TITLE: MOORING DEVICE

TECHNICAL FIELD

The present invention relates generally to mooring devices for releasably securing and retaining in position a large object in relation to a nearby second large object. More particularly, the present invention relates to robotic mooring devices for controlling the mooring and departure process for vessels from a fixed or floating dock, or from another vessel.

BACKGROUND ART

Whilst the invention relates to a mooring device for releasably securing and retaining in position a large object in relation to a nearby second large object, it will be described with reference to mooring devices for docking and undocking a vessel. However, it will be understood that the invention is not limited solely to such example.

The use of robot-like mooring devices has been proposed to reduce the labour intensity, hazards and time taken by using the traditional mooring lines. These devices should be capable of restraining movement of the ship in response to winds, currents, shifting tides, movement of the ship due to the addition or removal of cargo, and the like.

An example of such a device is shown in WO91/14615, which describes a mechanism with a prehensile assembly for engaging a bollard on the vessel. A disadvantage of this type of system is that the vessel must be specially adapted. Further, precision is required to align the two coupling components. The prehensile assembly is not adapted to be quickly disengaged during the departure process.

A known system of the applicants employs a mooring arm mounted within a ship to one end of which a vacuum cup is fixed. During mooring, the vacuum cup protrudes through an opening in the hull of the ship and attaches to a bearing plate. The bearing plate is fixed to the dock, but able to rise and fall freely relative to it. Such a system is significantly more efficient than the traditional mooring process but because of the bearing plate, it is only suited to applications where the ship has a dedicated dock. In addition, other means are provided for securing the vessel accurately in the fore and aft direction with respect to the dock. Where such is not the case, this inability to absorb forces acting on the vessel in the fore and aft direction and the

necessity to provide a means of raising and lowering the dock mounted attachment plate is a disadvantage of this known system.

US Pat. No. 3974794 illustrates an alternative dock mounted system which is able to handle a range of different vessels, with no modification to the vessel being necessary, since the vacuum cups bear on the ship's hull. Hydraulic cylinders are used to rotate the vacuum cup fixed to a dock to conform to the shape of the hull.

US Pat. No. 3463114 describes a mooring device with a buffered telescopic boom fitted with a vacuum cup for engagement with the hull of a ship. The boom is fixed in vertical guides and it is allowed to rise and fall with the ship when fastened thereto.

In both of these systems (in US Pat. Nos. 3463114 and 3974794) the ship is rigidly fixed to the mooring station in the longitudinal direction with respect to the ship, consequently the mooring device is subject to deleterious impact loads in this direction. Neither system may be used to control the position of the vessel in the fore-and-aft direction.

DE 2557964 illustrates a fending device with two dimensional movement and impact absorption. However there is no means for mooring a vessel, nor retain the moored vessel against a dock.

Generally, there are three degrees of freedom of the position of a floating vessel: fore-and-aft, rise-and-fall, and athwart-ship (and there are three degrees of freedom of its orientation or rotation: roll, pitch and yaw). When mooring a vessel, particularly a massive vessel, it is desirable to have a degree of compliance in the mooring device, to avoid impact loads which may occur in any direction. Additionally, when loading a vessel for example, it is often desirable to control and to vary the fore-and-aft position of the vessel relative to the dock, as well as to control the athwart-ship position.

It is an object of the present invention to provide a mooring device which automatically positions a first large object relative to a nearly second large object, with precise control of both the fore and aft and the athwart-ship position of the first object with respect to the second object, and which device resiliently buffers the mooring forces exerted between the two objects.

It is a further object of the present invention to provide a mooring device which provides increased control over the movement of the first large object relative to the second object, as compared with mooring devices known in the art.

It is a further object of the present invention to address the foregoing problems in respect of positioning a first large object relative to a second large object or to provide the public with a useful choice.

Further aspects and advantages of the present invention will become apparent from the ensuing description which is given by way of example only.

