Roller Assembly

FIELD OF INVENTION

The present invention relates broadly to a roller assembly for a turret, a bearing structure for a turret, and to a method of facilitating rotation of a turret.

BACKGROUND

In recent years, the use of floating facilities have became prevalent in the offshore oil and gas industry for the extraction and production of oil and gas from offshore fields. Floating facilities such as the floating, production, storage and offloading (FPSO) unit or the floating, storage and offloading (FSO) unit are typically floating platforms converted from oil tankers or in some cases vessels or barges specifically designed and built for the purpose.

The growth in interest of such floating facilities is due to the ease of installation, the minimal fixed infrastructure required, flexibility in usage and most importantly the ability to weathervane in response to the prevailing weather conditions as compared to the fixed oil platforms or oil rigs. When these floating facilities are moored in the open sea and exposed to the prevailing weather conditions, its ability to weathervane freely stems from the mooring system that it utilizes, one such mooring system is the turret mooring system.

WO2009/031971 describes a turret mooring system where a turret in the form of a vertical cylindrical shaft is fitted through a moonpool within the floating platform. The flange on one end of the cylindrical shaft is in turn mounted on a thrust bearing system which is fixed on the deck of the vessel. On the other end of the cylindrical shaft, a plurality of catenary mooring lines extends out from the shaft and anchored it to the seabed. In addition, a plurality of production risers runs from the wellheads on the seabed to the same end of the cylindrical shaft. The oil is then

transferred from the topside of the shaft to the oil processing equipment or storage tanks of the floating platform. This assembly of the turret, the mooring lines, the thrust bearing system and the deck of the vessel allows the turret to be fixed to a position with respect to the seabed and the floating platform to rotate or swivel about the vertical axis of the cylindrical turret, enabling the weathervane ability of the floating platform.

In the said turret mooring system, the thrust bearing system consists of roller assemblies arranged along the circumference of the circular thrust bearing system with the axes of the cylindrical rollers pointing toward the axis of the circular bearing. The roller assembly 100, as shown in figure 1, consists of a single rotatable cylindrical roller 102 supported by a non-rotating axle 104 which is bolted to the hydraulic supports 106, 108 on each end and in turn are fixed to a base plate 110.

The said hydraulic supports 106, 108 form a hydraulic system whereby they are interconnected via hydraulic line sharing the same source of hydraulic fluid. In such a set up of the hydraulic system, the two hydraulic supports 106, 108 would act in a counteracting manner. Therefore when a downward force acts on one of the hydraulic support e.g.106 and causes it to be depressed, the hydraulic fluid would be forced to flow to the other hydraulic support e.g.108 and causes it to be elevated.

In the normal operation of the floating platform out at sea, the floating platform is susceptible to the environmental conditions and would naturally roll or pitch following the prevailing weather conditions. Such motion would cause radial loading to the thrust bearing system, and the thrust bearing system 200 described in WO2009/031971 attempts to cushion the radial movement of the shaft by interspersing radial bearing assemblies 202 with the roller assemblies 100 as shown in figure 2. However, due to practical considerations, including the difficulties in positioning the turret entirely centrally within the moonpool, the radial bearing assemblies 202 still have to allow some movement of the shaft. Thus, the radial loading on the roller assemblies remains an issue.

SUMMARY

According to a first aspect of the present invention there is provided a roller assembly for a turret bearing, the roller assembly comprising a roller; an axle on which the roller is rotatably mounted; and a hydraulic support on each end of the axle; wherein the roller comprises a recess separating two bearing surfaces of the roller assembly.

The assembly may comprise two rollers mounted on the axle, and wherein a gap between respective surfaces of the roller functions as the recess for separating the two surfaces of the roller assembly.

The two rollers may be independently rotatably mounted on the axle.

The hydraulic supports on the respective ends of the axle may be configured for interconnection to a shared source of hydraulic fluid.

The assembly may further comprise a mounting plate for securing the roller assembly to a deck of a ship.

The mounting plate may support the hydraulic supports on the respective ends of the axle.

