram in which the bearing temperature of

the vertical pump including the bearing unit during dry operation is compared with that of the conventional bearing device.

Figure 9 is a diagram in which the vibration velocity of the vertical pump including the bearing unit during drainage operation is compared with that of the conventional bearing device.

Figure 10 is a schematic diagram of a longitudinal section of a conventional bearing device.

Figure 11 is a structural profile of a submerged bearing unit of an embodiment of the present invention.

Figure 12 is a structural profile of a submerged bearing unit of another embodiment.

Figure 13 is a structural profile of a submerged bearing unit of another embodiment.

Figure 14 is a cross-sectional view of a middle bearing unit cover.

Figure 15 is a structural profile of a submerged bearing unit of another embodiment.

Figure 16 is a structural profile of a submerged bearing unit of another embodiment.

DESCRIPTION OF EMBODIMENTS

[0021] Hereinafter, embodiments of a vertical pump of the present invention will be described in detail with reference to Figures 2 to 16. Note that in Figures 2 to 16, the same or corresponding components are assigned the same reference numerals, and redundant descriptions will be omitted. Also note that in the following description, "upper side" refers to

the upper side (discharge side) when the vertical pump is installed, and "lower side" refers to the lower side (suction side) when the vertical pump is installed.

[0022] Figure 2 is a schematic diagram of a vertical pump of an embodiment of the present invention. As shown in Figure 2, the vertical pump includes a guide casing 1 having a suction bellmouth 1a and a discharge bowl 1b, a suspension pipe 3 that suspends the guide casing 1 inside a water tank 5, a curved discharge pipe 4 connected to the upper end of the suspension pipe 3, an impeller 10 accommodated inside the guide casing 1, and a rotating shaft 6 to which the impeller 10 is fixed.

[0023] The suspension pipe 3 extends downward through an insertion hole 24 formed in a pump installation floor 22 in an upper part of the water tank 5, and is fixed to the pump installation floor 22 through a pump base 23 provided in the upper end of the suspension pipe 3. The rotating shaft (vertical shaft) 6 extends vertically through the curved discharge pipe 4 and the suspension pipe 3, and its lower end is positioned inside the guide casing 1. The guide casing 1 and the suspension pipe 3 form a pump casing 2. An above-floor part F, which is an area above the pump installation floor 22, is an area that can be inspected at any time, and a water tank part U, which is an area below the pump installation floor 22, is a submerged area.

[0024] As shown in Figure 2, the suction bellmouth 1a has an opening on the lower side (suction side), and the upper end of the suction bellmouth 1a is fixed to the lower end of the

discharge bowl 1b. The impeller 10 is fixed to a lower part of the rotating shaft 6, and the impeller 10 is configured to rotate integrally with the rotating shaft 6. The impeller 10 has multiple vanes, and multiple guide vanes 14 are arranged on the upper side (discharge side) of the impeller 10. These guide vanes 14 are fixed to an inner circumferential surface of the guide casing 1 and an outer circumferential surface of a bowl bushing 13.

[0025] Additionally, the rotating shaft 6 is rotatably supported by a submerged bearing unit 12 and an external bearing 11. The submerged bearing unit 12 is positioned on the lower side (suction side) of the impeller 10, and supports the lower end of the rotating shaft 6. The submerged bearing unit 12 is supported by a supporting member 15 fixed to an inner circumferential surface of the suction bellmouth 1a. Note that including the inside of the bowl bushing 13, no submerged bearing is placed between the external bearing 11 and the submerged bearing unit 12. The external bearing 11 is provided in an upper part (outside) of the curved discharge pipe 4, and supports an upper part (one end) of the rotating shaft 6. The rotating shaft 6 extends from the external bearing 11 through the impeller 10, without passing through any bearing other than the external bearing 11. The submerged bearing unit 12 has: an inner contact bearing (first bearing) that is arranged on the radially outer side of the rotating shaft 6 (around the rotating shaft 6), and supports a sliding part of the rotating shaft 6 on a bearing inner circumferential surface; and an outer contact bearing (second

bearing) that is arranged on the radially inner side of the rotating shaft 6, and supports a sliding part of the rotating shaft 6 on a bearing outer circumferential surface.

[0026] The first bearing and the second bearing provided in the submerged bearing unit 12 are so-called slide bearings that support the rotating shaft 6 while coming into sliding contact with the rotating shaft, during normal operation of the pump. The external bearing 11 is configured to receive not only a radial load but also a thrust load. The external bearing 11 may be a single bearing that can receive both of a radial load and a thrust load, or may be a combination of a radial bearing that can receive a radial load and a thrust bearing that can receive a thrust load.

[0027] As shown in Figure 2, the rotating shaft 6 protrudes upward from the curved discharge pipe 4. The upper end of the rotating shaft 6 is coupled to a drive shaft 42 of a speed reducer 41, through a universal coupling 45. Furthermore, the speed reducer 41 is coupled to a drive source 43. A diesel engine, a gas turbine, or a motor, for example, may be used as the drive source 43. Note that the speed reducer 41 is not used in some cases.