DISCLOSURE OF THE INVENTION

In a first aspect the present invention consists in a mooring robot for releasably fastening a vessel, the mooring robot being fixable to a mounting, the mounting being one selected from (a) a fixed dock, (b) a floating dock and (c) a second vessel, the mooring robot including:

an attractive attachment element for releasable engagement with a surface for making fast the vessel;

a three axis translation unit to which the attractive attachment element is pivotally engaged, the translation unit including actuation means to provide power-actuated translational movement of the attractive attachment element within limits and in three dimensions relative to said mounting,

said actuation means including horizontal plane drive means for driving the attractive attachment element relative to said mounting in a horizontal plane to, in use and when engaged with a vessel, move the vessel relative to the mounting in both the fore-and-aft and athwartship directions, the horizontal plane drive means being releasable to allow external forces to displace the vessel (and the attachment element) relative to the mounting in the horizontal plane away from a selected moored position; and

resilient means resiliently biasing the vessel (and the attractive attachment element) toward the selected moored position, the resilient means acting in both the fore-and-aft and athwartship directions.

Preferably the resilient means operates when the horizontal plane drive means is released, the actuation means including a vertical actuator for driving the attractive

attachment element vertically when not engaged to said vessel, the vertical actuator being releasable from driving, to allow the vessel (and the attachment element) to freely rise and fall.

Preferably the resilient means provides a restorative force proportional to the displacement of the attractive attachment element in the horizontal plane from the selected moored position.

Preferably the resilient means releases energy to restore the attractive attachment element to the selected moored position, the energy being stored during displacement of the attractive attachment element from the selected moored position.

Preferably said surface is the freeboard of the hull of a floating vessel.

Preferably the attractive attachment element comprises at least one suction cup having a circumferential elastomeric seal.

Preferably the translation unit includes a telescopic robot arm providing the translational motion of said attractive element, the robot arm being pivoted about a substantially vertical axis.

Preferably said vertical actuator is a linear actuator and the horizontal plane drive means includes two linear actuators for driving the attractive attachment element in the horizontal plane.

Preferably the robot arm is in use, mounted relative to said mounting for sliding relative thereto by means of vertical guides.

Preferably counterbalancing means counterbalance a substantial portion of weight of said robot arm.

Preferably a suction cup assembly of said attractive attachment element is fixed to the end of a telescoping portion of the robot arm.

Preferably the attractive attachment element is attached to the robot arm by a universal joint permitting limited rotation of the attractive attachment element relative to the robot arm and perpendicular to the axis thereof.

Preferably the mooring robot is mounted on the front face of and below the top of the dock and is retractable within the fender line of the dock.

Preferably the linear actuators are double-acting hydraulic rams.

Preferably the translation unit includes shock absorbing means for absorbing mooring forces between the attractive attachment element and a mounting of the translation unit.

In a further aspect the present invention consists in a mooring system including two or more mooring robots as hereinbefore described wherein the operating conditions of each mooring robot are centrally controlled and monitored.

Preferably the control and monitoring of each mooring robot is performed by a control system linked to the ship's alarms.

In a further aspect the present invention consists in a mooring robot substantially as hereinbefore described with reference to the accompanying drawings.

In a further aspect the present invention consists in a mooring system substantially as hereinbefore described with reference to the accompanying drawings.

In a further aspect the present invention consists in a method of operating a mooring system substantially as hereinbefore described with reference to the accompanying drawings.

BRIEF DESCRIPTION OF DRAWINGS

Further aspects of the present invention will become apparent from the following description which is given by way of example only and with reference to the accompanying drawings in which:

Figure 1 is a three-dimensional schematic view of a robot arm a first preferred embodiment of a mooring robot of the present invention;

Figure 2 is a pictorial view of the first preferred embodiment of the mooring robot of the present invention;

Figure 3 is an exploded view of the mooring robot of Fig. 2;

Figure 4 is a side elevation of a second preferred embodiment mooring robot of the present invention;

Figure 5 is a front elevation of the mooring robot of Fig. 4;

Figure 6 is a plan view of the mooring robot of Fig. 4;

Figure 7 is a side elevation of the first preferred embodiment of the mooring robot fixed to a dock, and

Figure 8 is a plan view of mooring device of the present invention.

