(19) DANMARK

(10) **DK/EP 2913439 T3**

Patent- og
Varemærkestyrelsen

(12) # Oversættelse af europæisk patentskrift

(51) Int.Cl.: ***E 02 D 7/20 (2006.01)***

(45) Oversættelsen bekendtgjort den: **2017-02-20**

(80) Dato for Den Europæiske Patentmyndigheds
bekendtgørelse om meddelelse af patentet: **2016-11-09**

(86) Europæisk ansøgning nr.: **15156799.7**

(86) Europæisk indleveringsdag: **2015-02-26**

(87) Den europæiske ansøgnings publiceringsdag: **2015-09-02**

(30) Prioritet: **2014-02-28 BE 201400139**

(84) Designerede stater: **AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR**

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(54) Benævnelse: **Apparat og fremgangsmåde til anbringelse af fundamentspæle i en bund under vand**

(56) Fremdragne publikationer:
GB-A- 2 309 246
US-A- 4 378 178
WO-A1-2013/049194

DESCRIPTION

FIELD OF THE INVENTION

[0001] The invention relates to a device for carrying under water a positioning framework which is configured to arrange foundation piles ordered in a geometric pattern in an underwater bottom. The invention likewise relates to a method for arranging foundation piles in an underwater bottom.

BACKGROUND OF THE INVENTION

[0002] The invention will be elucidated hereinbelow with reference to an offshore wind turbine. The reference to a wind turbine does not imply that the invention is limited to the use in the context of such a wind turbine. The device and the method can likewise be applied on any other structure, such as jetties, radar and other towers, platforms and the like. The support structure of a wind turbine normally has a slender design, for instance in the form of a tube or pillar. This pillar structure has to be coupled to a foundation in the bottom. For offshore wind turbines, which are placed in relatively shallow water, it is possible to make use of one mast extending from the machinery housing of the wind turbine to the foundation. In addition to such a mono-pole construction, the support structure of an offshore wind turbine can also comprise a tubular upper part and a lower part in the form of a lattice structure, also referred to as a jacket. A large part of the jacket extends underwater, where the jacket finds support on a foundation arranged in the underwater bottom.

[0003] A known method for arranging foundation piles in an underwater bottom makes use of an offshore platform which is fixed relative to the underwater bottom by means of spud poles resting on the underwater bottom. A positioning framework is then lowered onto the underwater bottom from the platform. A known positioning framework comprises mutually connected guide tubes for foundation piles arranged in a geometric pattern. The foundation piles are then carried through the guide tubes using a lifting crane present on the platform and driven into the underwater bottom using for instance pile-driving means. Once all the foundation piles have been arranged in the underwater bottom the jacket is arranged on the formed foundation by arranging legs of the jacket in the piles (also referred to as pin piling) or around the piles (also referred to as sleeve piling). The foundation piles and the legs of the jacket are configured to bring about a mutual connection. Hollow foundation piles are for instance thus provided in the case of pin piling, and hollow legs of the jacket in the case of sleeve piling.

[0004] It is of great importance to arrange the foundation piles at the correct positions in the underwater bottom and to ensure that the foundation piles are arranged in the underwater bottom at a precisely determined angle. It is thus only possible in many cases to allow a maximum angular deviation of 1° relative to the vertical direction. Use is therefore made in the known method of a platform and positioning framework resting on the underwater bottom, (see for example document US 4 378 178 A).

[0005] The known method is however less suitable when a foundation has to be formed in a relatively weak underwater bottom. Due to a reduced load-bearing capacity of at least an upper layer of the underwater bottom there is a risk of platform and/or positioning framework sinking into the top layer, which is undesirable, particularly during pile-driving.

[0006] The invention has for its object to provide a device and method for arranging foundation piles in accurate manner in an underwater bottom with reduced load-bearing capacity.

SUMMARY OF THE INVENTION

[0007] The invention provides for this purpose a device for carrying under water a positioning framework which is configured to arrange foundation piles ordered in a geometric pattern in an underwater bottom, the device comprising a floating body with sufficient buoyancy to float on a water surface and provided with anchor means which can hold the floating body in position relative to the underwater bottom, and an elongate guide construction for the positioning framework which is connected to the floating body and lowerable onto the underwater bottom, wherein the guide construction comprises on an underside thereof a support means which fixes the underside in the underwater bottom and allows a rotation around an axis running perpendicularly of a longitudinal axis of the guide construction.