[0028] When the drive source 43 rotates the impeller 10 through the rotating shaft 6, water (handled fluid) inside the water tank 5 is sucked in from the suction bellmouth 1a, and is transferred to discharge piping 20 through the discharge bowl 1b, the suspension pipe 3, and the curved discharge pipe 4. Note that the impeller 10 and the submerged bearing unit 12 are positioned below the water surface during drainage

operation of the vertical pump.

[0029] In a conventional vertical pump shown in Figure 1, a submerged bearing 508 is accommodated inside a bowl bushing, and therefore it is difficult to replace the submerged bearing 508 while the vertical pump remains installed. In the embodiment, the submerged bearing unit 12 is arranged on the lower side of the impeller 10. Hence, if the water inside the water tank 5 is removed and a worker enters a lower part of the vertical pump, the wear amount and degree of damage of the submerged bearing unit 12 can be easily determined by use of a gap gauge, for example. Moreover, it is possible to easily replace the submerged bearing unit 12.

[0030] Thus, since the submerged bearing unit 12 can be inspected and replaced without lifting the vertical pump, it is possible to eliminate cost required for lifting of the vertical pump, and significantly reduce inoperable time during inspection and replacement. Accordingly, it is possible to improve economic efficiency and reliability of the pump station. In addition, since the submerged bearing unit 12 is positioned lower than in conventional structures, that is, below the impeller 10, it is possible to surely submerge the submerged bearing unit 12 during operation of the pump. Hence, a water film formed between the submerged bearing unit 12 and the rotating shaft 6 suppresses wear of the submerged bearing unit 12, and can improve durability of the submerged bearing unit 12.

[0031] Next, a description will be given of the first slide bearing and the second slide bearing. Figure 3 is a schematic

diagram of a longitudinal section for describing the principle of the bearing unit. The bearing unit of the embodiment has a sleeve 31 on the outer circumference of a rotating shaft 30. The sleeve 31 is practically made of hard metal, stainless steel, or the like. A hollow cylindrical first slide bearing 44 is provided on the outer circumferential side of the sleeve 31. Specifically, the sleeve 31 comes into contact with and slides on the inner side of the first slide bearing 44. The first slide bearing 44 is practically made of resin material, ceramics, sintered metal, or surface-modified metal. An outer circumferential surface (first sliding part 46) of the sleeve 31 faces an inner circumferential surface (sliding surface) of the first slide bearing 44 with an extremely narrow first clearance 47 in between, and is configured to slide with respect to the sliding surface of the first slide bearing 44. An outer circumferential part of the first slide bearing 44 is fixed to an inner circumferential surface of a substantially cylindrical bearing case 32. The bearing case 32 is practically made of metal or resin.

[0032] In addition, a hollow cylindrical second slide bearing 39 is provided on an outer circumferential surface of the bearing case 32. The second slide bearing 39 is practically made of resin material, ceramics, sintered metal, or surface-modified metal.

[0033] A substantially cylindrical sleeve case 38 is fixed to the rotating shaft 30 with fixing means 33a such as a fixing pin or a bolt, and the sleeve case 38 is configured to rotate together with the rotating shaft 30, when the rotating

shaft 30 rotates. A sleeve 37 is provided on an inner circumferential surface of the sleeve case 38. An inner circumferential surface (second sliding part 36) of the sleeve 37 faces an outer circumferential surface (sliding surface) of the second slide bearing 39 with an extremely narrow second clearance 48 in between, and is configured to slide with respect to the sliding surface of the second slide bearing 39. That is, the sleeve 37 circumscribes and slides on the outer side of the second slide bearing 39. Note that although the sleeves 31, 37 are generally installed on the outer circumference of a shaft member or the like, for the sake of simplicity of the configuration of the bearing unit, in this application, those serving as main bearing members are referred to as first and second slide bearings, and corresponding members on which the slide bearings slide are referred to as sleeves.

[0034] Hereinabove, the configuration of the bearing unit has been described. The bearing unit is fixed to a supporting member 35 or the like that is continuous with a casing such as the pump, through a rib part 32a of the bearing case 32, with fixing means 33b such as a bolts. Note that in the example described above, the sleeve 31 is held on the outer circumference of a rotor (rotating shaft 30), and the non-rotary slide bearing corresponding to the outer circumferential side of the sleeve 31 serves as the first slide bearing 44. Meanwhile, the sleeve 37 is provided on the inner circumference of a rotor (sleeve case 38), and the non-rotary slide bearing corresponding to the inner

circumferential side of the sleeve 37 serves as the second slide bearing 39. However, a slide bearing may be held on the outer circumference of the rotor (rotating shaft 30), and a sleeve may be provided on the corresponding non-rotary body instead. Also, the first slide bearing may be in a state where a sleeve is held on the outer circumference of a rotor, and a corresponding slide bearing is on the non-rotary side, while a second slide bearing may be in a state where a slide bearing is held on the outer circumference of a rotor, and a corresponding sleeve is on the non-rotary side. This configuration may be reversed.

