

A coupling system, an assembly of a vessel and a coupling system, and an assembly of a coupling system, jacket pile and foundation pile

5 The present invention relates to a coupling system to be temporarily coupled to at least one of a jacket pile and a foundation pile, comprising an upper fixation member, a lower fixation member and a lifting device for moving the upper and lower fixation members with respect to each other.

10 Such a coupling system, which is also called a reusable jacket pile gripper, is known from EP 2 716 818 and can be used for installing offshore structures in the sea, such as offshore wind turbines. Such an offshore structure is anchored to the seabed by means of a jacket including tubular
15 jacket piles which are inserted into tubular foundation piles and fastened thereto. Usually three or four foundation piles are rammed into the seabed and the jacket with its tubular jacket piles is lowered onto the foundation piles by means of an appropriate lifting apparatus. After being introduced into
20 the seabed, the foundation piles may protrude from the seabed at different distances and orientations due to inaccuracies in the installation, which may require levelling of the jacket upon installing the jacket onto the foundation piles. A plurality of the known coupling systems can be used as
25 correcting devices for levelling a jacket with respect to the pre-installed foundation piles. Upper fixation members of the coupling systems are temporarily fixed to the respective jacket piles and lower fixation members of the coupling systems are temporarily fixed to corresponding foundation
30 piles. The upper and lower fixation members can be moved with respect to each other by the lifting device so as to level the jacket. After levelling, the jacket is permanently attached to

the foundation piles by means of a grouting action, in which spaces between the jacket piles and the foundation piles are filled with a grouting material.

5 An object of the invention is to provide a flexible coupling system.

This object is accomplished with the coupling system according to the invention, wherein the coupling system is provided with at least one of a grout transfer line for guiding grout from a grout supply to a space between a jacket
10 pile and a foundation pile upon installing the jacket pile to the foundation pile, and a cleaning device for cleaning the inner and/or outer side of a foundation pile, and a separating device for separating a jacket pile from a foundation pile upon de-installing the jacket pile with respect to the
15 foundation pile, and a measurement device for determining parameters of a jacket pile and/or a foundation pile. Since the fixation members can be temporarily fixed to the jacket piles and the foundation piles, the coupling system is reusable.

20 When the grout transfer line is part of the coupling system a grouting action can be performed relatively quickly since the grout transfer line is already at the desired location after the upper fixation member is fixed to a jacket pile and the lower fixation member is fixed to a corresponding
25 foundation pile upon installing the jacket pile onto a pre-installed foundation pile.

The cleaning device may be configured to clean the inner and/or outer side of the foundation pile to provide improved adherence of the grout to the foundation pile. For
30 example, the cleaning device may comprise one or more brushes.

In case of the presence of both a grout transfer line and a cleaning device, for example, the coupling system provides a flexible and multi-purpose system. Because of the presence of the grout transfer line and/or the cleaning device

at the coupling system separately lowering one or both of these items towards the seabed can be omitted, hence saving operating time.

The presence of a separating device in the coupling system provides the opportunity to use the coupling system for decommissioning a jacket, i.e. removing a jacket from its foundation piles at the end of its useful life.

The measurement device is configured to determine parameters of a jacket pile and/or a foundation pile, for example in case of inspection. Possible parameters to monitor during lifetime are marine growth on the jacket pile and/or foundation pile or material loss due to corrosion of the jacket pile and/or foundation pile.

In a practical embodiment the grout transfer line is located at one of the upper and lower fixation members. Upon installing a jacket onto foundation piles, a grouting tube can be connected to the grout transfer line before the upper fixation member is fixed to a jacket pile and lowered towards the seabed.

The grout transfer line may have a discharge opening which is located between the upper and lower fixation members such that the discharge opening is located at a transfer between a jacket pile and a foundation pile when the upper fixation member is fixed to a jacket pile and the lower fixation member is fixed to a foundation pile.

The separating device may comprise a cutting device for cutting at least one of a jacket pile and a foundation pile upon de-installing the jacket pile with respect to the foundation pile. Numerous alternative separating devices are conceivable.

In a practical embodiment the cutting device may be mounted to at least one of the upper and lower fixation members.