BEST MODES FOR CARRYING OUT THE INVENTION

Referring to Fig. 1, a first preferred embodiment of a mooring robot 100 of the present invention (illustrated schematically) is fixed to a dock 50 and may be fastened to the hull 51 of a vessel by means of vacuum cups 1. The mooring robot 100 includes a robot arm 10, having three degrees of translational freedom for positioning the vacuum cups 1 anywhere within a three-dimensional operating envelope 20. The robot arm 10 provides a telescoping movement along axis Z and is

fixed at one end in a gimbal 11 for rotation about two orthogonal axes X and Y, which are substantially vertical and horizontal respectively.

Fig. 2 illustrates this first preferred embodiment of the mooring robot 100, which includes a mounting frame 30 fixed to the dock 50. The robot arm 10 is fixed by means of the gimbal 11 (Fig. 1) to the mounting frame 30, and protrudes through a vertically extending aperture 33 in a sub-frame 31 which is slidably connected to the mounting frame 30. The sub-frame 31 provides generally horizontal actuation of the robot arm 10 and has a limited degree of sliding movement along a horizontal axis relative to the mounting frame 30 and includes a pivotally mounted collar 34 (see also Fig. 3) defining the aperture 33.

Fig. 3 is an exploded view of the mooring robot 100, wherein each vacuum cup 1 has a circumferential seal 2 which is presented towards the hull 51 (Fig. 1). The seal 2 is of a type described in the co-pending application based upon New Zealand Patent application No. 501394 (which description is incorporated herein by reference). Attached vacuum piping, valving, vacuum source and controls etc are not shown, for clarity. The vacuum cups 1 are arranged in a horizontal array supported by a horizontal member 4. Member 4 is a hollow section and also acts as a vacuum reservoir for the cups 1. In order to allow the vacuum cups 1 to conform to the shape of the hull 51 and to accommodate rotational displacement of the vessel, member 4 is mounted to the robot arm 10 about a universal joint 5, for rotations perpendicular to the axis of the robot arm 10. The collar 34 is pivotally fixed to the sub-frame 31 by bearings permitting rotation about a vertical axis V. The vacuum cups 1 are fixed to the member 4 by pivots 6 providing limited rotation of the vacuum pads 1 about a generally vertical axis.

The telescoping movement of the robot arm 10 is driven by a double acting hydraulic ram 21, having a position transducer 122. The robot arm 10 is pivoted about the axis Y to provide generally up and down movement of the vacuum cups 1. This is controlled by a double-acting hydraulic ram 22, both ends of which are pivotally fixed, one end to the mounting frame 30 the other end to the robot arm 10. Rotation about the axis Z generally provides fore-and-aft movement and is controlled by a double-acting hydraulic ram 23, one end of which is fixed to the mounting frame 30 the other end to the sub-frame 31. Rotary position transducers 37, 38 are fitted about the gimbal 11 for sensing rotation about axes X and Y respectively.

The hydraulic system (not shown) for actuating the rams 21 and 23 for controlling the position of the vacuum cups 1 in the horizontal plane includes a hydropneumatic accumulator for storing excess energy when the pressure in the rams 21 and 23 rises and releasing it when the pressure falls. Both sides of each double acting ram 21 and 23 are connected to the accumulator through

control valving. The valving allows the accumulator to be cut in or out of the system as a whole and includes means for sensing which side of the ram 21 and 23 is pressurised by mooring forces and directing fluid from the pressurised side to the accumulator. Both sides of ram 22 are provided with valving which, when opened, allows fluid to flow freely to and from a hydraulic reservoir, thereby providing a "free-floating" operational mode.

A second preferred embodiment of the mooring robot 200 is shown in Fig. 4, wherein the three degrees of translational freedom are provided by means of a cylindrical coordinate-type movement depending on two translational motions and one rotation. A pair of robots 200 is shown, each having vacuum cups 1 connected to a telescopic robot arm 210 for linear movement along axis Z thereof. The robot arm 210 is pivotably fixed to a carriage (not shown) for rotation about a vertical axis X and the carriage itself may be moved along a vertical axis A.