[0035] In consideration of a case where the bearing unit is used in a drainage pump such as a vertical pump, and is used in an underwater environment, the sleeve case 38 has a feed water port 40 that allows water containing slurry and the like into the first clearance 47 and the second clearance 48. The water having flowed into the feed water port 40 passes through the first clearance 47 and the second clearance 48 that serve as flow paths. Thus, flow paths for allowing water into the first clearance 47 and the second clearance 48 are formed, and the first clearance 47 and the second clearance 48 also function as flow paths. Accordingly, during drainage operation, water is allowed to flow smoothly into the first clearance 47 and the second clearance 48 without air retention, so that functions of the first slide bearing 44 and the second slide bearing 39 can be exerted promptly.

[0036] Additionally, at the time of startup, the first slide bearing 44 and the second slide bearing 39 support the

sleeve 31 and the sleeve 37 under a dry condition, and under a draining condition, support the sleeve 31 and the sleeve 37 through an extremely thin liquid film. In this description, a dry condition refers to a condition in which the atmosphere around the first slide bearing 44 and the second slide bearing 39 during operation is air with no lubrication by liquid, and dry operation refers to operation under such a condition.

[0037] To suppress constant whirling of the rotating shaft 30, and reduce load applied on the first slide bearing 44 and the second slide bearing 39 by whirling, it is preferable that the diametrical clearance dimension (inner diameter of first slide bearing 44 - outer diameter of sleeve 31) of the first clearance 47, and the diametrical clearance dimension (inner diameter of sleeve 37 - outer diameter of second slide bearing 39) of the second clearance 48, be not smaller than $1/1000$ and not larger than $1/100$ of the inner diameter of the first slide bearing 44, and not smaller than $1/1000$ and not larger than $1/100$ of the outer diameter of the second slide bearing 39, respectively. If the dimensions of the first clearance 47 and the second clearance 48 are larger than these ranges, constant whirling of the rotating shaft 30 increases, the load applied on the first slide bearing 44 and the second slide bearing 39 by the whirling also increases, and therefore stable operation may be hindered. Meanwhile, if the dimensions of the first clearance 47 and the second clearance 48 are smaller than these ranges, the first clearance 47 and the second clearance 48 may be blocked by contamination, or the first slide bearing 44 and the second slide bearing 39 may be burnt by friction

against the contamination.

[0038] Although it is preferable that the diametrical clearance dimension of the first clearance 47 and the diametrical clearance dimension of the second clearance 48 be the same, if the first slide bearing 44, the second slide bearing 39, the sleeve 37, or the sleeve 31 has elasticity, that is, if the member is formed of resin, for example, the function of the present invention can be exerted even if there is a difference in the dimensions. In this case, the ratio of the diametrical clearance dimension of the second clearance 48 to the diametrical clearance dimension of the first clearance 47 is preferably not smaller than 0.5 and not larger than 2.0, and more preferably not smaller than 0.7 and not larger than 1.3. Note, however, that as will be mentioned later, if the first slide bearing 44, the second slide bearing 39, the sleeve 37, or the sleeve 31 is fixed by also inserting a shock-absorbing material such as rubber in between (see Figure 11, for example), deformation of the shock-absorbing material allows the first slide bearing 44 and the second slide bearing 39 to simultaneously come into contact with the sleeve 31 and the sleeve 37, respectively, even if the dimensions are not within the above range, so that the function of the present invention can be exerted.

[0039] Figure 4 is a cross-sectional view of an XX' section shown in Figure 3. As shown in Figure 3, in the configuration, the centers of the outer circumferential surface of the sleeve 31, the inner circumferential surface of the first slide bearing 44, the outer circumferential surface of the second

slide bearing 39, and the inner circumferential surface of the sleeve 37 substantially coincide with a center axis O. Note that in Figure 4, the dimensions of the first clearance 47 and the second clearance 48 are enlarged for convenience.

[0040] Figure 5 is a diagram showing a movement of the bearing unit during dry operation. When the rotating shaft 30 rotates, the sleeve 31 fixed to the rotating shaft 30 and the sleeve 37 fixed to the sleeve case 38 also rotate. Under a dry condition, when the outer circumferential surface of the sleeve 31 comes into contact with the first slide bearing 44 at point A, a bearing reaction force F_{AN} is generated in the rotating shaft 30. This bearing reaction force F_{AN} generates a frictional force F_{AF} in a direction opposite to the rotation direction of the rotating shaft 30, and this frictional force F_{AF} becomes a destabilizing force that causes a whirling vibration in the rotating shaft 30, in the direction opposite to the rotation direction of the rotating shaft 30.