The cutting device may be rotatable with respect to the fixation members about an axis of rotation which is directed upwardly when the fixation members are located above each other. This provides the opportunity to guide the cutting device about a jacket pile and/or a foundation pile during cutting the jacket pile and/or the foundation pile.

In a particular embodiment one of the upper and lower fixation members comprises a circular guide along which the cutting device is drivable.

In a preferred embodiment the cutting device is located between the upper and lower fixation members, since the lifting device can move the upper and lower fixation members away from each other when they are fixed to the jacket pile and/or the foundation pile so as to reduce stress at the intended location of cutting, hence facilitating a cutting action.

In a preferred embodiment a lower side of the coupling system is provided with a tubular tapered element, which widens in a direction from the upper to the lower fixation member. This facilitates guiding of the coupling system onto the foundation pile when the coupling system is already coupled to the jacket pile and the jacket pile including the coupling system are directed towards the foundation pile in order to fit the jacket pile to the foundation pile.

The upper and lower fixation members may comprise respective grippers for clamping a jacket pile and a foundation pile, respectively.

In a particular embodiment each of the grippers has gripper arms and a pivot for rotating the gripper arms with respect to each other, wherein each of the grippers has a closed condition in which its gripper arms form a ring-shape and an open condition in which the gripper arms are moved outwardly with respect to each other.

At least one of the grout transfer line, the cleaning device, the separating device and the measurement device may be removably coupled to at least one of the upper and lower fixation members. This appears to be advantageous, since in case of installing a jacket, for example, the separating device is not necessary and in case of decommissioning a jacket, the grouting line is not necessary.

The invention is also related to an assembly of a vessel and a coupling system, wherein the coupling system has a gripper and the vessel comprises a hull and a holding cylinder which is mounted to the hull, wherein the gripper and the holding cylinder are adapted such that the gripper fits about the holding cylinder. The assembly provides the possibility for quickly and safely sea fastening the coupling system to the vessel.

More specifically the coupling system may be the coupling system as described hereinbefore, whereas the gripper is one of the upper and lower grippers.

The invention is also related to an assembly of a coupling system as described hereinbefore, a jacket pile and a foundation pile.

The invention will hereafter be elucidated with reference to very schematic drawings showing embodiments of the invention by way of example.

Fig. 1 is a cross-sectional view of an embodiment of a coupling system according to the invention.

Fig. 2 is a similar view as Fig. 1 of an alternative embodiment.

Fig. 3 is a top view of the embodiments of the coupling system as shown in Figs. 1 and 2.

Figs. 4-7 are perspective views of a jacket, foundation piles and an embodiment of the coupling system according to the invention, illustrating a manner of

installing the jacket onto the foundation piles by means of a plurality of the same coupling systems.

Figs. 8-11 are similar views as Fig. 4-7, but illustrating a manner of de-installing the jacket with respect to the foundation piles by means of a plurality of the same coupling systems.

Fig. 12 is a cross-sectional view of a part of an embodiment of an assembly of a vessel and a coupling system according to the invention.

Figs. 13 and 14 are similar views as Fig. 1, showing other alternative embodiments.

Fig. 15 is a similar view as Fig.3, showing an alternative embodiment.

Fig. 4 shows a jacket 1 to be installed onto foundation piles 2 which are pre-installed in a seabed. In the case as shown in Fig. 4 the foundation piles 2 are hollow cylinders including circular cross-sections. The jacket 1 has a central cylindrical support 3 which can be used for supporting a wind turbine after installing the jacket 1 on the seabed. The support 3 is fixed to three cylindrical jacket piles or jacket feet 4 via a frame 5. A different number of jacket feet 4 and corresponding number of foundation piles 2 is conceivable. The cylindrical jacket feet 4 have circular cross-sections and fit into the foundation piles 2. In order to compensate for possible deviations in location and orientation of the pre-installed foundation piles 2 the internal diameters of the foundation piles 2 are larger than the external diameters of the corresponding jacket feet 4 such that a space is left between the feet 4 and the respective foundation piles 2 after inserting the jacket feet 4 into the foundation piles 2. The space is filled with grout so as to fix the jacket 1 to the foundation piles 2.

