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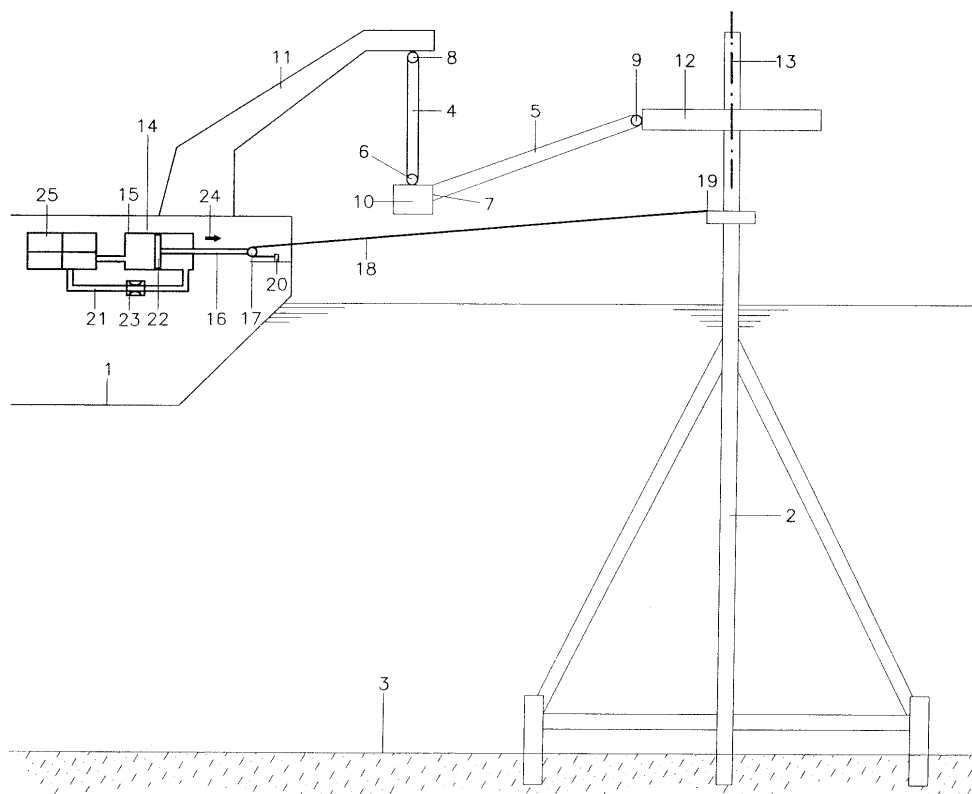
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(54) **Mooring assembly**

(57) A mooring assembly for mooring a floating structure, such as a vessel (1), to a further floating or fixed structure (2), comprises a connecting structure (5) acting with the vessel as a mass spring system with respect to

at least the surge motion between the floating structure (1) and the further floating or fixed structure (2). It comprises a damping system (14) for damping said surge motion.



## Description

**[0001]** The invention relates to a mooring assembly for mooring a floating structure, such as a vessel, to a further floating or fixed structure, comprising a connecting structure acting with the vessel as a mass spring system with respect to at least the surge motion between the floating structure and the further floating or fixed structure.

**[0002]** In such a mooring assembly the connecting structure enables the floating structure to maintain a position with respect to the further floating or fixed structure which may vary within predetermined margins (defining a 'position window'). The floating structure may be a vessel, whereas the further floating or fixed structure may be a buoy, a further vessel or a fixed tower anchored to the seabed. The mass spring system character of the connecting system provides a reciprocating surge motion (motion along the longitudinal axis of the floating structure). Such a reciprocating surge motion can become undesirably large when the mass spring system (connecting structure with vessel) is excited in or close to a natural frequency (generally as a result of environmental loads, such as current, waves and wind).

**[0003]** Thus it is an object of the present invention to provide an improved mooring assembly of the above-mentioned type.