[0008] The floating body not only imparts buoyancy to the positioning framework, whereby the positioning framework can be transported relatively easily in floating manner to a desired location, but also allows the positioning framework to be positioned at different depths under water using the guide construction. It is thus possible for instance to carry the positioning framework to a small height above the underwater bottom without it supporting on the underwater bottom. In order to enable accurate positioning of the positioning framework it is no longer necessary according to the invention to have the positioning framework rest on the underwater bottom. With the invented positioning framework it becomes possible to arrange foundation piles in an underwater bottom with at least an upper layer which has relatively little load-bearing capacity. Possible sinking of a positioning framework placed on an underwater bottom is likewise reduced or even prevented.

[0009] An embodiment according to the invention provides a device in which a positioning framework is connected rigidly to the guide construction and is located under the floating body.

[0010] Another embodiment according to the invention relates to a device wherein a positioning framework is connected to the guide construction for displacement along the longitudinal axis of the guide construction, and is located under the floating body.

[0011] In yet another embodiment of the device according to the invention the guide construction is connected to the floating body by means of a connection pivoting around an axis running perpendicularly of a longitudinal axis of the guide construction.

[0012] A further embodiment relates to a device wherein the guide construction is connected to the floating body by means of a connection pivoting around two axes running perpendicularly of a longitudinal axis of the guide construction.

[0013] It is advantageous according to an embodiment of the invention to provide a device wherein the guide construction is connected to the floating body by means of a connection which allows substantially no rotation of the guide construction relative to the floating body around an axis running parallel to the longitudinal axis of the guide construction.

[0014] It can also be desirable in yet another embodiment for the device to be characterized in that the guide construction is connected to the floating body in a central position of a work deck of the floating body.

[0015] A further embodiment relates to a device wherein the support means of the guide construction allows a rotation around two axes running perpendicularly of the longitudinal axis of the guide construction.

[0016] In another embodiment the anchor means are configured to rotate the guide construction around an axis perpendicularly of a longitudinal axis of the guide construction.

[0017] A suitable embodiment comprises here a device wherein the anchor means comprise traction cables which are provided with anchors and which can be tightened by means of winches mounted on the floating body, and the resultant of the traction cable stresses does not pass through the longitudinal axis of the guide construction. The floating body - and hereby also the guide construction - can hereby be rotated around a vertical axis.

[0018] In order to support and anchor the device in the underwater bottom the support means has in an embodiment a conical contact surface with the underwater bottom. In another, likewise suitable, embodiment the support means comprises a spherical contact surface with the underwater bottom. Such support means allow the guide construction to be anchored to the underwater bottom in a manner such that a rotation of the guide construction relative to the underwater bottom remains possible, wherein soil displacement is limited but a translation is substantially avoided.

[0019] In an embodiment the positioning framework comprises mutually connected guide tubes for the foundation piles arranged in the geometric pattern. The dimensions of the positioning framework in the plane are in principle larger than the dimensions out of the plane, wherein the direction out of the plane corresponds to a direction parallel to the lowering direction of the positioning framework. The guide tubes are adapted to receive and guide the foundation piles to be arranged in the underwater bottom and preferably comprise cylindrical casings, the longitudinal axis of which runs parallel to the direction of the positioning framework out of the plane. The guide tubes are arranged in a geometric pattern, wherein this pattern corresponds to the desired geometric pattern of the foundation piles. Tubular lattice elements extending between the guide tubes and optionally the guide construction ensure that the guide tubes remain in position during raising and lowering of the positioning framework. It is optionally possible to make the positioning framework geometrically adjustable, for instance by applying lattice elements adjustable in length.

[0020] In an embodiment the longitudinal axis of the guide construction extends substantially parallel to a central axis of the guide tubes.

[0021] In an embodiment the positioning framework comprises measuring means configured to determine the inclination of the positioning framework and/or the height position of foundation piles arranged in the underwater bottom. It is also possible to equip the positioning framework with drive means such as for instance thrusters in order to enable accurate positioning.

[0022] Another embodiment relates to a positioning framework wherein the guide tubes comprise an elongate body of a length such that they extend above the water surface during use. This embodiment has the advantage that it becomes simpler, from a floating body and with the positioning framework in an immersed operating position, to guide the foundation piles through the guide tubes. The tops of the guide tubes will after all be visible to an operator of a lifting crane with which the foundation piles are placed.

