(54) Title: HEAVE COMPENSATION SYSTEM

(57) Abstract: The invention pertains to a heave compensation system for continuous operation on a floating vessel (1), the system comprising at least one buoyant body (11), at least one lever arm (10) for arrangement in a generally horizontal plane, pivotal means capable of limited rotation about a horizontal axis and arranged to connect one end of the lever arm to the buoyant body (11), at least one hinge (13) connected to an intermediate point on the lever arm (10) and capable of allowing limited rotational movement of the lever arm (10) in a vertical plane, means to attach the hinge (13) to the floating vessel (1), and at least one counterbalance weight (12) connected to the lever arm (10) on the side of the hinge (13) away from the buoyant body (11), whereby the inertia of the counterbalance weight (12) resists heave movements of the buoyant body (11) relative to the floating vessel.
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Heave Compensation System

The invention pertains to a heave compensation system, a vessel fitted with a heave compensation system and a method for continuously compensating heave between a floating vessel and a buoyant body.

Floating vessel, as traditional floating platforms called semi submersible platforms has its limitations when it comes to being operable during large waves and harsh weather conditions. This has resulted in that drilling rigs for the i.e. Barents Sea have to be built very large and to a high cost to try to have acceptable operation time during these conditions. This lack of operability means large economic losses for the operator of the platform. Therefore has there for some time been a wish to provide good systems which may increase the operative time for a floating structure which.

Another aspect of the problem is that ordinary heave compensation systems generally are large in size and weight, which both factors, size and weight, are crucial for floating structures. An aim for the present invention is to provide a heave compensation system which provides large operational windows for the floating structure. Another aim is to provide a floating vessel which undergoes less heave motions, which for a floating oil/gas platform results in less variation in vertical forces in risers and eventual anchoring systems, and therefore reduced or eliminated use for other heave compensation systems specifically for instance for the risers. It is also an aim for the present invention to provide an improved heave compensation system usable for other floating structures than semi submersibles, as pontoons, foundations for cranes and offshore oil buoy loading systems, bridge foundations, riser hangoffs, turrets etc. It is an aim to provide a system that affects a drilling rig's ability to operate under harsh weather conditions.

The aims of the invention are obtained with a system, vessel and method as described in the following independent claims. Additional features of the invention are apparent from the dependent claims and the following description and drawings.

The invention pertains to a heave compensation system for continuous operation on a floating vessel. The system comprising at least one buoyant body, at least one lever arm for arrangement in a generally horizontal plane, pivotal means capable of limited rotation about a horizontal axis and arranged to connect one end of the lever arm to the buoyant body. The lever arm has also at least one hinge connected to an intermediate point on the lever arm and capable of allowing limited rotational movement of the lever arm in a vertical plane and means to attach the hinge to the floating vessel. On the lever arm there is at least one counterbalance weight connected to the lever arm on the side of the hinge away from the buoyant body,
whereby the inertia of the counterbalance weight resists heave movements of the buoyant body relative to the floating vessel.

The heave compensation system is applicable to a large range of floating vessels as semi submersibles, pontoons, foundations for cranes, floating bridges etc. as this is the case is the description of the floating vessel made as a general description covering the different embodiments.

By connecting a drilling module of a floating platform to a guided buoyancy tank connected to the main floater of the platform via balance arm, will the drilling module get its own behaviour and heave period relative to the main floating object, i.e. the platform.

The system will for some applications only require one balance arm, for others many. Many may be used where the space is limited, i.e. inside vessels. The ballast will mainly consist of solids such as steel, but can also consist of a fluid, for instance water, if there is a need to have variable ballast.

The heave compensating system according to the invention will reduce the vertical forces in the buoyancy-support system and will under ideal conditions be +/- zero. A drilling rig has a normal heave compensation “stroke” of 48 feet (ca. 14.5 meter). The present invention may reduce this requirement or even make the whole existing compensations system redundant.

The buoyancy tank in the heave compensation system may be open in the centre, have a “moon pool” allowing sub sea equipment (i.e. BOP and sub sea production equipment) to be lifted to and from the seabed in a clam environment. For other applications, this opening will be limited or even zero.

The water plane inside the buoyancy tank can be altered by use of water pumps or compresses air. The buoyancy chamber may be partially or fully open in the bottom to reduce the effect of the “added mass” due to the exposure from the sea. The capacity of the buoyancy thank for the drilling rig purpose of a normal size today will have to be in the order of 200 to 400 tonnes. However, there will be different diameters and capacities for the various uses of the heave compensation system according to the invention.

In a preferred embodiment of the invention is the buoyancy tank in the heave compensation system guided by use of guiding means for instance rollers or gliders mounted in the mains structure. These guiding means should be mounted on at least two levels, one of these levels may be below the water surface. The system according to the invention will compensate the vertical forces acting on the system and maintain the module in a horizontal position. The lower guiding means may be operates by winches and or hydraulic cylinders and will constantly move the lower
guiding means to keep the buoyancy tank vertical. The guide means are the
elements which will connect the heave compensation system to the main floating
structure.

The lever arm may in one embodiment comprise additional weights in form of for
instance clumps. These weights may be used to alter the vertical support capacity of
the lever arm.