Fig. 5 shows vertical columns 90, in which the carriage (not shown) moves, the columns 90 extend above and below the surface of the dock D. Each carriage is counterweighted by means of cables 94 fixed through pulleys 91 to counterweights (not shown), and is driven both up and down by means of a looped drive cable 92 connected to a winch 93.

Referring to Fig. 6, adjacent to each column 90 is a tube 95 extending vertically and enclosing the counterweight (not shown). A pair of wheels 98 on either side of the carriage 97 carry it in the column 90. The carriage 97 has a pivot 99, defining axis X, about which the robot arm 10 is pivoted by means of a double-acting hydraulic ram 223. The robot arm 210 is telescoped by a double-acting hydraulic ram 221. The rams 221, 223 are connected to a hydropneumatic accumulator, in the manner described above.

With reference to Fig. 7, the first preferred embodiment of the mooring robot 100 is shown mounted to a fixed dock 50. A range of sizes of ship S may be accommodated by the dock 50, which may be fixed or floating.

A mooring system 500 preferably includes two or more mooring robots 100, as described above. Optionally the mooring system may include robots 200 or both robots 100 and 200. Optionally energy-absorbing fenders F, of the known type may be retained at intervals along the front face of the dock 50. The mooring robots 100 are mounted on the front face and below the top of the dock 51 so as not to interfere with loading and unloading operations. It will be appreciated that the mooring system 100 may equally be fixed to a ship S, permitting the ship S to be made fast to a surface attached to the dock 51 or another ship S.

In the mooring system 500 several mooring robots 100 are connected by service lines 131 to a single power / control unit 30 mounted on the dock 50. The power /control unit 30 provides control signals to the mooring robot 100 and provides means to power the rams 21, 22, 23 (Fig. 3) and the vacuum cups 1 (Figs. 1-3). It also receives feedback signals indicating the operating conditions of each mooring robot 100. Positional feedback indications from the mooring robot 100 can be provided to other systems, for example, automatic loading systems which require information on the position of the ship S. Preferably the mooring system 100 operates automatically in the sequence to be described below, this operation being controlled remotely from the shore or the ship S by a unit 32.

The operation of the mooring robot (100, 200) is described herein below with reference to Figures 7 and 8. To make fast a ship S the mooring arm (10, 210) is extended generally perpendicular to the front mooring face of the docked area In operation, when the ship S draws near to the dock 50, the robot arm (10, 210) extends the vacuum cups 1 out toward the hull of the ship S. The ship S is positioned so that the vacuum cups 1 engage a planar section of the hull.

The assumption that the ship side is substantially planar is not critical to the operation of the mooring robot (100, 200) since the pivots (5, 3) allow the vacuum cups 1 to rotate to conform to the curve of the hull of the ship S. Although some vessels have slightly rounded sides for greater seaworthiness, for most container ships (in particular) this assumption is valid, except possibly near the bow and stern of the ship. This is because ships designed to stow containers have flat sides to use the space efficiently, and the bow and stern of the ship are not used for mooring .

Sensors of a known type (not shown) indicate engagement with the hull. The vacuum cups 1 are then actuated to fasten to the ship S in the known manner. With both mooring robots (100, 200) fixed, the ship S is automatically moved into a docked position (not shown) maintaining it at a pre-set (but variable) distance clear of the dock 50. This position is the preferred, or pre-determined operating position.

Referring to the first preferred embodiment, and Figs. 1-3, the operation of each mooring robot 100 maintains the ship S, within certain limits in the docked position in response to changing conditions of wind, tide, swell and displacement. If each mooring robot 100 is too rigid to allow movement of the ship S fore-and-aft, athwart ship and also in pitch, roll, and yaw, then failure of the vacuum in the cups 1, or of the ship's hull could occur.