**[0004]** According to the present invention the mooring assembly is characterized by a damping system for damping at least said surge motion.

**[0005]** The damping system provides damping forces for damping the reciprocating surge motion of the floating structure relative to the further floating or fixed structure, such that said surge motion is kept within acceptable limits. As such the damping system in a very simple, yet nevertheless reliable manner provides an additional functionality to the mass spring system which, on itself, does not provide adequate damping.

**[0006]** In one embodiment of the mooring assembly according to the present invention the damping system only dampens the surge motion of the floating structure away from the further floating or fixed structure. This means that only when the reciprocating surge motion is in a phase in which the floating structure (such as a vessel) moves away from the further floating or fixed structure (such as a fixed tower) damping forces are generated to dampen the surge motion. In this embodiment the complexity of the damping system can be kept at a minimum.

**[0007]** The above, however, does not preclude the provision of a damping system which creates damping forces during substantially the entire surge motion (generally no damping forces will be created at the transitions between the surge motion of the floating structure away from and towards, respectively, the further floating or fixed structure) which will make the damping more effective but generally will lead to a more complicated damping system.

**[0008]** Preferably the damping system is devised for transforming kinetic energy of the surge motion into heat.

**[0009]** It is possible that the damping system is devised for transforming the surge motion into a displacement of a fluid through a restriction means and thus for transforming the displacement of the fluid into the generation of heat.

**[0010]** The surge motion will force a fluid (such as for example a hydraulic fluid) through the restriction means, as a result of which the kinetic energy of the fluid is transformed into heat which can be drained to the environment. As a result part of the kinetic energy of the surge motion is transformed into heat, thus limiting the resultant surge motion.

**[0011]** In an effective embodiment of the mooring assembly according to the invention the restriction means is a narrowed orifice in a line for the fluid, which line is in communication with a piston chamber of a cylinder-piston assembly of which the piston is movable in correspondence with the surge motion.

**[0012]** The surge motion (or part of the surge motion in case the damping system only dampens the surge motion of the floating structure away from the further floating or fixed structure) leads to a corresponding motion of the piston, thus displacing fluid from the piston chamber into the fluid line and through the narrowed orifice. It is noted that 'corresponding motion' not necessarily means that the surge motion and the motion of the piston are equally large.

**[0013]** Preferably the cylinder of the cylinder piston assembly is connected to the floating structure, whereas the piston of the cylinder piston assembly is connected to a point externally of the floating structure of which the distance to the floating structure varies as a result of the surge motion. Thus, the main part of the damping system is part of the floating structure and can be used in combination with several further floating or fixed structures and is always at hand when needed.

**[0014]** Basically there are two possibilities then. Firstly, it is conceivable that said point externally of the floating structure is part of the further floating or fixed structure. For example this may mean that the piston of the cylinder piston assembly is connected to a fixed tower. It is noted that in this respect 'connected' is to be understood as comprising an indirect connection too, for example by means of intermediate constructive members (which, however, generally will have a stationary position relative to, in this example, the fixed tower).

**[0015]** The second possibility comprises embodiments in which said point externally of the floating structure is part of the connecting structure. For example, when the connecting structure comprises first and second parts movable relative to each other and moveable connected to a vessel and fixed tower, respectively, said point may be located at the interconnection between said parts. Then, not only a damping of the surge motion of the vessel, but also a damping of the movement of components of such connecting structure is obtained.

**[0016]** Mechanically, the transformation of the surge motion into the motion of the piston may be obtained, for

example, when the piston carries a pulley around which a flexible member, such as a cable, rope or alike, extends of which a first end is connected to said point externally of the floating structure and of which the second end is attached to the floating structure.

**[0017]** This embodiment is an example of a damping system which only dampens the surge motion of the floating structure away from the further floating or fixed structure. As a result of the provision of the pulley the magnitude of the piston motion is half, or even less, the magnitude of the surge motion, thus keeping the piston motion within acceptable limits.

