

SYSTEM AND METHOD FOR TRANSFERRING A FLUID

5 The invention relates to a system for transferring a fluid, such as a petroleum product, and an associated transfer method. More particularly it is a system for transferring liquefied natural gas where the transfer takes place between two ships on the open sea (offshore transfer).

 The first of the two ships can be a production ship known as LNGP
10 (for "liquefied natural gas producer"), LNG-FPSO (for "Liquefied Natural Gas Floating Production Storage and Offloading"), or also FLNG (for "Floating Liquid Natural Gas Unit"), a reliquefaction ship (FSRU for "Floating Storage and Regasification Unit"), a GBS (for "Gravity Base Structure") or finally a platform.

 The second of the two ships can be a ship adapted to receive the
15 gas for its transport such as a tanker or an LNG-C (for "Liquefied Natural Gas Carrier", for example a methane carrier).

 In particular, in order to carry this out rigid and articulated loading systems are known which have a fluid transfer line end fastened to a base or a support and linked to a tank of fluid to be transferred, and an opposite movable
20 line end provided with a connect-disconnect device for the connecting to a target duct, itself linked to a tank of fluid.

 Generally, in such a system (cf. FR 2813872 and FR 2854156), the loading arm comprises articulated piping, mounted on a base linked to a tank of fluid and on which is mounted a first pipe called an inner pipe via a portion of
25 tube bent at 90° allowing a rotation of one of its ends about a vertical axis, and the other end about a horizontal axis. At the opposite end of the inner tube, a second pipe, called an outer pipe is mounted in rotation about a horizontal axis. At the end of the outer pipe the connect-disconnect device is mounted, for example a hydraulic coupler.

30 The coupler thus has at least three degrees of freedom relative to the base bearing the fixed end of the duct, and the movements following each of

these degrees of freedom are controlled by actuators such as jacks or hydraulic motors. To this end the operator has a control interface available.

The transfer of fluid on the open sea has always proved to be difficult due to the relative movements of the two ships and more particularly those of the second, the first of the two defined above being generally in the form of a platform which is more or less fixed.

In order to allow the connection of the loading arms under difficult meteorological conditions (very rough sea), a cable system subjected to a constant pressure is therefore implemented on the above-mentioned arms, cooperating with the movable line end in order to synchronize the movements of the arm with those of the receiving ship.

This type of system is entirely satisfactory, but it would nevertheless be desirable to be able to have a loading system available which puts no strain, or the minimum possible strain, on this movable line end during the connection process.

To this end, the present invention proposes a system for transferring a fluid product, comprising a balanced arm for transferring the fluid product, having a transfer compass comprising a transfer line having a line end fastened to a support and a movable line end provided with a connect-disconnect device which is adapted for the connection of the line to a target duct, the system being characterized in that it further comprises a telescopic arm which is adapted to be joined by one of its longitudinal ends to the movable line end to move that end towards a position for connecting the connect-disconnect device to the target duct and which is mounted by its opposite longitudinal end on a parallel robot controlled according to the detection of movements experienced by the target duct to compensate for the movements of the target duct at the connect-disconnect device.

Due to these arrangements, it is possible to carry out a method for complete connection/disconnection that puts very little or no stress on the movable line end and moreover leads to other advantages, as will be seen in more detail below.

According to other arrangements of the present invention being able to be implemented either independently or in a combined fashion, in particular due to their convenience of manufacture or of use:

- 5 - the parallel robot comprises a support on which the telescopic arm and the actuators for moving the support with at least three degrees of freedom are mounted.
- the parallel robot is in the form of a Stewart platform.
- the actuators of the parallel robot are hydraulic, pneumatic or electrical jacks.
- 10 - the system comprises a control system adapted to control the actuators of the parallel robot according to signals received from detection means for detecting movements of the target duct relative to an item in the surroundings.
- the detection means comprise a global positioning system, in particular of GPS type, an optical system, such as a camera or a laser or infrared system, an acceleration measuring system, an inertial stabilizing system for measuring angles, an autonomous system for detecting initial coordinates, or a combination of two or more of these systems.
- 15 - the control system is adapted to process the signals received from the detection means by means of pre-programmed algorithms.
- the telescopic arm is pivotally mounted on the support so as to be able to raise or lower it.
- the telescopic arm is rigidly linked to the movable line end.
- the system comprises a carriage mounted movable in translation over an outer segment of the telescopic arm and which is adapted to be fastened to the movable line end.
- 25 - the transfer arm comprises at least three actuators each one to control the movement of the transfer arm with a degree of freedom according to a first mode of operation, and is adapted to be set to coast according to a second mode of operation.
- 30

- the movable line end of the transfer arm comprises means for guiding and aligning the connect-disconnect device onto the target duct when it reaches the immediate vicinity thereof.

- the transfer arm is equipped with sensors adapted to act on the movement controls of the arm for the purpose of limiting the loads applied to a ship bearing the target duct.

The invention also relates to an assembly for fluid product transfer, comprising a transfer system as defined above and a target duct provided with a support member for the end of the telescopic arm located on the side of the movable line end.

Finally, the invention relates to a method of fluid transfer by means of a system as defined above, comprising the following steps:

- bringing the telescopic arm towards the target duct, to reach a position spaced from the target duct;
- connecting the telescopic arm to the movable line end of the transfer arm;
- setting the transfer arm to coasting mode; and
- bringing the connect-disconnect device towards a position for connection to the target duct by means of the telescopic arm.

In such case, the connect-disconnect device can be moved, over a portion of final travel, by the sliding of a carriage on the telescopic arm.

The disclosure of the present invention will now continue with the detailed description of two embodiment examples, given hereafter by way of non-limitative illustration, with reference to the attached drawings in which:

- Figure 1 is a very diagrammatic side elevation view of a transfer system according to a first embodiment of the invention; and
- Figure 2 is a very diagrammatic side elevation view of a transfer system according to a second embodiment of the invention.

These figures represent a transfer system, in this case with a double counterweight for transferring a fluid product according to the invention, and have two embodiments of the means of actuation and of the means of movement compensation.

In these embodiments selected only by way of example in order to illustrate the application of the invention, the transfer system 1 comprises a transfer arm 10 comprising, generally, a deformable duct portion 11 which is adapted to be connected at one end to a fixed pipeline leading to a tank (not shown) and terminated at its other end by a coupler 12, in this case to an hydraulic motor, or any other connect-disconnect device (coupling) of a known type and adapted to be connected to a second pipeline or target duct carried by the ship 2.

This hydraulic coupler 12 is linked by an assembly of elbows and swivel joints, in this case cryogenic and of the Chiksan® type swivel joint, to the free end of the deformable duct portion 11. The assembly of elbows and swivel joints is, in practice, a style 80 equipped with an Emergency Release System (ERS) and a Quick Connect-Disconnect Coupler system (QCDC). This quick connection/disconnection system is used in normal operation.

It should be noted here that in the field the expressions "style 40" and "style 50" are known, defining on the one hand a fitting or swivel joint the two ends of which are each welded onto an elbow, and the other the assembly of a first swivel fitting, then an elbow, then a second swivel fitting forming an angle of 90° with said first fitting, then an elbow. A style 80 corresponds to a style 50 completed by a third fitting parallel to the first fitting and connected to the second by an elbow. These styles of swivel joints are all cryogenic, in this case of the Chiksan ® type swivel joint.

The deformable duct portion 11 mainly comprises two tubes 13, 14, or transfer components connected by a swivel joint 15 with a horizontal axis (style 40), thus forming a compass with a variable opening. One of these tubes, called the inner tube 13, is adapted to be connected via a style 50 to a pipeline adapted to fluidically connect the transfer arm to the tank (components not shown in the figures) while the other tube, called the outer tube 14, is connected, as indicated above, to the coupler 12.