[0041] Meanwhile, when the sleeve 37 comes into contact with the second slide bearing 39 at point B, a bearing reaction force F_{BN} is generated. This bearing reaction force F_{BN} generates a frictional force F_{BF} , which is a force in a direction opposite to the frictional force F_{AF} . Since the frictional force F_{AF} and the frictional force F_{BF} cancel each other out in the system of the rotating shaft 30, the rotating shaft 30 can rotate stably. In addition, since the load (bearing reaction force) of the rotating shaft 30 is distributed to points A and B, the frictional force acting on the slide bearings, too is distributed. As a result, heating

due to friction is suppressed, so that an increase in the temperature of the bearing during dry operation can be suppressed.

[0042] Figure 6 is a diagram showing a movement of the bearing unit during drainage operation. The first clearance 47 and the second clearance 48 are filled with water, the water in the clearances form a liquid film 49 and a liquid film 50, respectively, whereby the bearing unit of the embodiment functions as a fluid lubrication-bearing unit. At this time, rotation of the rotating shaft 30 causes an unevenness of pressure in the circumferential direction in the liquid film 49. This generates a radial hydrodynamic force F_{AR} and a circumferential hydrodynamic force F_{AT} in the rotating shaft 30. This circumferential hydrodynamic force F_{AT} becomes a destabilizing force that causes vibration during drainage operation. Note that the circumferential hydrodynamic force F_{AT} is a force in a direction opposite to the frictional force F_{AF} generated in the aforementioned dry operation.

[0043] Conventionally, the inner shape of a bearing has been formed into a multi-lobed shape instead of a perfect circle, to prevent the unstable vibration caused by liquid film in a vertical rotating shaft. However, when a bearing made of resin is used in water containing a large amount of slurry, the inner shape of the bearing gradually deforms toward a perfect circle by wear, and loses the vibration-suppressing effect in some cases.

[0044] Here, according to the bearing unit of the embodiment, rotation of the sleeve 37 causes an unevenness of

pressure in the circumferential direction in the liquid film 50 in the second clearance 48, whereby a radial hydrodynamic force F_{BR} and a circumferential hydrodynamic force F_{BT} are generated in the rotating shaft 30. At this time, since the circumferential hydrodynamic force F_{AT} and the circumferential hydrodynamic force F_{BT} act in opposite directions, the destabilizing forces of the liquid film 49 and the liquid film 50 cancel each other out. Hence, the rotating shaft 30 can rotate stably without generating vibration due to the destabilizing forces.

[0045] As has been described, the bearing unit is a slide bearing that supports the rotating shaft by constantly sliding on sliding surfaces, during both normal operations of dry operation and drainage operation. What is more, in the bearing unit, frictional forces acting on a contact point of the first slide bearing and on a contact point of the second slide bearing cancel each other out, so that vibration of the rotating shaft due to destabilizing forces can be suppressed, and stable rotation of the rotating shaft can be maintained.

[0046] Figure 7 is a diagram showing the vibration velocity of a vertical pump provided with the bearing unit shown in Figure 3, during dry operation performed in the atmosphere of air, without lubrication or cooling by water. For comparison purposes, Figure 7 also shows the vibration velocity of a vertical pump (conventional structure) including a bearing device having a conventional structure shown in Figure 10, during dry operation.

[0047] The conventional bearing device shown in Figure 10

has a sleeve 29 on the outer circumference of a rotating shaft 25. A hollow cylindrical slide bearing 28 is provided on the outer circumferential side of the sleeve 29. An outer circumferential surface of the sleeve 29 faces an inner circumferential surface (sliding surface) of the slide bearing 28 with an extremely narrow clearance in between, and is configured to slide with respect to the slide bearing 28. The diameter and rotation speed of the rotating shaft 25, and materials of the sleeve 29 and slide bearing 28 shown in Figure 10 are the same conditions as the bearing unit shown in Figure 3.

[0048] As can be seen from Figure 7, the vertical pump (embodiment) including the bearing unit of Figure 3 is operated constantly at a lower vibration velocity than the vertical pump including the bearing device of the conventional structure, from startup to stop.

[0049] Figure 8 is a diagram showing the bearing temperature of the vertical pump provided with the bearing unit shown in Figure 3, during dry operation. For comparison purposes, Figure 8 also shows the bearing temperature of the vertical pump (conventional structure) including the bearing device having the conventional structure shown in Figure 10, during dry operation.

[0050] As can be seen from Figure 8, the vertical pump (embodiment) including the bearing unit of Figure 3 is constantly kept at a lower bearing temperature than the vertical pump including the bearing device of the conventional structure, from startup to stop.