**[0018]** Preferably the piston of the cylinder piston assembly is provided with a pretension such as to keep the flexible member taut during the entire surge motion. As a result the damping system will operate in a most effective manner.

**[0019]** Such a pretension of the piston, for example, may be caused by a hydraulic actuator connected to the cylinder piston assembly. Such a hydraulic actuator may be active but also passive (in the latter case, for example, comprising a pressurised accumulator with large volume).

**[0020]** In other embodiments the damping system is devised for transforming the surge motion into a relative motion between friction plates, or the damping system is devised for transforming the surge motion into the flow of an electric current through an electrical resistance. One solution could be the use of a pretension winch with hydro- or electromotors.

**[0021]** Although the mooring assembly may be of any type, in one embodiment it is provided with a connecting structure of the type comprising pendulum members and a rigid arm assembly, which at a first end are hingedly interconnected and each at a second end are connected to the floating structure and further floating or fixed structure, respectively, and further comprising ballast weights at the interconnected ends.

**[0022]** Hereinafter the invention will be elucidated while referring to the only figure illustrating schematically and in a side elevational view an embodiment of the mooring assembly according to the present invention.

**[0023]** A vessel 1 (for example a tanker) is moored to a fixed tower 2 anchored to the seabed 3. The mooring assembly for mooring the vessel 1 is of the type comprising pendulum members 4 and rigid arm assemblies 5, which at a first end 6,7 are hingedly interconnected and each at a second end 8,9 are hingedly connected to the vessel 1 and fixed tower 2, respectively, and further comprising ballast weights 10 at the interconnected first ends 6,7. In the illustrated embodiment (and preferably) the ballast weights 10 are rigidly connected to the first end 7 of the rigid arm assemblies 5. The pendulum members 4 at their second ends 8 are connected to support arms 11 mounted on the vessel 1. The connection between the second ends 9 of the rigid arm assemblies 5 and the fixed tower 2 occurs through a turntable 12 rotatably supported on the fixed tower 2 around a vertical axis 13.

**[0024]** The mooring assembly defines a connecting structure acting with the vessel as a mass spring system with respect to at least the reciprocating surge motion (movement along the longitudinal axis) between the vessel 1 and the fixed tower 2 in a manner known and thus not described in detail here. It is noted only that such a reciprocating surge motion can become undesirably large when the mass spring system (connecting structure with vessel) is excited in or close to its natural frequency (generally as a result of environmental loads, such as current, waves and wind).

**[0025]** To prevent such large surge motions, the mooring system is provided with a damping system 14 for damping said surge motion. As will be described later, in the illustrated embodiment the damping system 14 only dampens the surge motion of the vessel 1 in its stage away from the fixed tower 2 (which, of course, results in damping the entire surge motion and, thus, also any swaying motion of other components, e.g. the ballast weight 10).

**[0026]** In the illustrated embodiment the damping system 14 comprises a cylinder piston assembly with a cylinder 15 mounted to the vessel 1 and a piston 16 movable relative to the cylinder 15. The piston 16 at its free end is provided with a pulley 17 around which a flexible member 18 (cable, rope etc.) extends. A first end 19 of the flexible member 18 is attached to the fixed tower 2 (or to the turntable 12 thereof) whereas a second end 20 of the flexible member is attached to the vessel 1.

**[0027]** A bypass line 21 ends extends between a piston chambers at one end of the piston head 22 and a hydraulic control unit 25, and comprises a restriction 23 (e.g. a narrowed orifice). When fluid (preferably hydraulic fluid) is forced through the bypass line 21 and through the restriction 23 its kinetic energy is transformed into heat.

**[0028]** When the vessel 1 moves away from the fixed tower 2 the flexible member 18 moves the piston 16 with piston head 22 according to arrow 24 thus forcing the fluid in the cylinder through the bypass line 21 and restriction 23. Therefore, the damping system is devised for transforming the surge motion (movement of the vessel 1 away from the fixed tower 2) into a displacement of a fluid through said restriction 23 and thus for transforming the displacement of the fluid into the generation of heat. Thus this movement away from the fixed tower is dampened (and therefore the entire surge motion).