There may in another embodiment of the invention be hydraulic cylinders used in
addition to the lever arm, to improve the effect of the lever arm or improve the
accuracy of the system.

The invention also comprises a vessel when fitted with a heave compensation
system as described above. The vessel may as earlier mentioned be any kind of
floating structure from a oil/gas platform to a foundation for a floating crane or
bridge or used for parts of a system of floating structures.

The invention also comprises a method of continuously compensating heave
between a floating vessel and a buoyant body comprising the steps of constraining
the buoyant body for movement generally vertically with respect to the floating
vessel, disposing at least one lever arm in a generally horizontal plane on the
floating vessel with a hinge at an intermediate point on the lever arm which
connects the lever arm to the floating vessel, so that the lever arm is capable of
limited rotational movement in a vertical plane, connecting one end of the lever arm
to the buoyant body to allow angular movement there between about a horizontal
axis, and connecting a counterbalance weight to the lever arm on the side of the
hinge away from the buoyant body, whereby vertical movement of the
counterbalance weight resists heave movements of the buoyant body relative to the
floating vessel.

The invention will now be explained in more detail with preferred embodiments,
with references to the drawings where:

Fig. 1 shows a side sketch of the invention according to one embodiment in
connection with a semi submersible platform,

Fig. 2 shows the embodiment of the invention as shown in fig. 1 without the main
parts of the platform,

Fig. 3 shows a side sketch of another embodiment of the invention with a floating
vessel indicated with dotted lines,

Fig. 4 shows the embodiment in fig. 3 seen from above.

Fig. 1 shows the invention for dampening the motion of a floating structure in the
water in one embodiment, where the floating vessel 1 is a semi submersible
platform with a buoyant body 2a and several supporting columns 2b supporting a main deck structure 2c. On the deck structure is it arranged cranes, drilling derrick 4, flare booms 3 and other equipment necessary to perform the tasks of the semi submersible platform. The drilling derrick 4 with the main drilling area 4a is in this embodiment arranged in the middle of the floating vessel. From the drilling area 4a are there risers 5 running down through the body of water to the seabed, where they are connected to a manifold 6 and template 7. The drilling derrick 4 with connection of the risers 5 are arranged according to the invention in connection with a buoyant tank 11. The buoyant tank 11 may have ballast 11a and buoyancy 11b systems to regulate the buoyancy of the buoyant tank 11. In the embodiment shown in fig. 1 has the tank 11 a moon pool 20 wherein the risers 5 are arranged. The buoyant tank 11 is in this embodiment in connection with two lever arms 10, through an interface point 14 at one end of the lever arms. The lever arms 10 have a mainly horizontal orientation, and may rotate about the interface point 14. At the opposite end of the lever arm is arranged a ballast tank 12, which work as counterweight. At a point between the ballast tank 12 and the interface point 14 is the lever arm 10 hinged to the floating vessel 1 through a hinge connection 13, around which the lever arm may rotate around a mainly horizontal axis. The buoyant tank 11 and the floating vessel 1 are to a certain extent free to move relatively to each other in the mainly vertical direction. The ballast tank 11 is normally affected by vertical guide system to keep its movement in relation to the floating vessel 1 mainly vertical. The guide system in this embodiment comprises guide rollers 17 arranged by an upper and lower part of the buoyancy tank 11. The guide rollers may be regulates by hydraulic cylinders, winches or other equipment to keep the buoyancy tank 11 constantly in the most vertical position as possibly. As one can see from this embodiment may the system comprise two lever arms 10 facing opposite directions, and it may be arranged beneath the floating vessel’s 1 main deck structure 2c.

As shown in fig. 2 the heave compensation system according to the invention comprises at least one lever arm 10 connected to a buoyancy tank 11 at interface points 14. There is arranged a ballast tank 12 at the opposite end of the lever arm 10. The effect of the ballast tank 12 on the system may be changed either by changing the ballast itself or changing its position along the lever arm. The same is the case for the buoyancy tank which may comprise both ballast and buoyancy, which may be variable, with compressed air systems and or water pumps etc.(not shown in figures)

At an intermediate point between the interface point 14 and the ballast tank 12 is the lever arm 10 connected to the floating vessel 1 at a hinge connection 13.

There is shown another embodiment of the invention in fig. 3 and 4. The floating vessel 1 is shown with dotted lines, and shown as anchored to the seabed with mooring lines 9. According to the invention is the lever arm 10 connected to the
buoyancy tank 11 at an interface point 14. The lever arm also comprises ballast tank 12, and is further equipped with extra clump weight 15. The lever arms 10, two shown in fig. 3 is in this embodiment arranged above the main part of the floating vessel 1. There is also arranged an additional hydraulic cylinder 16 between the floating vessel 1 and the lever arm 11 at a distance from the hinge connection 13. The buoyancy tank 11 is further equipped with mooring lines 19 from the lower part of the tank 11 to subsea clump weights 18, arranged on the seabed. These clump weights 18 may be other kind of foundations or anchors and they may also be used for anchoring the floating vessel 1 as indicated with the mooring lines 9 running from the floating vessel 1 down to the weights 18. The mooring lines 19 helps keep the buoyancy tank 11 in its position. The vessel has in this embodiment also a moon pool 20 for the not shown risers, umbilicals drillstring etc.s

As shown in fig. 4 which is the system shown in fig. 3 see from above, comprises the heave compensation system in this embodiment two pairs of lever arms 10, arranged at 90 degrees intervals around the floating vessel.