[0023] In a further preferred embodiment a positioning framework is provided according to the invention wherein the guide tubes are sound-damping. This can for instance be achieved by giving the guide tubes a double-walled form and introducing air between or along the two walls, preferably from below. The thus created air bubble curtain ensures that the sound waves occurring during arranging of the foundation piles in the underwater bottom are damped. This is favourable for organisms living in the surrounding area. In this embodiment the guide tubes preferably extend from the underwater bottom to a position above the water surface.

[0024] The invention likewise relates to a method for arranging in an underwater bottom foundation piles ordered in a geometric pattern for the purpose of manufacturing a foundation for a mass located at height, such as the jacket of a wind turbine or a jetty. The invented method comprises the steps of providing a device according to the invention; holding the floating body in position relative to the underwater bottom by means of the anchor means; lowering a positioning framework connected to the guide construction in the direction of the underwater bottom to an operating position, wherein the support means fixes the underside of the guide construction in the underwater bottom; and driving the piles into the underwater bottom through the guide tubes of the positioning framework in the operating position. The desired position of at least one foundation pile is generally determined beforehand, and the positioning framework is positioned using the floating body and the anchor means such that at least one guide tube of the positioning framework is situated directly above said pile position.

[0025] In an embodiment of the method the positioning framework is connected rigidly to the guide construction and is situated under the floating body, and the guide construction is lowered into the operating position. In an alternative embodiment of the method the positioning framework is situated under the floating body and is displaced along the longitudinal axis of the guide construction into the operating position.

[0026] Provided in yet another embodiment is a method wherein the guide construction is aligned substantially vertically in the operating position by displacing the floating body, wherein the guide construction is rotated relative to the connection to the floating body around an axis running perpendicularly of the longitudinal axis of the guide construction.

[0027] Another embodiment provides a method wherein the guide construction is aligned substantially vertically in the operating position by displacing the floating body, wherein the guide construction is rotated relative to the connection to the floating body around two axes running perpendicularly of the longitudinal axis of the guide construction.

[0028] It is advantageous when according to an embodiment the guide construction is not rotated relative to the floating body around an axis running parallel to the longitudinal axis of the guide construction. The guide construction can hereby be rotated in simple manner around the associated axis by rotating the floating body around this axis. This can be achieved for instance with an embodiment wherein the guide construction is rotated by means of the anchor means around an axis running perpendicularly of a longitudinal axis of the guide construction.

[0029] The arranging of a first pile through the at least one guide tube fixes the positioning framework. In a fixed position the guide tubes for the other piles will automatically be located in their correct positions because their relative positions are determined by the geometric design of the positioning framework. A position determination for each individual pile is hereby no longer necessary.

[0030] The foundation piles can be arranged in the underwater bottom in any manner, such as for instance by means of a pneumatic or hydraulic hammer, generally from the floating device.

[0031] Once the foundation piles have been arranged in the underwater bottom, the positioning framework can if desired be removed by being lifted with lifting means present on the floating device, but preferably by raising the positioning framework with a hoisting system associated with the guide construction, or raising it simultaneously with the guide construction. The positioning framework can then be transported away together with the floating body in floating state.

[0032] The invention further relates to a method for installing on a foundation a mass located at height, such as the jacket of a wind turbine or a jetty, wherein the foundation comprises a number of foundation piles arranged by means of the above described method in an underwater bottom, the method comprising of arranging legs of the mass located at height into or around the piles, and anchoring the legs to the foundation piles by means of grouting.

[0033] The method according to the invention is particularly suitable for application with cylindrical (optionally) hollow foundation piles having an outer diameter of at least 1.2 m, more preferably at least 1.5 m, and most preferably at least 1.8 m, and with an (optional) wall thickness of 0.01 to 0.1 m, more preferably of 0.02 to 0.08 m, and most preferably of 0.04 to 0.06 m.

[0034] The method according to the invention is further particularly suitable for cylindrical (hollow) foundation piles with a length of more than 20 m, more preferably at least 25 m and most preferably at least 30 m, and a weight of 20 to 250 tonnes, more preferably of 60 to 200 tonnes and most preferably of 75 to 180 tonnes.