On attaining the docked position (or pre-determined operating position), the hydraulic pumps for actuating the rams (21, 22, 23) are stopped, the accumulator is cut into the lines to the ram 21 and

23 and the vertical movement ram 22 is switched into free-floating mode allowing the mooring robot (and thus the ship S) to rise and fall with the tide, state of loading, etc..Once in the docked position, pressure is regulated on each side of the piston of the rams 21 and 23 such that movement of the robot arm 10 in any direction in the horizontal plane away from the docked position results in a proportional force acting to restore the arm 10 to the pre-determined operating position, and thus return the ship S to the docked position.

Movement in the horizontal plane from the predefined docked position will result in pressurising of the fluid in the accumulator which provides hydraulic pressure to the rams (21, 23) tending to restore the arm 10 to the pre-determined operating position and thus the ship S to the docked position. The maximum ram pressure, and hence the maximum load able to be applied to the vacuum cups 1, is limited to a level safely below the load capacity of the vacuum cups 1. Under severe conditions, if the travel of the rams 21, 22, 23 approaches its limit under maximum operating pressure, an alarm condition is indicated, allowing the ship's captain or port authorities to take emergency action. All other operating conditions are also monitored and preferably linked to the ship's alarms.

The ram 22 permits the ship S to rise and fall relative to the dock 51. Optionally, the method of mooring the ship S includes a first step of initially selecting the height of the vacuum cups 1, depending on the state of the tide and state of loading of the ship S. The ram 22 is then operated to move the cups 1 to that height. In this way the vertical travel necessary to accommodate the full range of ships S may be reduced.

Referring to Figs 4 & 5, in the operation of the second preferred embodiment of the mooring robot 200, the resilient action in the horizontal plane is accomplished in a similar manner to that described above for the first preferred embodiment of the mooring robot 100. The two rams 221 and 223 are connected to an accumulator. Vertical movement of the carriage 97 is controlled by allowing the mooring robot 200 to rise and fall freely. It will be appreciated that the mooring robot 200, as compared to mooring robot 100, provides an increased vertical range of operation and is thereby able to accommodate a wider variations in this direction, due to load and tidal flow etc.

The mooring robots 100, 200 may optionally include means for absorbing and/or resiliently buffering substantially vertical mooring forces for providing the increased stability, particularly with respect to roll and pitch of the ship S. For example, this may be provided by means of shock absorbers (not shown) connected to the robot arm 10 or may be provided through the

actuating elements controlling vertical movement – the ram 22 and winch/cable 92, 93 in the two preferred embodiments respectively.

Even providing for the resilience as described, the ship S is more rigidly held in the docked position by these mooring systems (100, 200) than by the traditional (mooring line) method. Also, not only are paint abrasion and impact damage to the ship S prevented, but this increased stability is also advantageous when transferring cargo between the ship S and shore. Additionally, it has been found in practice that the mooring system (100, 200) consumes less energy to moor a ship S than systems using automatic tensioning devices to control mooring lines.

The mooring system (100, 200) also eliminates the need for close-in manoeuvring on departure from the dock 51 as the mooring robot 100 can be used to push the ship S clear of the dock 51. As with the mooring process, the departure is automated and remotely controlled by the unit 32.

Whilst the invention has been described with reference to a fixed dock 50, it will be appreciated that the dock may be a floating dock or that the dock may be replaced by a second vessel. Similarly the above invention has been described with the mooring system 500 afixed to the dock 51. It will be appreciated that the mooring system may be afixed to the movable vessel.

Similarly, the above embodiment of the invention as embodied in a docking system for vessel, it will be appreciated that there are other applications for the invention; for example the docking of one object to another under water, or in other environments. In such situations it will be apparent that he use of the term 'horizontal' plane is not limiting; but is used by way of reference to assist in defining the plane of restorative movement relative to the orientation of the object being dock and/or relative to any constant force (in the example above, gravity)

Aspects of the present invention have been described by way of example only and it should be appreciated that modifications and additions may be made thereto without departing from the scope thereof.