According to a second aspect of the present invention there is provided a roller bearing structure for a turret, the roller bearing structure comprising a plurality of roller assemblies as defined in the first aspect.

The roller assemblies may be disposed radially around a moon pool of a ship.

According to a third aspect of the present invention there is provided a method of facilitating rotation of a turret; the method comprising the steps of providing a roller; providing an axle on which the roller is rotatably mounted; and

providing a hydraulic support on each end of the axle; wherein the roller comprises a recess separating two bearing surfaces of the roller assembly.

The method may comprise providing two rollers mounted on the axle, and wherein a gap between respective surfaces of the roller functions as the recess for separating the two surfaces of the roller assembly.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will be better understood and readily apparent to one of ordinary skill in the art from the following written description, by way of example only, and in conjunction with the drawings, in which:

Figure 1 shows a drawing illustrating a prior art roller assembly for a turret.

Figure 2 shows a drawing illustrating a prior art bearing structure comprising roller assemblies of Figure 1.

Figure 3 shows a drawings illustrating different forces and during radial loading of the roller assembly of Figure 1.

Figure 4 shows a drawing illustrating a bearing structure according to an example embodiment.

Figure 5 shows a drawing illustrating a cross-sectional view of the bearing structure of Figure 4 supporting a turret.

Figure 6 shows a drawing illustrating a roller assembly for a turret according to an example embodiment.

Figure 7 shows a drawing illustrating a roller assembly for a turret according to an example embodiment.

Figure 8 shows a flowchart illustrating a method of facilitating rotation of a turret according to an example embodiment.

DETAILED DESCRIPTION

The present inventors recognize that in a thrust bearing system such as the thrust bearing system 200 disclosed in WO2009/031971, radial movement of the

turret shaft may have a significant impact on the performance and functionality of the rollers in the thrust bearing system. Therefore, in an attempt to seek to provide a better design for the thrust bearing system to moderate such impact, the inventors conducted detailed analysis of the interaction between the radial and axial load acting on the thrust bearing system 200.

When the turret shaft is mounted on the thrust bearing system 200 such that the flange at one end of the turret shaft sits on the cylindrical rollers 102, the axial load acting on the thrust bearing system may be distributed over the rollers 102 in a manner where each roller 102 assumes a portion of the total load. The portion of axial load supported by each roller 102 may be transpired as vertical load and is denoted by *Fv* in figure 1.

On the other hand, the radial movement of the turret may exert radial loading to the thrust bearing system and this radial force may again be distributed to the individual rollers 102. As a result, the distributed radial force may translate to a lateral force acting on the top of each roller 102 as denoted by *Fh* in figure 1. This lateral force *Fh* acting on the roller 102 may create a moment of force on the entire roller assembly 100, which may be construed as a tendency to rotate the entire roller assembly, as denoted by *M* in figure 1.

In the roller assembly 100, the counterbalancing characteristic of the hydraulic supports 106, 108 may result in the cylindrical roller 102 and its axle 104 trying to rotate slightly or tilt in the direction of the moment *M* when the lateral force *Fh* is acting on the roller 102. This tendency of the roller 102 to rotate slightly or tilt in the direction of the moment *M*, may result in the contact surface of the roller 102, which is in contact with the flange of the turret shaft, to experience a linearly distributed load 112 as illustrated in figure 1. On the side 114 where the lateral force is acting, the intensity of the distributed load may be at a maximum of $w + \Delta w$, and on the opposite side 116, the intensity of the distributed load may be at a minimum of $w - \Delta w$. This linearly distributed load 112 may create a restoring moment to counter the moment created by the lateral force *Fh*.

In the single roller assembly 100 described above, the restoring moment of the roller assembly 100 may be represented by the following equation.

$$M' = (2 \times \Delta w)/2 \times a \times (a / 6) = \underline{(a^2 \Delta w) / 6}$$

As the lateral force *Fh* increases, the difference between the intensity of the distributed load at the ends of the roller 102 may become larger and once the intensity of the linearly distributed load 112 at one end exceed the material limits of the roller 102, material failure might occur at that end. As a consequence, the roller 102 may experience deformation at its ends. In an instance of extreme deformation, the entire roller 102 might be permanently tilted 302 and deformed 304 as illustrated in figure 3. Even when the intensity of the distributed load is within the acceptable limits of the material, prolong exposure of uneven load distribution on the contact surface, especially with the higher load intensity at the ends of the roller, may result in different rate of wear across the span of the contact surface and deformation 304 of the roller may occur.