The deformable duct portion 11 has associated counterweight balancing systems which are adapted to make it possible for the arm to remain stable in any configuration when empty. This is necessary for the operations of

coupling the arm to and decoupling it from the movable pipeline to proceed smoothly. Therefore, no significant effort is required to maintain the arm in position.

5 The main balancing, i.e. of the movable components of the arm that are the inner 13 and outer 14 tubes articulated to each other as well as the coupling assembly formed by the hydraulic coupler 12 and the means of connection thereof to the outer tube 14, is ensured by means of at least one primary counterweight 16. A system of balancing the section of outer tube 14 and the above-mentioned coupling assembly, is, in this case, also provided. It is in the form of a pantograph system 17 which comprises at least one secondary counterweight 18.

Moreover, the jacks constitute actuation devices or actuators of these inner 13 and outer 14 tubes. In this case they are hydraulic jacks controlled by an operator by means of a control interface.

15 These jacks are, in this case, three in number, i.e. one jack for controlling the movement of the arm with each degree of freedom. That actuating the arm 10 in rotation about a vertical axis is not shown in the figures while those actuating the inner 13 and outer 14 tubes have the reference numbers 14 and 20 respectively.

20 Moreover, the movable line end is equipped with the hydraulic coupler which is of the QCDC type as well as an Emergency Release System (ERS).

The transfer arm as it has just been described is well known to a person skilled in the art and will therefore not be described in more detail here. In fact it is an arm similar to those described in the above-mentioned applications (FR 2813872 and FR 2854156).

The remainder of the description relates more precisely to the two embodiments of the means of actuation and the means of movement compensation according to the invention.

30 In the case of the first embodiment, the system 1 for transferring a fluid product comprises, as indicated, a balanced transfer arm 10 with a double counterweight, installed in this case on an offshore platform 21, with its

deformable duct portion 11 or transfer compass forming a transfer line with a line end fastened to a mast 22 and a movable line end 23 provided with the hydraulic coupler 12 which is adapted for the connection of this transfer line to a target duct 24 installed, in this case, on an LNG-C.

5 In practice, the transfer arm 10 comprises, in the case of this embodiment and also as indicated, three hydraulic jacks (not shown in the figure) each for controlling the movement of the arm with a degree of freedom in a first mode of operation (by actuation of the inner tube 17, the outer tube 14 and rotation about a vertical axis). This arm 10 is moreover adapted to be set
10 to coasting according to a second mode of operation.

 According to the present invention, the transfer system further comprises a telescopic arm 25, in this case hydraulic and with two segments 26, 27, which is adapted to be joined by one of its longitudinal ends to the movable line end 23, to move that end towards a position for connecting the
15 hydraulic coupler 12 to the target duct 24.

 This telescopic arm is, moreover, mounted by its opposite longitudinal end on a parallel robot 28 controlled according to detection of the movements experienced by the target duct 24, in order to compensate at the level of the hydraulic coupler 12 for the movements of the target duct 24.

20 More precisely, the parallel robot 28 is, in the case of this embodiment, a Stewart platform with hydraulic jacks, also known by the name of hexapod positioner. This is a parallel robot comprising six actuators (hydraulic jacks) and therefore having six degrees of freedom: the three translational coordinates as well as the angles of pitch, roll and yaw (Euler
25 angles) or as a variant, their nautical equivalent. Examples of such platforms are in particular described in the patent applications WO99/28095 and US2010/0191500.

 Only two of these hydraulic jacks of the Stewart platform are in this case shown in Figure 1 and have the reference number 29.

30 For the control of the movements of this Stewart platform, a control system (not shown) is provided which is adapted to control the hydraulic jacks of the platform according to signals received from means for detection of the

movements of the LNG-C ship and, consequently, of the target duct 24, relative to an item in the surroundings, such as the hydraulic coupler 12, or another item in the surrounding environment.