[0051] As shown in Figures 7 and 8, in the vertical pump including the bearing device of the conventional structure, the frictional force applied on the rotating shaft is large. Hence, a large vibration occurs, which causes a large increase in the temperature of the bearing. On the other hand, in the vertical pump including the bearing unit of the embodiment, vibration can be suppressed and frictional force can be reduced, as described in Figure 5. Hence, increase in the bearing temperature can be suppressed.

[0052] Figure 9 is a diagram showing the vibration velocity of the vertical pump provided with the bearing unit shown in Figure 3, during drainage operation. The bearing unit is submerged in water during drainage operation. For comparison purposes, Figure 9 also shows the vibration velocity of the vertical pump (conventional structure) including the bearing device having the conventional structure shown in Figure 10, during drainage operation. Note that the results in Figure 9 were obtained by operating the vertical pump under conditions that are likely to cause vibration, and then measuring the vibration.

[0053] As can be seen from Figure 9, the vertical pump (embodiment) including the bearing unit of Figure 3 is operated constantly at a lower vibration velocity than the vertical pump including the bearing device of the conventional structure, from startup to stop.

[0054] As has been described, according to the bearing unit shown in Figure 3, even if whirling of the axis of the rotating shaft 30 during dry operation causes rotors (sleeve

31 and sleeve 37) to collide with the first slide bearing 44 and the second slide bearing 39, frictional forces act in opposite direction at the time of collision and cancel each other out. Hence, it is possible to keep the whirling of the rotating shaft 30 from spreading, and prevent vibration due to destabilization. In addition, it is possible to reduce friction caused by the vibration, and suppress increase in the bearing temperature.

[0055] The bearing unit shown in Figure 3 has the first slide bearing 44 and the second slide bearing 39. Hence, it is possible to distribute frictional force on the bearing sliding surface during dry operation, and suppress heating of the bearing sliding surface due to friction. This enables use of bearing materials having a higher friction coefficient than the conventional structure, that is, bearing materials having a higher wear resistance, so that stable operation can be continued over a long time period.

[0056] Also, the bearing unit shown in Figure 3 holds the first slide bearing 44 on the inner circumferential surface of the bearing case 32, and holds the second slide bearing 39 on the outer circumferential surface of the bearing case 32. Hence, the structure of the bearing unit can be downsized in the axial direction of the vertical pump.

[0057] Incidentally, in the vertical pump including the bearing unit of the embodiment, only slide bearings such as the first slide bearing 44 and the second slide bearing 39 support parts (sleeve 31 and sleeve 37) of the rotating shaft 30 submerged in water. That is, since rolling bearings such

as a ball bearing and a roller bearing are not suitable for a submerged bearing of a rotating machine that performs drainage operation, the effects of the embodiment can be exerted by slide bearings.

[0058] (Fitting and Detaching Configuration: Unitization)

Next, a bearing unit structure provided in a vertical pump of the present invention will be described. The principle of the bearing unit is the same as the principle of the bearing unit described in Figures 3 to 6. Figure 11 shows a bearing unit attached to the supporting member 15 fixed to the inner circumferential surface of the suction bellmouth 1a of the vertical pump in Figure 2. A rotating shaft 6 has an end part having a hollow cylindrical structure. The bearing unit has a first slide bearing 52 and a second slide bearing 57. A sleeve 51 (one example of a sliding part of the rotating shaft) that corresponds to the first slide bearing 52 arranged on the radially outer side of the rotating shaft 6 (around the rotating shaft 6) is provided, on the outer circumference of the end part of the rotating shaft 6 below the impeller. A sleeve 55 (one example of a sliding part of the rotating shaft) corresponding to the second slide bearing 57 is provided on the inner side of the hollow cylindrical structure of the end part of the rotating shaft 6, with a shock-absorbing material 56 interposed therebetween. A pressure plate 58 fixes the sleeve 55 corresponding to the second slide bearing 57 and the shock-absorbing material 56 to the rotating shaft 6.

[0059] The first slide bearing 52 is held to a

substantially cylindrical first bearing case 54 with a shock-absorbing material 53 interposed therebetween. The first bearing case 54 is fixed to the supporting member 15. The first bearing case 54 has a substantially disc-like rib part 54a. The rib part 54a is detachably attached to a lower surface of the supporting member 15 with bolts 61a, so that the first bearing case 54 can be detached to the vertically lower side (suction side) of the pump. Additionally, the second slide bearing 57 is arranged immediately below the first slide bearing 52, and is fixed to the first bearing case 54 by a substantially columnar or cylindrical second bearing case 60. The second bearing case 60 has a substantially disc-like rib part 60a, and the rib part 60a is detachably attached to a lower surface of the first bearing case 54 with bolts 61b.

[0060] Since the first bearing case 54 and the second bearing case 60 are thus formed separately, inspection and replacement of the bearings only require detachment of devices having minimum size and load.