In the thrust bearing system 200, the addition of radial bearing assemblies 202 may have the effect of reducing the lateral force *Fh* acting on the roller. However, it may not be able to ease the uneven load distribution situation on the contact surface of the roller 102. And therefore this may not be sufficient or adequate to moderate the overall impact of radial movement of turret on the rollers of the thrust bearing system.

One possible method of easing the uneven load distribution condition may be to reduce the difference between the intensity of the load distribution at both ends by increasing the width of the roller. This may create a larger restoring moment arm and thus result in a smaller difference in the load intensity at its ends as compared to a roller with a narrower width experiencing the same lateral force *Fh*. However, a wider roller may lead to problem with respect to the rotational speed. Naturally, the end of the roller which is nearer to the centre of the turret may have to rotate at a slower speed as compared to the other end of the roller which is farther. This differential in speed may result in sliding motions along the contact surface as a single roller can only rotate at a single speed. Therefore this solution is rendered unfeasible.

The inventors have conceived the following preferred embodiments to seek to provide more desirable solutions to the above problem.

Figure 4 is a schematic diagram illustrating the plan view of a preferred embodiment of the thrust bearing system 400 of the present invention. The thrust bearing system 400 consists of a plurality of roller assemblies 402 fitted on the deck of the floating platform and arranged along the circumference of the circular thrust bearing system 400 with the axis 406 of the cylindrical rollers 404 in each of the roller assembly 402 pointing towards the axis of the circular thrust bearing system 400.

Figure 5 is a cross sectional view illustrating an example of the interaction between the turret shaft, the roller assemblies of the thrust bearing system and the deck of the floating platform. The vertical turret shaft 506 is fitted in the moonpool 508 of the floating facilities with the shaft flange 504 at the upper end of the vertical turret shaft 506 resting on the highest tips of the rollers 404 in a roller assembly 402. The roller assembly 402 is in turn fixed on the flange portion 502 of a circular combing 510 extruded from the deck 512 of the floating facilities. The circular combing 510 and its flange portion 502 are erected such that when the thrust bearing system 400 is fitted on the flange portion 502, the thrust bearing system 400 may lie on a plane parallel to the horizontal plane of the ground even when the deck 512 of the floating platform is constructed in an inclined manner.

An embodiment of the rollers assembly is illustrated in figure 6. The rollers assembly 602 comprises of a single rotatable groove type roller 604, where the roller body has two contacting surfaces 606, 608 separated by an inner recess 610, supported by a non-rotating axle 612 which is bolted at both ends by bolts 614, 616 to the hydraulic supports 608, 610 respectively. Both the hydraulic supports 618, 620 are in turn fixed to a base plate 622. The groove type roller 604 is designed such that the width of each of the contacting surfaces 606, 608 and the recess 610 are one third the overall width of the groove type roller 604. The hydraulic supports 618, 620 supporting each end of the axle 612, are interconnected via a hydraulic line (not shown) interconnecting respective hydraulic fluid ports 621a,b in the

hydraulic supports 618, 620, and sharing the same source of hydraulic fluid such that the two hydraulic supports may act in a counteracting manner, in this example embodiment. Therefore when a downward force acts on one of the hydraulic support e.g. 618 and causes it to be depressed, the hydraulic fluid may be forced to flow to the other hydraulic support e.g. 620 and may cause it to be elevated. The arrangement of the axle 612 bolted to the hydraulic supports 618 and 620 may enable the groove type roller 604 and axle 612 to vacillate up and down with respect to the base plate 622 in a motion which is similar to that of a seesaw motion.