These detection means comprise, in the case of this embodiment, a
5 laser system (30a, 30b), of the type emitting a laser or infrared beam towards the target duct 24 or a target fixed relative to this duct, and adapted to capture the reflected beam and to measure the transit time of the beam in order to deduce information on the relative positioning of the target duct 24 with respect to the coupler 12. Advantageously, this system is coupled to other movement
10 sensors, such as accelerometers, for this control requirement.

The control system is, for its part, adapted to process the signals received from these detection means using pre-programed algorithms. It can be, for example, a computer system equipped with a processor and a memory in which these algorithms are stored. Naturally, these can also be stored on an
15 external medium, thus forming a computer program product.

This control system can, moreover, manage the hydraulic jacks of the transfer arm. A user control interface can advantageously complete this control system.

It will also be noted that the telescopic arm is, in this case, mounted
20 swivelling on the Stewart platform, so as to be able to raise it or lower it, by means of, for example, a hydraulic jack (not shown in Figure 1). In practice it swivels about an axis 31 extending parallel to the upper plate 32 of the Stewart platform and transversally to the axis of the mast 22 supporting the transfer compass.

At its other end, the telescopic arm 25 comprises, in the case of this
25 first embodiment, a carriage 33 mounted movable in translation on the outer segment 27 of the telescopic arm 25, in two opposite directions represented diagrammatically by the arrows A and B. In order to be able to move the hydraulic coupler 12 in translation, this carriage is fastened to the movable line
30 end 23.

In the case of this embodiment, a manifold 34, or more simply a flange is also provided on the LNG-C, at the end of the target duct 24, adapted

to be connected to the hydraulic coupler, and having the form of a part added onto a section of standard duct 35 equipping the LNG-C. A square-shaped support 36 is fastened to and under this manifold in order to be able to receive and support the free end of the telescopic arm 25.

5 The connection method is carried out, according to this first embodiment, as follows:

- the telescopic arm 25 and the transfer arm 10 (with its own jacks) are, firstly, deployed so as to be positioned between a storage or folded position and a position for connecting to the target duct.

10 - the transfer arm 10 is then connected (in practice linked for example by screwing) to the movable carriage 33 of the telescopic arm 25.

- the transfer arm 10 is then not yet in coasting mode but the carriage is able to carry out a backward movement (in the direction of arrow B) in translation in order to compensate for the movement in the opposite direction

15 by the outer segment 27 of the telescopic arm 25.

Then, the telescopic arm 25 is brought into the support position on the square support 36 connected to the manifold 34, by a translational movement of the outer segment 27 of this arm.

20 This leads to the positioning shown in Figure 1. In this position, the hydraulic coupler 12 is also set back relative to the free end of the telescopic arm 25, i.e. the free end of the outer segment 27 of this arm.

In other words, the movements of this end are synchronized with those of the LNG-C and this end is therefore in a fixed position relative to the LNG-C. The same applies to the hydraulic coupler 12, with the exception of its

25 translational displacement movement for bringing it closer to the manifold 34.

While carrying out this movement compensation, the carriage 33, with the transfer arm 10 linked thereto, is then moved in translation up to the hydraulic coupler 12 i.e. into position for connection to the manifold 34. During this translational movement, the transfer arm is set in coasting mode.

30 The final coupling between the hydraulic coupler 12 and the manifold 34 is, in the case of this first embodiment, carried out manually due to the degrees of freedom possessed, in practice and in a manner known *per se*, by

the movable line end 23 relative to the remainder of the outer duct 14. As a variant, as will be seen hereafter, the final alignment can also be ensured by the means for guiding and aligning.

5 The second embodiment will now be described with reference to Figure 2. The components of this Figure 2 that are identical or similar to those of Figure 1, have the same reference numbers.