Installation of the jacket 1 onto the foundation piles 2 can be easily performed by means of a number of

coupling systems 6 according to the present invention. An embodiment of one coupling system 6 is shown in Fig. 1. The coupling system 6 comprises an upper fixation member and a lower fixation member, which is located below the upper

5 fixation member under operating conditions. The upper fixation member is formed by an upper gripper 7 which has gripper arms 7a, 7b and a pivot 8, see Fig. 3. The pivot 8 serves to rotate the gripper arms 7a, 7b with respect to each other such that they can receive one of the jacket feet 4 when the upper

10 gripper 7 is in an open condition. In a closed condition of the upper gripper 7 the gripper arms 7a, 7b form a ring-shape and can surround one of the jacket feet 4. The gripper arms 7a, 7b can be locked with respect to each other in the closed condition by means of a lock 9. Each of the gripper arms 7a,

15 7b is provided with hydraulic cylinders 10 which are arranged such that in the closed condition of the upper gripper 7 they can exert a force in radial direction to a centreline of the ring-shaped gripper 7. Consequently, the upper gripper 7 can be temporarily fixed to one of the jacket feet 4. In order to

20 create a large opening in an open condition of the upper gripper 7 the gripper arms 7a, 7b have substantially the same dimensions and form semi-circular elements.

Similarly, the lower fixation member is formed by a lower gripper 11 which is also provided with gripper arms, a

25 pivot, a lock and hydraulic cylinders. In an open condition of the lower gripper 11 its gripper arms can receive one of the foundation piles 2. In a closed condition of the lower gripper 11 its gripper arms form a ring-shape and can surround the foundation piles 2, whereas the lower gripper 11 can be

30 temporarily fixed to one of the foundation piles 2 by activating its hydraulic cylinders. Fig. 1 shows that centerlines of the upper and lower grippers 7, 11 coincide.

The lock 9 allows the hydraulic cylinders to exert a clamping force onto the jacket feet 4 and the foundation pile

2 without opening the upper and lower grippers 7, 11, and also prevents the gripper arms 7a, 7b from automatic opening upon unexpected loss of hydraulic pressure loss in the hydraulic cylinders 10. This means that the coupling system 6 will not immediately sink to the seabed in case of emergency.

Fig. 15 shows an alternative embodiment of the coupling system 6. In this case, one of the gripper arms 7a of the upper gripper 7 has a U-shape which fits around a foundation pile 2 as well as a jacket foot 4. The other gripper arm 7b is a beam which is pivotable with respect to the U-shaped gripper arm 7a through the pivot 8 and can be locked with respect thereto through the lock 9. Similar as in the embodiment as shown in Fig. 3, the hydraulic cylinders 10 can exert a force in radial direction to a centreline of the ring-shaped gripper 7. Similarly, the lower gripper 11 may also be provided with gripper arms, a pivot, a lock and hydraulic cylinders. Alternatively, the beam 7b can be slidably mounted to the U-shaped gripper arm 7a rather than pivotably.

The functioning of the upper and lower grippers 7, 11 upon installing the jacket 1 to the foundation piles 2 is illustrated in Figs. 5-7. In the situation as shown in Fig. 5 the upper grippers 7 of three similar coupling systems 6 are fixed to the three jacket feet 4. The jacket 1 can be lowered towards the seabed and the jacket feet 4 can be inserted into the corresponding foundation piles 2 until the lower grippers 11 have passed respective upper ends of the foundation piles 2. Subsequently, the lower grippers 11 can be fixed to the respective foundation piles 2 by activating their hydraulic cylinders 10. As a result, each of the jacket piles 4 and the respective foundation piles 2 are mutually coupled. This condition is shown in Fig. 1.

Each of the coupling systems 6 also comprises a lifting system in the form of upwardly directed hydraulic

cylinders 12 for moving the upper and lower grippers 7, 11 with respect to each other in vertical direction. This provides the opportunity to adjust the height and orientation of the jacket 1 after the jacket feet 4 and the respective foundation piles 2 are mutually coupled with the coupling systems 6.