When the vertical cylindrical turret is mounted on the thrust bearing system such that the flange at the upper end of the turret shaft sits on the two contacting surfaces 606, 608 of the groove type roller 604, the axial load acting on the thrust bearing system may be distributed to the pair of contacting surfaces 606, 608 of the groove type rollers 604 of the roller assembly 602 in the thrust bearing system 400. Each pair of contacting surfaces 606, 608 of the groove type roller 604 may assume a portion of the total axial load and the portion of the axial load supported by each pair of contacting surfaces 606, 608 may be translated as vertical load acting on the respective pair of surfaces. This vertical load acting on each pair of contacting surfaces 606, 608 is denoted by *Fv* in figure 6.

In addition, when the floating platform rolled or pitched under the influence of the prevailing weather conditions, the radial movement of the turret may cause radial loading on the thrust bearing system 400 and this radial force may be distributed to the groove type roller 604 of all the rollers assembly 602. As a result, the distributed radial force may translate to a lateral force acting on the top of each groove type roller 604 as denoted by *Fh* in figure 6. This lateral force *Fh* acting on the groove type roller 604 may create a moment of force on the entire roller assembly 602, which may be construed as a tendency to rotate the entire roller assembly 602, as denoted by *M* in figure 6. Due to the characteristic of the groove type roller 604 and its axle 612 being able to oscillate in a seesaw motion with respect to the base plate 622, the effect of lateral force *Fh* may be that the groove type roller 604 and its axle 612 may try to rotate slightly or tilt in the direction of the moment *M*.

As a result of the tendency to rotate slightly or tilt in the direction of the moment *M*, the pair of contacting surfaces 606, 608 of the groove type roller 604, which are in contact with the flange 504 of the turret shaft 506, may experience a linearly distributed load 624, 626 on each of the contacting surfaces 606, 608 as illustrated in figure 6. In this embodiment, due to the recess 610 between the contacting surfaces 606, 608, the linearly distributed load 624, 626 on each of the contacting surfaces 606, 608 may only possess slight linearity and thus the load distribution may be approximated to an uniformly distributed load. Therefore the intensity of the uniformly distributed load 624 on the contact surface 606 closer to the lateral force may be approximated to $w_1 + \Delta w_1$, while the intensity of the uniformly distributed load 626 on the contact surface 608 away from the lateral force may be approximated to $w_1 - \Delta w_1$. The difference between the load intensity on each of the contacting surfaces 606, 608, will result in a restoring moment created to counter the moment of the lateral force *Fh*.

In this embodiment of the present invention, the restoring moment of the roller assembly 602 may be represented by the following equation.

$$M_1' = \Delta w_1(2a/3)(a/3) + (\gamma\Delta w_1/2)(a/3)(a/6 + 2a/9) + (\gamma\Delta w_1/2)(a/3)(a/6 + a/9)$$
$$= \underline{(2a^2\Delta w_1)/9 + (a^2\gamma\Delta w_1)/9}$$

Since the linearity of the distributed load on each roller may be negligible and the width of the groove type roller 604 in the roller assembly 602 may be equal to the width of the single roller in a single roller assembly, while keeping all the forces and load constant, the equation of the restoring moment of the roller assembly 602 in this embodiment may be further represented by the following.

$$M_1' = (2a^2\Delta w_1)/9$$
$$= (2a^2/9)(3\Delta w/2)$$
$$= \underline{(a^2\Delta w)/3}$$

Therefore, it may be concluded that this embodiment of the present invention may be able to create a larger restoring moment under the same conditions. At the same time, this may be achieved while exposing the contacting surfaces 606, 608 to an almost uniform load distribution across the span of each surface. The qualitative advantage of this embodiment of the present invention would be that the roller

assembly 602 may have a longer lifespan under the same operating conditions. This may give rise to an overall improved functions and stable operation of the entire thrust bearing system, whereby the impact of radial movement of the turret to the rollers of the thrust bearing system may be minimized.