**[0029]** For the damping system to be effective the piston 16 of the cylinder piston assembly has to be connected to a point externally of the vessel 1 of which the distance to the vessel varies as a result of the surge motion. In the illustrated embodiment said point externally of the vessel 1 is part of the fixed tower 2. However it is possible too that said point externally of the vessel 1 is part of the connecting structure, and for example located at the ballast weights 10 or rigid arm assemblies 5. In such a case also a sideways motion of such components could be dampened by the damping system.

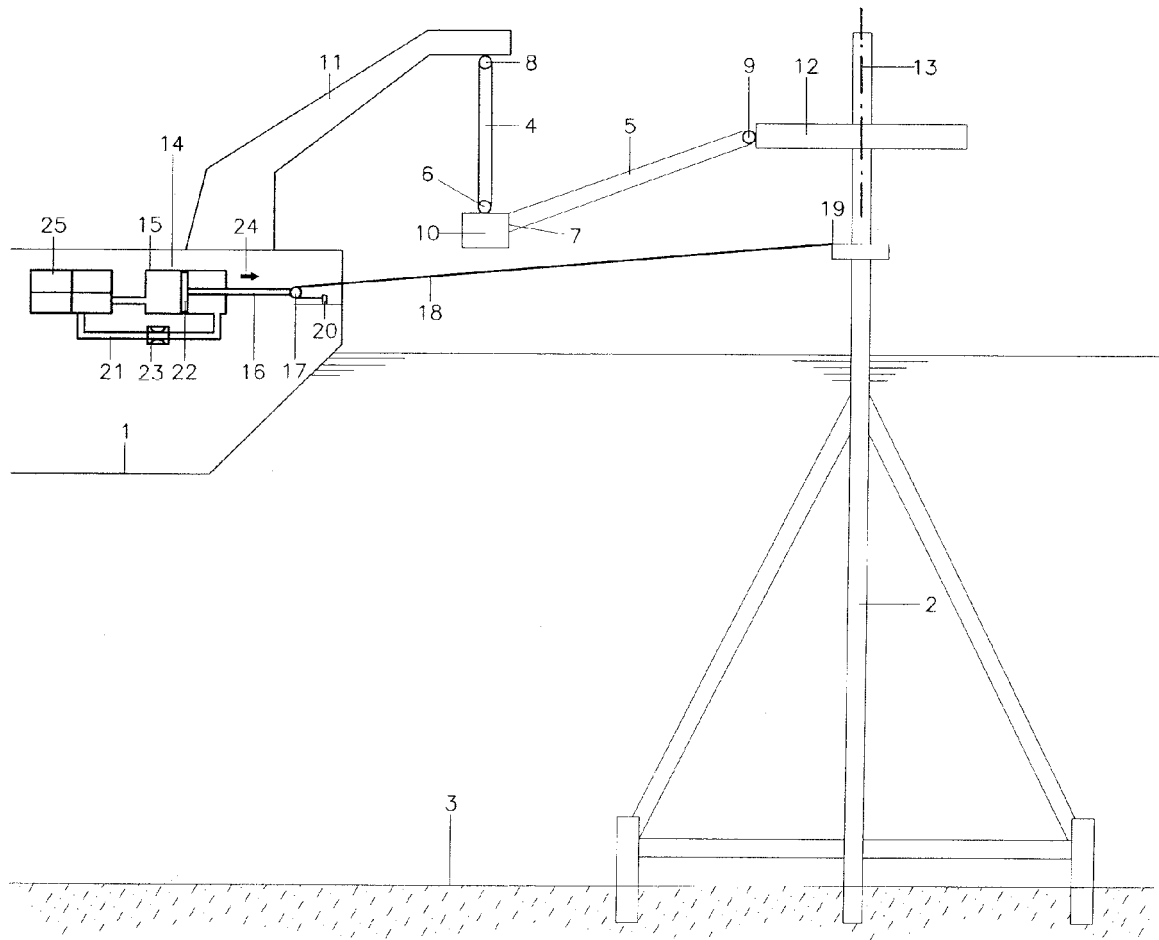
**[0030]** The piston 16 of the cylinder piston assembly is provided with a pretension such as to keep the flexible member 18 taut during the entire surge motion, and especially when the vessel 1 closes in to the fixed tower 2. In the illustrated embodiment the pretension of the piston 16 is caused by the hydraulic control unit 25 connected to the cylinder piston assembly in a manner known per se and indicated only schematically here.