[0061] For example, when inspecting to observe the state of wear of a bearing, even if the vertical pump has a large capacity and the bearing unit is large, checking and maintenance of the bearing can be facilitated by separating the second bearing case 60 from the first bearing case 54 and detaching only the second bearing case 60. On the other hand, after the inspection, all that is required is to assemble the second bearing case 60 to the first bearing case 54, and therefore workability can be improved.

[0062] In this case, in addition to the improvement in

workability of detachment and assembly, it is possible to accurately align the cores of the first slide bearing 52 and the second slide bearing 57 by using the first bearing case 54 as a base. Hence, the operating state after inspection can be maintained in the same state as before the inspection, whereby a highly stable bearing unit can be formed.

[0063] Also, when replacing the bearings, the first slide bearing 52 and the second slide bearing 57 can be detached simultaneously as one unit, by detaching the first bearing case 54. Hence, workability during replacement of the bearings can be improved. Note that in a case where the diameter of the rotating shaft 6 is relatively small, the devices are also relatively small, and therefore an integral-type bearing case 62 holding a first slide bearing 52 and a second slide bearing 57 as in Figure 12 may be used, instead of the part including the separate first bearing case 54 and second bearing case 60. The integral-type bearing case 62 has a substantially disc-like rib part 62a, and the rib part 62a is detachably attached to a lower surface of a supporting member 15 with bolts 61c, so that the integral-type bearing case 62 can be detached to the vertically lower side (suction side) of the pump.

[0064] In addition, it is preferable that multiple water supply and drainage ports (holes) 59 be provided in the second bearing case 60 of Figure 11 and the integral-type bearing case 62 of Figure 12. By providing the water supply and drainage ports 59, it is possible to surely guide water flow of the pump to the surfaces of the first slide bearing 52 and

the second slide bearing 57 to reduce friction by water on the surfaces of the bearings, so that life of the bearings can be extended, and vibration can be suppressed.

[0065] Figure 13 is a diagram showing another embodiment of a bearing unit provided in the vertical pump of the present invention. The structure of the bearing unit is applied to a large vertical pump, in which an outer diameter D_2 of a rotating shaft 6 is larger than an outer diameter D_1 of the rotating shaft 6 shown in Figure 11. A second slide bearing 57 is installed on an inner surface of a hollow cylindrical structure of the rotating shaft 6, on a substantially horizontal XX plane on which a first slide bearing 52 is installed. By thus arranging the first slide bearing 52 and the second slide bearing 57 on the same horizontal plane instead of in vertically (axially) separate positions, the bearings are more likely to come into contact with the rotating shaft 6 in positions opposite to each other on the same horizontal plane. Hence, the bearings are not affected by bending of a long rotating shaft 6 due to rotation of the shaft, for example, and therefore can slide more stably.

[0066] Also, by arranging the first slide bearing 52 and the second slide bearing 57 on the same horizontal plane, the vertical (axial) length of the bearing unit can be reduced, and the configuration of the bearing unit can be downsized. Since the bearing unit becomes compact, there are less parts that hinder the flow of the handled fluid. This can suppress adverse effects on pumping performance, such as reduction in pumping efficiency and increase in the no-discharge shaft

power.

[0067] (Unit Cover)

Figure 14 is a diagram showing a protection cover provided in the vertical pump of the present invention. A protection cover 63 has a tip end formed into a substantially spherical shape, and is detachably attached to a second bearing case 60 with fixing members 64. Additionally, water supply and drainage ports (small holes) 63a for supplying and draining the handled fluid of the pump are provided in the protection cover 63, along the horizontal direction (laterally). This configuration of the bearing unit can reduce head loss occurring in the bearing unit, which is installed below the rotor of the pump and directly receives water flow. Hence, it is possible to prevent deterioration in pumping performance (efficiency).

[0068] Also, since the water supply and drainage ports 63a are provided in the protection cover 63 along the horizontal direction (direction perpendicular to axial direction of rotating shaft 6), even when using a river or sewer drainage pump where the handled fluid contains slurry, it is possible to prevent slurry from entering the bearing part, and suppress wear of the bearing. Note that the water supply and drainage ports 63a of the embodiment drain water inside the bearing part to the suction tank side when the pump is stopped, and therefore have an effect of preventing slurry from pooling inside the pump bearing.

[0069] Also, the protection cover 63 is detachably attached to the second bearing case 60 with the fixing members 64.

Hence, the protection cover 63 can be detached during inspection or attachment and detachment of the bearing, to keep the protection cover 63 from hindering these operations. Note that although the protection cover 63 is detachably attached to the second bearing case 60 in Figure 14, it may be detachably attached to the first bearing case 54 or the supporting member 15 instead.