BRIEF DESCRIPTION OF THE FIGURES

[0035] The invention will now be elucidated in more detail with reference to the drawings, without otherwise being limited thereto. In the figures:

Fig. 1 is a schematic perspective view of an embodiment of the device according to the invention;

Fig. 2 is a schematic top view of the embodiment of the device according to the invention shown in figure 1;

Fig. 3 is a schematic side view in the Y-direction of the embodiment of the device according to the invention shown in figure 1;

Fig. 4 is schematic side view in the X-direction of the embodiment of the device according to the invention shown in figure 1;

Fig. 5 is a schematic perspective view of another embodiment of the device according to the invention;

Fig. 6 is a schematic top view of the embodiment of the device according to the invention shown in figure 5;

Fig. 7 is a schematic side view in the Y-direction of the embodiment of the device according to the invention shown in figure 5;

Fig. 8 is a schematic side view in the X-direction of the embodiment of the device according to the invention shown in figure 5; and

Fig. 9 shows schematically a jacket of a wind turbine placed according to the invention on a foundation of piles.

DETAILED DESCRIPTION OF EMBODIMENTS

[0036] Shown with reference to figure 1 is an embodiment of a device 10 according to the invention. Device 10 is suitable for carrying a positioning framework 1 under water.

[0037] Foundation piles 40 ordered in a geometric pattern can be arranged in an underwater bottom 30 with positioning framework 1.

[0038] The shown embodiment of device 10 comprises a floating body in the form of a pontoon, or the shown combi-float 11, which is assembled from a number of (21) pontoons connected together. The chosen dimensions of combi-float 11 in transverse directions X and Y are smaller than the transverse distance between guide tubes (2a, 2b, 2c, 2d) of positioning framework 1. Combi-float 11 further has sufficient buoyancy to float on a water surface 32 during use. Combi-float 11 can be carried to a desired location by a vessel using towing cables 28. Combi-float 11 is provided with anchor means in the form of four traction cables 12, which are provided at an outer end with anchors (not shown) for engagement with underwater bottom 30. Traction cables 12 can be tightened by means of winches 14 present on a work deck 13 of combi-float 11, whereby combi-float 11 can be displaced over water surface 32 in the transverse directions X and Y. In order to also enable rotation of combi-float 11 around an axis running in vertical direction Z the resultant of the traction cable stresses preferably does not pass through the geometric centre of work deck 13 of combi-float 11. Combi-float 11 can be held in position relative to underwater bottom 30 by tightening all traction cables 12.

[0039] Device 10 further comprises an elongate guide construction for a positioning framework 1. The guide construction takes the form of a guide pillar 15 which is connected to combi-float 11 and which can be lowered onto underwater bottom 30, and can likewise be raised, by means of a jack-up device 16 or other lifting device. Guide pillar 15 comprises on an underside thereof a support base 17 for supporting on underwater bottom 30. In the embodiment shown in figures 1-4 support base 17 has a spherical contact surface 17a (in the form of a spherical segment) with underwater bottom 30. An upper part 17b of support base 17 takes a conical form, wherein this upper part 17b widens in the direction of underwater bottom 30 in order to provide sufficient support surface. The spherical contact surface 17a on the one hand provides sufficient fixation of the underside of guide pillar 15 to underwater bottom 30, but allows on the other a rotation of guide pillar 15 around axes X and Y running perpendicularly of a longitudinal axis 15a of guide pillar 15. A rotation Ry around the Y-axis is shown in figure 3, while figure 4 shows a rotation Rx around the X-axis. The rotations Rx and Ry can be obtained by tightening and/or paying out some traction cables 12, whereby combi-float 11 is displaced through a relatively small distance and guide pillar 15 rotates around the X-axis and/or the Y-axis. Guide pillar 15 can in this way be placed in a precisely determined vertical position, wherein longitudinal axis 15a runs parallel to the vertical direction Z.

[0040] The support means of the guide construction, in particular support base 17 of guide pillar 15, is preferably embodied with a hollow inner space to which a medium with a lower density than water (for instance air) can be supplied so as to be able to increase the buoyancy of the guide construction.

[0041] Guide pillar 15 is connected to combi-float 11 at a central position on work deck 13 of combi-float 11. Work deck 13 of combi-float 11 is provided for this purpose with a central opening 18 which provides access to the water mass and through which guide pillar 15 runs. In the embodiment shown in figure 1 guide pillar 15 is in a lowered operating position, wherein only a small part of guide pillar 15 still protrudes above work deck 13 and the greater part extends via opening 18 to a position below water surface 32.