According to this second embodiment shown in Figure 2, the transfer arm 10, via its movable line end 23, is rigidly linked directly to the outer segment 27 of the telescopic arm 25. In other words, there is no longer a carriage movable in translation.

In practice, there is a bracket 37 fastened, on the one hand, to the outer segment of the telescopic arm and, on the other hand, to the movable end 23 of the transfer line, between the last rotation of the latter and the hydraulic coupler 12. The fastening can be carried out for example by screwing. It will also be noted that the last rotation can be blocked during the translational movement of the hydraulic coupler 12 described hereafter.

It will also be noted that the transfer system 1 according to this second embodiment comprises means for guiding and aligning the hydraulic coupler 12 onto the manifold 34 when it reaches the immediate vicinity thereof. In this case these are two complementary tapered guiding components (one tapered male component and one tapered female component which are adapted to fit into one another).

It will be noted that this embodiment does not require, on the other hand, support for the telescopic arm 25 on the manifold 34.

25 The connection method according to this second embodiment is the following:

- the telescopic arm 25 is, firstly, extended up to a position spaced from the manifold 34 (without movement compensations by means of the parallel robot).

30 The transfer arm 10 is then deployed by means of its actuators until the hydraulic coupler 12 is situated close to the free end of the outer segment 27 of the telescopic arm 25.

The transfer arm 10 is then rigidly linked to this end of the telescopic arm 25 and set in coasting mode.

Then the telescopic arm 25 is moved up to a position for connecting the hydraulic coupler 12 to the manifold 34, the parallel robot 28 being started
5 simultaneously in order to ensure compensation of the movements of the manifold 34. The means of guiding and aligning then ensure the final guiding and alignment of the hydraulic coupler 12 onto the manifold 34.

In practice, it is of course possible to envisage, for example, compensating for a movement of the LNG-C in the direction of the platform by
10 the absence of a forward movement of the hydraulic coupler 12, instead of making it go backwards then forwards. In this way advantage is taken of the LNG-C moving closer, in order to bring the hydraulic coupler 12 close to the manifold 34.

The disconnection procedure can be carried out in a similar manner
15 to the connection procedure, but in reverse. It should however be noted that in the case of emergency disconnection, the guiding system formed by the telescopic arm is not used. In fact, the telescopic arm is withdrawn after connection of the arm to the ship's manifold and therefore only the latter and the arm are present during the emergency disconnection. The emergency
20 disconnection sequence is identical to that conventionally carried out on the transfer arms.

Thanks to the present invention, the procedure for connecting a transfer arm to a target duct can be carried out without exerting particular stress on the movable end of the transfer line and without it being necessary to install
25 thereon additional means used during the connection procedure, which would impose on this end an additional weight which would be transferred to the manifold after connection.

Moreover, the connection can be ensured smoothly and with a virtually conventional transfer arm .

30 The present invention is not limited to the preferred embodiments described above by way of non-limitative examples and illustrated by the

drawings. It relates to all the embodiment variants within the scope of a person skilled in the art.

5 In particular, it is possible, for example, to envisage moving the support or plate of the parallel robot, on which the telescopic arm is mounted, with only three degrees of freedom (pitch, roll and yaw), while the translational movements could be undertaken by displacement of the telescopic arm equipped with suitable actuators.

10 Movement compensation can also be envisaged in the case of relative movements of the first and second ships, if the platform is not substantially stationary.

In this case, it is possible to provide for determination of the relative positioning of the connect-disconnect device with respect to the target duct, instead, for example, of detecting only the movements of the second ship with respect to a reference point or a fixed item.

15 Moreover, the means of guiding and aligning can be in a form other than the tapered male and female components, such as for example in the form of rods having a shape allowing the guiding and the aligning of the hydraulic coupler in order to bring it into its final position of connection to the manifold.

20 Moreover, the use of the telescopic arm mounted on the parallel robot can be envisaged in order to ensure compensation for the movements of two transfer arms arranged side by side.