Another embodiment of the roller assembly is illustrated in figure 7. The rollers assembly 702 comprises of two rotatable cylindrical rollers 704, 706 supported by a non-rotating axle 708 which is bolted at both ends by bolts 710, 712 to the hydraulic supports 714, 716 respectively. Both the hydraulic supports 714, 716 are in turn fixed to a base plate 718. The two rotatable cylindrical rollers 704, 706 are spaced slightly apart when connected to the axle 708 such that the rollers 704, 706 may not slide along the axle 708 nor may they interfere with each others rotation as they rotate, and each of them may be able to rotate at its own rotational speed. The hydraulic supports 714, 716 supporting each end of the axle 708, may be interconnected via a hydraulic line (not shown) interconnecting respective hydraulic fluid ports 717a,b in the hydraulic supports 714, 716, and sharing the same source of hydraulic fluid such that the two hydraulic supports would act in a counteracting manner, in this example embodiment. Therefore when a downward force acts on one of the hydraulic support e.g. 714 and causes it to be depressed, the hydraulic fluid may be forced to flow to the other hydraulic support e.g.716 and may cause it to be elevated. The arrangement of the axle 708 bolted to the hydraulic supports 714, 716 may enable the rollers 704, 706 and axle 708 to vacillate up and down with respect to the base plate 718 in a motion which is similar to that of a seesaw motion.

When the vertical cylindrical turret is mounted on the thrust bearing system such that the flange at the upper end of the turret shaft sits on the cylindrical rollers 704, 706 of the rollers assemblies 702, the axial load acting on the thrust bearing system is distributed to the rollers 704, 706 of all the rollers assemblies 702 in the thrust bearing system 400. Each pair of rollers 704, 706 may assume a portion of the total axial load and the portion of the axial load supported by each pair of rollers 704, 706 may be translated as vertical load acting on the respective pair. This vertical load acting on each pair of rollers 704, 706 is denoted by *Fv* in figure 7.

When the floating platform rolled or pitched under the influence of the prevailing weather conditions, radial movement of the turret may cause radial loading to the thrust bearing system 400 and this radial force may be distributed to the rollers 704, 706 of the rollers assembly 702. As a result, the distributed radial force may be translated as lateral force acting on the top of each pair of rollers 704, 706 as denoted by *Fh* in figure 7. This lateral force *Fh* acting on each pair of rollers 704, 706 may create a moment of force on the entire roller assembly 702, which can be construed as a tendency to rotate the entire roller assembly 702, as denoted by *M* in figure 7. Due to the characteristic of the pair of rollers 704, 706 and the axle 708 being able to oscillate in a seesaw motion with respect to the base plate 718, the effect of lateral force *Fh* would be that the pair of rollers 704, 706 and its axle 708 may try to rotate slightly or tilt in the direction of the moment *M*.

As a result of the tendency to rotate slightly or tilt in the direction of the moment *M*, the contact surfaces of the pair of rollers 704, 706, which are in contact with the flange 504 of the turret shaft 506, may experience a linearly distributed load 720, 722 on each of the rollers 704, 706 as illustrated in figure 7. In this embodiment, due to the slight spacing between the rollers 704, 706, the linearly distributed load 720, 722 on each of the rollers 704, 706 may only possesses slight linearity and thus the load distribution on each roller 704, 706 may be approximated to an uniformly distributed load. Therefore the intensity of the uniformly distributed load 720 on the contact surface of the roller 704 closer to the lateral force may be approximated to $w_2 + \Delta w_2$, while the intensity of the uniformly distributed load 722 on the contact surface of the roller 706 away from the lateral force may be approximated to $w_2 - \Delta w_2$. The difference between the load intensity on each of the rollers 704, 706, may result in a restoring moment created to counter the moment of the lateral force *Fh*.