**[0031]** It is also possible to replace the cylinder-piston assembly by friction plates which are moved relative to each other through an element corresponding to piston 16. Or one could use a means generating an electrical current flowing through an electrical resistance, for example.

**[0032]** The invention is not limited to the embodiments described before which may be varied widely within the scope of the invention as defined by the appending claims. For example, the cylinder piston assembly also may be attached to the fixed tower 2 *mutatis mutandis*. Further the invention, for example, also applies to a situation in which pendulum members are provided which are hingedly connected to the fixed tower in stead of to the vessel.

## Claims

1. Mooring assembly for mooring a floating structure, such as a vessel, to a further floating or fixed structure, comprising a connecting structure acting with the vessel as a mass spring system with respect to at least the surge motion between the floating structure and the further floating or fixed structure, **characterized by** a damping system for damping at least said surge motion.
2. Mooring assembly according to claim 1, wherein the damping system only dampens the surge motion of the floating structure away from the further floating or fixed structure.
3. Mooring assembly according to claim 1 or 2, wherein the damping system is devised for transforming the kinetic energy of the surge motion into heat.
4. Mooring assembly according to claim 3, wherein the damping system is devised for transforming the surge motion into a displacement of a fluid through a restriction means and thus for transforming the displacement of the fluid into the generation of heat.
5. Mooring assembly according to claim 4, wherein the restriction means is a narrowed orifice in a line for the fluid, which line is in communication with a piston chamber of a cylinder-piston assembly of which the piston is movable in correspondence with the surge motion.
6. Mooring assembly according to claim 5, wherein the cylinder of the cylinder piston assembly is connected to the floating structure, whereas the piston of the cylinder piston assembly is connected to a point externally of the floating structure of which the distance to the floating structure varies as a result of the surge motion.
7. Mooring assembly according to claim 6, wherein said point externally of the floating structure is part of the further floating or fixed structure.
8. Mooring assembly according to claim 6, wherein said point externally of the floating structure is part of the connecting structure.
9. Mooring assembly according to any of the claims 6-8, wherein the piston carries a pulley around which a flexible member, such as a cable, rope or alike, extends of which a first end is connected to said point externally of the floating structure and of which the second end is attached to the floating structure.
10. Mooring assembly according to claim 9, wherein the piston of the cylinder piston assembly is provided with a pretension such as to keep the flexible member taut during the entire surge motion.
11. Mooring assembly according to claim 10, wherein the pretension of the piston is caused by a hydraulic actuator connected to the cylinder piston assembly.
12. Mooring assembly according to claim 3, wherein the damping system is devised for transforming the surge motion into a relative motion between friction plates.
13. Mooring assembly according to claim 1 or 2, wherein the damping system is devised for transforming the surge motion into the flow of an electric current through an electrical resistance.
14. Mooring assembly according to any of the previous claims, wherein the connecting structure is of the type comprising pendulum members and a rigid arm assembly, which at a first end are hingedly interconnected and each at a second end are connected to the floating structure and further floating or fixed structure, respectively, and further comprising ballast weights at the interconnected ends.





European Patent  
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# EUROPEAN SEARCH REPORT

Application Number  
EP 07 12 2733

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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 17 June 2008	Examiner Moya, Eduardo
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EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT  
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EP 07 12 2733

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