After levelling the jacket 1 the jacket feet 4 can be fixed to the foundation piles by inserting grout 13 in the existing space between the respective jacket feet 4 and foundation piles 2. For this reason the lower gripper 11 of the coupling system 6 is provided with a grout transfer line 14 for guiding grout 13 to that space. The grout transfer line 14 has a discharge opening 15 which is located between the upper and lower grippers 10, 11 and directed downwardly. The grout transfer line 14 is connected to a grouting tube 16 which extends from the lower gripper 11 in upward direction to a vessel (not shown) from which the grout 13 is supplied. Such a grouting action is illustrated in Fig. 6. The grouting tubes 16 can be coupled to the respective coupling systems 6 before the jacket 1 including the fixed coupling systems 6 is lowered towards the seabed.

After the grout 13 has been cured the gripper arms 7a, 7b of the upper gripper 7 and the gripper arms of the lower gripper 11 are moved outwardly with respect to each other such that the upper and lower grippers 10, 11 are in their open positions. Subsequently, the coupling systems 6 are moved away in lateral direction from the respective jacket feet 4 and foundation piles 2 to decouple the coupling system 6 therefrom. Fig. 7 shows the jacket 1 and foundation piles 2 in a fixed condition. The coupling systems 6 can be removed in order to install a next jacket 1.

Fig. 2 shows another embodiment of the coupling system 6. This embodiment has a lot of similarities to the embodiment as described hereinbefore, but it does not have a

grout transfer line and it is provided with a separating device in the form of a cutting device 17. Elements of this embodiment which are the same as the elements of the embodiment as described hereinbefore are indicated by the same reference numbers. The upper gripper 7 comprises a circular guide 18 to which the cutting device 17 is mounted. The cutting device 17 is drivable along the guide 18 such that it can cut a jacket foot 4 as illustrated in Figs. 2, 8 and 9. Prior to a cutting action three coupling system 6 can be lowered towards the seabed and the gripper arms of the upper and lower grippers 7, 11 are moved outwardly with respect to each other such that the upper and lower grippers 7, 11 are in their open positions. Subsequently, the coupling systems 6 are moved in lateral direction to the respective jacket feet 4 where the upper grippers 7 are fixed to the respective jacket feet 4 and the lower grippers 11 are fixed to the corresponding foundation piles 2. This situation is illustrated in Fig. 8. After finalizing the cutting action the jacket 1 is lifted from the foundation piles 2 and small pieces 4' of the respective jacket feet 4 remain fixed to the foundation piles 2, see Fig. 9.

It is also possible to fix the coupling system 6 at lower positions, for example at locations where the upper grippers 7 are also fixed to the foundation piles 2. This is illustrated in Fig. 10. In this situation the respective cutting devices 17 cut both the foundation piles 2 and the jacket feet 4. Fig. 11 illustrates that the jacket 1 can be lifted from the foundation piles 2 whereas pieces 2' of the respective foundation piles 2 are still fixed to the jacket feet 4. Similarly, both the upper and lower grippers 7, 11 may be fixed to the jacket feet 7 only before cutting the jacket feet 4.

A cutting action can be facilitated by moving the upper and lower grippers 7, 11 away from each other by the

hydraulic cylinders 12 when they are fixed to the jacket feet 4 and/or the foundation piles 2 such that stress at the intended location of cutting is minimized.

5 Figs. 1 and 2 show that the lower gripper 11 is provided with a tubular tapered element 22. When the coupling system 6 is already attached to the jacket pile 4 and the jacket pile 4 including the coupling system 6 are moved towards the foundation pile 2 in order to insert the jacket pile 4 into the foundation pile 2 they can be easily guided by 10 means of the tapered element 22.

The embodiments as shown in Figs. 1 and 2 and described hereinbefore may be integrated in one embodiment which is suitable for both a grouting action and a cutting action. For example, the embodiment of Fig. 1 is already 15 prepared for a cutting action by the presence of the guide 18 to which the cutting device 17 can be mounted.

Fig. 13 shows an embodiment wherein the coupling system 6 is provided with a cleaning device 23 for cleaning the inner and/or outer side of a foundation pile 2, for 20 example, before a grouting action will be started. In this case the cleaning device 23 makes use of the guide 18 which can also be used by the cutting device 17 as shown in Fig. 2. The cleaning device 23 may comprise brushes for locally cleaning the foundation pile 2 before grouting, but an 25 alternative cleaning device is conceivable, for example high pressure water jetting.