In this embodiment of the roller assembly 702, the restoring moment of the roller assembly may be represented by the following equation.

$$M_2' = 2\Delta w_2 a(a/2 + b/2) + a(\delta\Delta w_2/2)(2a/3 + b/2) + a(\delta\Delta w_2/2)(a/3 + b/2)$$

$$= \underline{\Delta w_2 (a^2 + ab) + \delta\Delta w_2(a^2/2 + ab/2)}$$

Since the linearity of the distributed load on each roller may be negligible, the width of each roller 704, 706 in the roller assembly 702 may be equal to the width of the single roller in a single roller assembly, and the width of the spacing between the rollers may be taken to be a fifth of the width of each roller, while keeping all the forces and load constant, the equation of the restoring moment of the roller assembly 702 in this embodiment may be further represented by the following.

$$M_2' = \Delta w_2(a^2 + ab)$$
$$= (a^2 \Delta w /2) + (a^2 \Delta w /10)$$
$$= \underline{3\, a^2 \Delta w /5}$$

Therefore, it may be concluded that this embodiment of the present invention is able to create a larger restoring moment under the same conditions. At the same time, it may be achieved while exposing the individual rollers 704, 706 to an approximately uniform load distribution. The qualitative advantage of this embodiment of the present invention would be that the rollers assembly may withstand a significantly higher radial force before any permanent deformation or damage to the rollers 704, 706 may occur. At the same time, the rollers 704, 706 may have a longer lifespan under the same operating conditions as the rollers 704, 706 in this embodiment are not repeatedly exposed to uneven load distribution. This may give rise to an overall improved functions and stable operation of the entire thrust bearing system 400, whereby the thrust bearing system 400 may remain in its horizontal plane regardless of the roll and pitch motions of the floating platform. Furthermore, the twin roller 704, 706 design of the rollers assembly 702 may provide additional advantage in that there is inherent redundancy in the number of rollers provided. Therefore in the event that even if only one roller e.g. 704 is taking the load, the rollers assembly 702 may still function. Another advantage of the embodiment of the present invention may be that the thrust bearing system 400 may preferably not require any additional radial bearing, because the roller assembly in the embodiment of the present invention may be sufficient and adequate to withstand both the axial load and the radial load of the turret shaft.

Figure 8 shows a flow chart 900 illustrating a method of facilitating rotation of a turret according to an example embodiment. At step 902, a roller is provided. At step 904, an axle on which the roller is rotatably mounted is provided. At step 906, a

hydraulic support on each end of the axle is provided, wherein the roller comprises a recess separating two bearing surfaces of the roller assembly.

It will be appreciated by a person skilled in the art that numerous variations and/or modifications may be made to the present invention as shown in the specific embodiments without departing from the spirit or scope of the invention as broadly described. The present embodiments are, therefore, to be considered in all respects to be illustrative and not restrictive.

CLAIMS

1. A roller assembly for a turret bearing, the roller assembly comprising:

a roller;

an axle on which the roller is rotatably mounted; and

a hydraulic support on each end of the axle;

wherein the roller comprises a recess separating two bearing surfaces of the roller assembly.

2 The assembly as claimed in claim 1, comprising two rollers mounted on the axle, and wherein a gap between respective surfaces of the roller functions as the recess for separating the two surfaces of the roller assembly.

3. The assembly as claimed in claim 2, wherein the two roller s are independently rotatably mounted on the axle.

4. The assembly as claimed in any one of the preceding claims, wherein the hydraulic supports on the respective ends of the axle are configured to interconnection to a shared source of hydraulic fluid.

5. The assembly as claimed in any one of the preceding claims, further comprising a mounting plate for securing the roller assembly to a deck of a ship.

6. The assembly as claimed in claim 5, wherein the mounting plate supports the hydraulic supports on the respective ends of the axle.

7. A roller bearing structure for a turret, the roller bearing structure comprising a plurality of roller assemblies as claimed in any one of claims 1 to 6.

8. The structure as claimed in claim 7, wherein the roller assemblies are disposed radially around a moon pool of a ship.

9. A method of facilitating rotation of a turret; the method comprising the steps of:

providing a roller;

providing an axle on which the roller is rotatably mounted; and

providing a hydraulic support on each end of the axle;

wherein the roller comprises a recess separating two bearing surfaces of the roller assembly.

10. The method as claimed in claim 9, comprising providing two rollers mounted on the axle, and wherein a gap between respective surfaces of the roller functions as the recess for separating the two surfaces of the roller assembly.