CLAIMS

1. A mooring robot for releasably fastening a vessel, the mooring robot being fixable to a mounting, the mounting being one selected from (a) a fixed dock, (b) a floating dock and (c) a second vessel, the mooring robot including:

an attractive attachment element for releasable engagement with a surface for making fast the vessel;

a three axis translation unit to which the attractive attachment element is pivotally engaged, the translation unit including actuation means to provide power-actuated translational movement of the attractive attachment element within limits and in three dimensions relative to said mounting,

said actuation means including horizontal plane drive means for driving the attractive attachment element relative to said mounting in a horizontal plane to, in use and when engaged with a vessel, move the vessel relative to the mounting in both the fore-and-aft and athwartship directions, the horizontal plane drive means being releasable to allow external forces to displace the vessel (and the attachment element) relative to the mounting in the horizontal plane away from a selected moored position; and

resilient means resiliently biasing the vessel (and the attractive attachment element) toward the selected moored position, the resilient means acting in both the fore-and-aft and athwartship directions.

2. A mooring robot as claimed in claim 1 wherein the resilient means operates when the horizontal plane drive means is released, the actuation means including a vertical actuator for driving the attractive attachment element vertically when not engaged to said vessel, the vertical actuator being releasable from driving, to allow the vessel (and the attachment element) to freely rise and fall.

3. A mooring robot as claimed in claim 1 or claim 2 wherein the resilient means provides a restorative force proportional to the displacement of the attractive

attachment element in the horizontal plane from the selected moored position.

4. A mooring robot as claimed in claim 3 wherein the resilient means releases energy to restore the attractive attachment element to the selected moored position, the energy being stored during displacement of the attractive attachment element from the selected moored position.

5. A mooring robot as claimed in any one of claims 1 to 4 wherein said surface is the freeboard of the hull of a floating vessel.

6. A mooring robot as claimed in any one of claims 1 to 5 wherein the attractive attachment element comprises at least one suction cup having a circumferential elastomeric seal.

7. A mooring robot as claimed in any one of claims 1 to 6 wherein the translation unit includes a telescopic robot arm providing the translational motion of said attractive element, the robot arm being pivoted about a substantially vertical axis.

8. A mooring robot as claimed in any one of claims 2 to 7 wherein said vertical actuator is a linear actuator and the horizontal plane drive means includes two linear actuators for driving the attractive attachment element in the horizontal plane.

9. A mooring robot as claimed in claim 7 wherein the robot arm is in use, mounted relative to said mounting for sliding relative thereto by means of vertical guides.

10. A mooring robot as claimed in claim 9 wherein counterbalancing means counterbalance a substantial portion of weight of said robot arm.

11. A mooring robot as claimed in any one of claims 7 to 9 wherein a suction cup assembly of said attractive attachment element is fixed to the end of a telescoping portion of the robot arm.

12. A mooring robot as claimed in any one of claims 7 to 10 wherein the attractive attachment element is attached to the robot arm by a universal joint permitting limited rotation of the attractive attachment element relative to the robot arm and perpendicular to the axis thereof.

13. A mooring robot as claimed in any one of claims 1 to 11 wherein the mooring robot is mounted on the front face of and below the top of the dock and is retractable within the fender line of the dock.

14. A mooring robot as claimed in claim 8 wherein the linear actuators are double-acting hydraulic rams.

15. A mooring robot as claimed in any one of claims 1 to 4 wherein the translation unit includes shock absorbing means for absorbing mooring forces between the attractive attachment element and a mounting of the translation unit.

16. A mooring system including two or more mooring robots as claimed in any one of claims 1 to 15 wherein the operating conditions of each mooring robot are centrally controlled and monitored.

17. A mooring system as claimed in claim 16 wherein the control and monitoring of each mooring robot is performed by a control system linked to the ship's alarms.

18. A mooring robot substantially as hereinbefore described with reference to the accompanying drawings.

19. A mooring system substantially as hereinbefore described with reference to the accompanying drawings.

20. A method of operating a mooring system substantially as hereinbefore described with reference to the accompanying drawings.

21. A mooring robot as claimed in any one of claims 1 to 16 with reference to the accompanying drawings.

22. A mooring system as claimed in any one of claims 1 to 16 with reference to the accompanying drawings.

23. A method of operating a mooring system as claimed in claim 17 with reference to the accompanying drawings.