[0070] Next, bearing unit structures of other embodiments of the present invention will be described. As shown in the embodiment of Figure 13, in the method of providing the sleeve 51 on the outer surface of the rotating shaft 6, and holding the first slide bearing 52 corresponding to the sleeve 51 by the first bearing case 54 on the outer side of the sleeve 51, an increase in the outer diameter D_2 of the rotating shaft 6 increases the peripheral velocity, and therefore increases load on the sliding parts. In addition, if an outer diameter D_3 of the sliding part of the second slide bearing 57 in the embodiment shown in Figure 13 is extremely smaller than the outer diameter D_2 of the rotating shaft 6, there is a large difference between the distance from the center to the outer circumference of the sleeve 51, and the distance from the center to the outer circumference of the second slide bearing 57. Hence, contact pressure of the sleeve 55 cannot be applied on the second slide bearing 57. This makes the bearing reaction force of the second slide bearing 57 insufficient, whereby a difference occurs between the frictional forces in opposite directions respectively acting on the first slide bearing 52 and the second slide bearing 57.

[0071] Against this background, bearing units shown in Figures 15 and 16 provide bearing unit structures that ensure maintainability such as ease in replacement and inspection as described above, and also ensure optimal peripheral velocity and optimal contact pressure of the sliding parts and optimal bearing reaction force that do not directly depend on the diameter size of the rotating shaft 6.

[0072] Figure 15 shows a bearing unit of another embodiment of the present invention, which is attached to the supporting member 15 fixed to the inner circumferential surface of the suction bellmouth 1a of the vertical pump shown in Figure 2. A first bearing case 71 is fixed to an end part of a rotating shaft 6 with a fixing member (such as a bolt) 70. The first bearing case 71 has a hollow cylindrical part 71a, and a sleeve 55 (one example of a sliding part of the rotating shaft) is provided on an inner circumferential surface of the hollow cylindrical part 71a, with a shock-absorbing material 56 interposed therebetween. A pressure plate 58 fixes the sleeve 55 and the shock-absorbing material 56 to the first bearing case 71. Additionally, a first slide bearing 52 is provided on an outer circumferential surface of the cylindrical part 71a of the first bearing case 71. The first bearing case 71 is fixed to the rotating shaft 6, and therefore rotates together with the rotating shaft 6.

[0073] Meanwhile, a second bearing case 65 is fixed to the supporting member 15 with fixing members (such as bolts) 69. The second bearing case 65 has a columnar part 65a inserted into the hollow part (inside of cylinder) of the hollow

cylindrical part 71a of the first bearing case 71, and a cylindrical part 65b surrounding the outer circumference of the hollow cylindrical part 71a of the first bearing case 71. A second slide bearing 57 is provided on an outer circumferential surface of the columnar part 65a, in such a manner as to correspond to the sleeve 55 provided on the inner circumferential surface of the hollow cylindrical part 71a of the first bearing case 71 with the shock-absorbing material 56 interposed therebetween. Additionally, a sleeve 51 (one example of a sliding part of the rotating shaft) is provided on an inner circumferential surface of the cylindrical part 65b of the second bearing case 65 with a shock-absorbing material 53 interposed therebetween, in such a manner as to correspond to the first slide bearing 52 provided on the first bearing case 71. A pressure plate 66 fixes the sleeve 51 and the shock-absorbing material 53 to the second bearing case 65.

[0074] An outer diameter D_2' of the sliding part of the first slide bearing 52 is smaller than an outer diameter D_2 of the rotating shaft 6, and is set such that the peripheral velocity of the sliding part falls within a range that enables continuous appropriate use of the sliding member, when the rotating shaft 6 rotates. Also, an outer diameter D_3 of the sliding part of the second slide bearing 57 is smaller than the outer diameter D_2' of the sliding part of the first slide bearing 52, but is sized within a range that enables an appropriate contact pressure of the sleeve 55 to be applied on the second slide bearing 57.

[0075] With this configuration, it is possible to downsize

the first bearing case 71 and the second bearing case 65 without giving much consideration to the diameter of the rotating shaft 6. Also, in terms of maintenance, it is possible to inspect and replace the first slide bearing 52 and the second slide bearing 57 by detaching only the second bearing case 65, whereby workability is improved.

[0076] Moreover, in the embodiment, the first bearing case 71 having sliding parts on inner and outer circumferential surfaces thereof is fixed to the end part of the rotating shaft 6, while the second bearing case 65 having sliding parts corresponding to the sliding parts on the inner and outer circumferential surfaces of the first bearing case 71 is fixed to a non-rotary fixed body, such as the supporting member 15. Hence, even with a rotating shaft 6 having a larger diameter, it is possible to keep the peripheral velocity of rotation of the sliding parts within an appropriate range, keep the contact pressure applied on the sliding parts within an appropriate range, and keep the opposite frictional forces within an appropriate range, so that a stable bearing performance can be exerted.