Fig. 14 shows another embodiment wherein the coupling system 6 is also provided with a measurement device 24 for determining parameters of a jacket pile 4 and/or a foundation 30 pile 2. The measurement device 24 may comprise one or more sensors for measuring local wall thicknesses of the jacket feet 4 and/or the foundation piles 2.

Fig. 12 shows a part of a vessel 19, which has a hull including a deck 20 on which holding cylinders 21 are

attached, for example by means of welding. The diameters of the holding cylinders 21 are in the same order of magnitude as the above-mentioned jacket feet 4 and foundation piles 2. Fig. 12 shows that the lower gripper 11 fits about the holding cylinder 21 in its closed condition. In case of transporting the coupling systems 6 to and from an offshore location the lower grippers 11 can be temporarily fixed to respective holding cylinders 21.

The invention is not limited to the embodiments shown in the drawings and described hereinbefore, which may be varied in different manners within the scope of the claims and their technical equivalents.

CLAIMS

1. A coupling system (6) to be temporarily coupled to at least one of a jacket pile (4) and a foundation pile (2), comprising an upper fixation member (7), a lower fixation member (11) and a lifting device (12) for moving the upper and lower fixation members (7, 11) with respect to each other, wherein the coupling system (6) is provided with at least one of

a grout transfer line (14) for guiding grout (13) from a grout supply to a space between a jacket pile (4) and a foundation pile (2) upon installing the jacket pile (4) to the foundation pile (2), and

a cleaning device (23) for cleaning the inner and/or outer side of a foundation pile (2), and

a separating device (17) for separating a jacket pile (4) from a foundation pile (2) upon de-installing the jacket pile (4) with respect to the foundation pile (2), and

a measurement device (24) for determining parameters of a jacket pile (4) and/or a foundation pile (2).

2. A coupling system (6) according to claim 1, wherein the grout transfer line (14) is located at one of the upper and lower fixation members (7, 11).

3. A coupling system (6) according to claim 1 or 2, wherein the grout transfer line (14) has a discharge opening (15) which is located between the upper and lower fixation members (7, 11).

4. A coupling system (6) according to any one of the preceding claims, wherein the separating device comprises a cutting device (17) for cutting at least one of a jacket pile (4) and a foundation pile (2) upon de-installing the jacket pile (4) with respect to the foundation pile (2).

5. A coupling system (6) according to claim 4, wherein the cutting device (17) is mounted to at least one of the upper and lower fixation members (7, 11).

6. A coupling system (6) according to claim 4 or 5, wherein the cutting device (17) is rotatable with respect to the fixation members (7, 11) about an axis of rotation which is directed upwardly when the fixation members (7, 11) are located above each other.

7. A coupling system (6) according to claim 6, wherein one of the upper and lower fixation members (7, 11) comprises a circular guide (18) along which the cutting device (17) is drivable.

8. A coupling system (6) according to any one of the claims 4-7, wherein the cutting device (17) is located between the upper and lower fixation members (7, 11).

9. A coupling system (6) according to any one of the preceding claims, wherein a lower side of the coupling system is provided with a tubular tapered element (22), which widens in a direction from the upper to the lower fixation member (7, 11).

10. A coupling system (6) according to any one of the preceding claims, wherein the upper and lower fixation members comprise respective grippers (7, 11) for clamping a jacket pile (4) and a foundation pile (2), respectively.

11. A coupling system (6) according to claim 10, wherein each of the grippers has gripper arms (7a, 7b) and a pivot (8) for rotating the gripper arms (7a, 7b) with respect to each other, wherein each of the grippers (7, 11) has a closed condition in which its gripper arms (7a, 7b) form a ring-shape and an open condition in which the gripper arms (7a, 7b) are moved outwardly with respect to each other.

12. A coupling system (6) according to any one of the preceding claims, wherein at least one of the grout transfer line (14), the cleaning device (23), the separating

device (17) and the measurement device (24) is removably coupled to at least one of the upper and lower fixation members (7, 11).

13. An assembly of a coupling system according to any one of the claims 1-12, a jacket pile (4) and a foundation pile (20).