The invention is now explained with embodiments showing details on how to implements the invention, but the invention should not be limited to those embodiments. A person skilled in the art will be able to perform a lot of alterations and other embodiments which are within the scope of the invention as defined in the following claims.
CLAIMS

1. A heave compensation system for continuous operation on a floating vessel (1), the system comprising at least one buoyant body (11), at least one lever arm (10) for arrangement in a generally horizontal plane, pivotal means capable of limited rotation about a horizontal axis and arranged to connect one end of the lever arm to the buoyant body (12), at least one hinge (13) connected to an intermediate point on the lever arm (10) and capable of allowing limited rotational movement of the lever arm (10) in a vertical plane, means to attach the hinge (13) to the floating vessel (1), and at least one counterbalance weight (12) connected to the lever arm (10) on the side of the hinge (13) away from the buoyant body (11), whereby the inertia of the counterbalance weight (12) resists heave movements of the buoyant body (11) relative to the floating vessel.

2. A heave compensation system as claimed in claim 1, in which hinge (13) for the lever arm is arranged so that forces applied by the tendency of the buoyant body (11) to move vertically with respect to the vessel (1) are balanced by restraining forces arising from the counterbalance weight (12) acting on the lever arm (10) at a distance from the hinge (13), such that only minimal forces external forces (e.g. from hydraulic cylinders) are required to damp heave motions of the buoyant body (11).

3. A heave compensation system as claimed in claim 1, in which there are two similar lever arms (10) aligned with and diametrically opposed to each other, and in which the lever arms (10) are attached to the buoyant body (11) at their proximate ends, the hinges on the respective lever arms (10) have means for attachment to the floating vessel (1), and respective counterbalance weights (12) are connected to respective lever arms (10) on the sides of the hinges (13) away from the buoyant body (11).

4. A heave compensation system as claimed in claim 3, in which there are two pairs of similar lever arms (10) aligned with and diametrically opposed to each other.

5. A heave compensation system as claimed in claim 4, in which the two pairs of similar lever arms (10) are at right angles to each other and/or several pairs of similar lever arms (10) are positioned in equal distance to each other around in a circle.

6. A heave compensation system as claimed in any one of the preceding claims, with means to constrain the buoyant body (11) for movement generally vertically
with respect to the floating vessel (1), in which the means for instance are guides 
(17) for association with the vessel (1) to restrain the buoyant body (11) for 
generally vertical movement.

7. A heave compensation system as claimed in any one of the preceding 
claims, in which there are mooring lines (9) between low points on the buoyant 
body (11) and the seabed to restrain the buoyant body (11) for generally vertical 
movement.

8. A heave compensation system as claimed in any one of the preceding claims, 
in which the buoyant body (11) is adjustably ballastable.

9. A heave compensation system as claimed in claim 8, in which the buoyant 
body (11) is ballastable with water.

10. A heave compensation system as claimed in claim 9, in which the water may 
be expelled from the buoyant body (11) by use of compressed air and/or water 
Pumps.

11. A heave compensation system as claimed in any one of the preceding claims, 
in which the counterbalance weight (12) is arranged to be above the wave effected 
zone in respect of the limiting wave height in which the system is intended to 
operate.

12. A heave compensation system as claimed in any one of the preceding claims, 
in which the counterbalance weight (12) is adjustably ballastable.

13. A heave compensation system as claimed in claim 12, in which the 
counterbalance weight (12) is ballastable with water.

14. A heave compensation system as claimed in any one of the preceding claims, 
in which the effect of the counterbalance weight (12) is supplemented by a 
hydraulic piston cylinder (16) arrangement disposed between the lever arm (10) and 
an attachment to the floating vessel (1).

15. A heave compensation system as claimed in any one of the preceding claims, 
in which the buoyant body (11) has a throughway (moon pool) extending between 
upper and lower parts of the body.

16. A heave compensation system as claimed in claim 15, in which the buoyant 
body (11) is a drilling module.
17. A vessel when fitted with a heave compensation system as claimed in any one of the preceding claims.

18. A method of continuously compensating heave between a floating vessel and a buoyant body comprising the steps of constraining the buoyant body for movement generally vertically with respect to the floating vessel, disposing at least one lever arm in a generally horizontal plane on the floating vessel with a hinge at an intermediate point on the lever arm which connects the lever arm to the floating vessel, so that the lever arm is capable of limited rotational movement in a vertical plane, connecting one end of the lever arm to the buoyant body to allow angular movement there between about a horizontal axis, and connecting a counterbalance weight to the lever arm on the side of the hinge away from the buoyant body, whereby vertical movement of the counterbalance weight resists heave movements of the buoyant body relative to the floating vessel.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B63B35/44 E21B19/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
IPC 7 B63B E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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