[0077] Figure 16 shows a bearing unit structure of another embodiment of the present invention, which is attached to the supporting member 15 fixed to the inner circumferential surface of the suction bellmouth 1a of the vertical pump shown in Figure 2. A first bearing case 72 is fixed to an end part of a rotating shaft 6 with fixing members (such as bolts) 77. The first bearing case 72 has a columnar part 72a, and a hollow cylindrical part 72b surrounding the columnar part 72a.

A second slide bearing 57 (one example of a sliding part of the rotating shaft) is provided on the outer circumference of the columnar part 72a, and a sleeve 51 (one example of a sliding part of the rotating shaft) is provided on the inner circumference of the cylindrical part 72b, with a shock-absorbing material 53 interposed therebetween. A pressure plate 79 fixes the sleeve 51 and the shock-absorbing material 53 to the first bearing case 72. The first bearing case 72 is fixed to the rotating shaft 6, and therefore rotates together with the rotating shaft 6.

[0078] Meanwhile, a second bearing case 73 is fixed to the supporting member 15 with fixing members (such as bolts) 74. The second bearing case 73 has a cylindrical part 73a inserted between the columnar part 72a and the cylindrical part 72b of the first bearing case 72. A sleeve 55 corresponding to the second slide bearing 57 is provided on an inner circumferential surface of the cylindrical part 73a of the second bearing case 73, with a shock-absorbing material 56 interposed therebetween. A pressure plate 80 fixes the sleeve 55 and the shock-absorbing material 56 to the second bearing case 73. A first slide bearing 52 corresponding to the sleeve 51 is provided on an outer circumferential surface of the cylindrical part 73a of the second bearing case 73.

[0079] An outer diameter D_2' of the sliding part of the first slide bearing 52 is smaller than an outer diameter D_2 of the rotating shaft 6, and is set such that the peripheral velocity of the sliding part falls within a range that enables continuous appropriate use of the sliding member, when the

rotating shaft 6 rotates. Also, an outer diameter D_3 of the sliding part of the second slide bearing 57 is smaller than the outer diameter D_2' of the sliding part of the first slide bearing 52, but is sized within a range that enables an appropriate contact pressure of the sleeve 55 to be applied on the second slide bearing 57.

[0080] Since effects of the bearing unit of the embodiment shown in Figure 16 are the same as the effects of the bearing unit shown in Figure 15, descriptions thereof are omitted.

[0081] (Standby, Resin Bearing)

Ceramics, resin, rubber or the like may be used as the material of the first slide bearing 52 and the second slide bearing 57 of the bearing unit of the embodiment. Note that in a standby pump that performs aerial operation and drainage operation, resin or a resin composite that is usable in a dry state is used instead of brittle material such as ceramics, to prevent damage in the bearing due to a sudden change in the operation state (including a sudden change in the bearing temperature). When using such a resin bearing, there are problems that a resin bearing is less wear resistant than a ceramics bearing, and that the large friction coefficient of the bearing increases its heating value during aerial operation. However, it is possible to suppress the amount of wear and heating, by using the unit of the present invention that combines the first slide bearing 52 and the second slide bearing 57.

[0082] In the bearing device and the bearing unit structure of the present invention described above, shock-absorbing

materials do not necessarily have to be provided opposite to the sleeves and the sliding surfaces of the slide bearings. Although preferred embodiments of the present invention have been described, the present invention is not limited to the above embodiments, and may be implemented in various different forms within the scope of the technical idea of the invention, as a matter of course.

REFERENCE SIGNS LIST

[0083] 1 ... guide casing
3 ... suspension pipe
4 ... curved discharge pipe
6 ... rotating shaft
10 ... impeller
11 ... external bearing
44, 52 ... first slide bearing
39, 57 ... second slide bearing
63 ... protection cover
63a ... water supply and drainage port

CLAIMS

1. A vertical pump comprising:
 - an impeller;
 - a rotating shaft that extends through the impeller and to which the impeller is fixed;
 - an external bearing that supports the rotating shaft; and
 - a bearing unit that is provided below the impeller, and supports the rotating shaft penetrating the impeller, wherein:
 - the rotating shaft extends from the external bearing through the impeller, without passing through any bearing other than the external bearing; and
 - the bearing unit has
 - a first bearing that supports a sliding part of the rotating shaft on a bearing inner circumferential surface, and
 - a second bearing that supports a sliding part of the rotating shaft on a bearing outer circumferential surface.
2. The vertical pump according to claim 1, wherein
 - the bearing unit is detachably attached below the impeller.
3. The vertical pump according to any one of claims 1 and 2, wherein
 - the first bearing and the second bearing are configured in a detachable manner below the impeller.
4. The vertical pump according to any one of claims 1 to 3, further comprising a protection cover that is provided below the bearing unit, wherein
 - the protection cover has a small hole that is directed

laterally, and configured to guide water flow toward the bearing unit.

5. The vertical pump according to any one of claims 1 to 4, wherein:

the first bearing and the second bearing are made of the same material; and

the material is made of resin or a resin composite.