As for the transfer arm, it can be a balanced arm on a single counterweight.

25 It will also be noted that the autonomous system for detecting initial coordinates (position, orientation, etc.) mentioned above is of the type of those described in the application EP 0 029 768.

30 The sensors which may equip the transfer arm (preferably its exterior end of the outer tube) with a view to acting on its commands in order to limit the loads exerted on the second ship can be for example force or acceleration sensors.

CLAIMS

1. A system (1) for transferring a fluid product, comprising a balanced arm (10) for transferring the fluid product, having a transfer compass (13, 14) comprising a transfer line having a line end fixed to a support and a movable line end (23) provided with a connect-disconnect device (12) adapted for the connection of the line to a target duct (24), characterized in that it further comprises a telescopic arm (25) which is adapted to be joined by one of its longitudinal ends to the movable line end (23) to move that end towards a position for connecting the connect-disconnect device (12) to the target duct (24) and which is mounted by its opposite longitudinal end on a parallel robot (25) controlled according to the detection of movements experienced by the target duct (24) to compensate for the movements of the target duct at the connect-disconnect device.

2. A system according to claim 1, characterized in that the parallel robot comprises a support on which is mounted the telescopic arm and actuators for moving the support with at least three degrees of freedom.

3. A system according to claim 2, characterized in that the parallel robot is in the form of a Stewart platform.

4. A system according to claim 2 or 3, characterized in that the actuators of the parallel robot are hydraulic, pneumatic or electrical jacks.

5. A system according to any one of the preceding claims, characterized in that it comprises a control system adapted to control the actuators of the parallel robot according to the signals received from detection means for detecting movements of the target duct relative to an item in the surroundings.

6. A system according to claim 5, characterized in that the detection means comprise a global positioning system, in particular of GPS type, an optical system, such as a camera or a laser or infrared system, an acceleration measuring system, an inertial stabilizing system for measuring angles, an autonomous system for detecting initial coordinates, or a combination of two or more of these systems.

7. A system according to claim 5 or 6, characterized in that the control system is adapted to process the signals received from the detection means by means of pre-programmed algorithms.

5 8. A system according to any one of claims 2 to 7, characterized in that the telescopic arm is pivotally mounted on the support so as to be able to raise or lower it.

9. A system according to any one of claims 1 to 8, characterized in that the telescopic arm is rigidly linked to the movable line end.

10 10. A system according to any one of claims 1 to 9, characterized in that it comprises a carriage movable in translation over an outer segment of the telescopic arm and which is adapted to be fastened to the movable line end.

11. A system according to any one of claims 1 to 10, characterized in that the transfer arm comprises at least three actuators each one to control the movement of the transfer arm with a degree of freedom according to a first
15 mode of operation, and is adapted to be set to coast according to a second mode of operation.

12. A system according to any one of claims 1 to 11, characterized in that the movable line end of the transfer arm comprises means for guiding and aligning the connect-disconnect device onto the target duct when it reaches the
20 immediate vicinity thereof.

13. A system according to any one of claims 1 to 12, characterized in that the transfer arm is equipped with sensors adapted to act on the movement controls of the arm for the purpose of limiting the loads applied to a ship bearing the target duct.

25 14. An assembly for fluid product transfer, comprising a transfer system according to any one of claims 1 to 13 and a target duct provided with a support member for the end of the telescopic arm located which is the near end to the movable line end.

30 15. A method of fluid transfer by means of a system according to any one of claims 1 to 13, comprising the following steps:

- bringing the telescopic arm towards the target duct, to reach a position spaced from the target duct;

- connecting the telescopic arm to the movable line end of the transfer arm;
 - setting the transfer arm to coasting mode; and
 - bringing the connect-disconnect device towards a position for
- 5 connection to the target duct by means of the telescopic arm.

16. A method according to claim 15, whereby the connect-disconnect device is moved, over a portion of final travel, by the sliding of a carriage on the telescopic arm.