[0042] The connection of guide pillar 15 to combi-float 11 comprises an outer frame 19a which is arranged round the peripheral surface of guide pillar 15 and which can rotate around the Y-axis around a pivot shaft 18b mounted on edges of opening 18 via supports 18a. The connection further comprises an inner frame 19b which is arranged round the peripheral surface of guide pillar 15 and which can rotate around the X-axis around a pivot shaft 18c mounted in outer frame 19a. Jack-up device 16 engages on the peripheral surface of guide pillar 15 and supports on inner frame 19b. It will be apparent that there are other possible embodiments for configuring the cardan coupling between guide pillar 15 and combi-float 11. The described cardan coupling allows guide pillar 15 to rotate around two axes X and Y running perpendicularly of longitudinal axis 15a of guide pillar 15.

[0043] As shown in figure 1 the connection (18a, 18b, 18c, 19a, 19b) between guide pillar 15 and combi-float 11 is configured such that it allows substantially no rotation of guide pillar 15 around an axis Z running parallel to longitudinal axis 15a of guide pillar 15.

[0044] Such a movement of guide pillar 15 can be realized by rotating combi-float 11 around an axis running in vertical direction Z using traction cables 12 as already noted above.

[0045] According to the embodiment shown in figures 1-4, a positioning framework 1 is connected rigidly to guide pillar 15, this such that positioning framework 1 is located under combi-float 11. A positioning framework 1 according to the invention comprises four cylindrical guide tubes (2a, 2b, 2c, 2d) placed at corner points and configured to receive and guide a pile 40. Guide tubes (2a, 2b, 2c, 2d) are connected rigidly to the conical upper part 17b of support base 17 by lattices (3a, 3b, 3c, 3d) constructed from tubular structural elements. Cross braces (4a, 4b) between the lattices (3a, 3b, 3c, 3d) provide additional structural stiffness, wherein the cross braces are provided if desired with female docking stations (5a, 5b) which co-act with male docking stations (20a, 20b) provided on an underside of combi-float 11 for the purpose of docking positioning framework 1 in a rest position against the underside of combi-float 11. The longitudinal axis 15a of guide pillar 15 extends substantially parallel to a central axis of guide tubes (2a, 2b, 2c, 2d).

[0046] Guide tubes (2a, 2b, 2c, 2d) are held in a fixed position relative to each other by side lattices (3a, 3b, 3c, 3d) and cross braces (4a, 4b), this such that guide tubes (2a, 2b, 2c, 2d) are arranged in a geometric pattern, this pattern being in the embodiment shown in figure 1 a quadrilateral with a side of for instance 20 m. Any other geometric pattern is however possible, such as a triangle or other polygon, or for instance a circle. Each guide tube (2a, 2b, 2c, 2d) can if desired be supported by a foot (not shown) and extend above water surface 32 during use. Guide tubes (2a, 2b, 2c, 2d) can also take a sound-damping form, which can for instance be achieved by giving the tubes (2a, 2b, 2c, 2d) a double-walled form and introducing air between the two walls from below. Guide tubes (2a, 2b, 2c, 2d) are further preferably provided on an upper side with inlet funnels (6a, 6b, 6c, 6d) for a pile 40 to be received.

[0047] Shown with reference to figures 5-8 is another embodiment of device 10 according to the invention. The reference numerals stated in figures 5-8 designate the same components as in figures 1-4 and reference is made to the description of figures 1-4 for a description of these components, to the extent the components do not differ appreciably. The shown embodiment of device 10 comprises a floating body in the form of a circular pontoon 21, the chosen diameter of which is smaller than the transverse distance between guide tubes (2a, 2b, 2c, 2d) of positioning framework 1. Pontoon 21 has sufficient buoyancy to float on a water surface 32 during use. Pontoon 21 is further provided with anchor means in the form of four traction cables 12 which can be tightened by means of winches 14 present on a work deck 13 of pontoon 21, whereby pontoon 21 can be displaced in transverse directions X and Y over water surface 32. In order to enable rotation of pontoon 21 round an axis running in vertical direction Z, the resultant of the traction cable stresses preferably does not pass through the geometric centre of work deck 13 of pontoon 21. Pontoon 21 can be held in position relative to underwater bottom 30 by tightening all traction cables 12.

[0048] Device 10 further comprises a guide pillar 15 for a positioning framework 1, which guide pillar 15 is connected to pontoon 21 and can be lowered onto underwater bottom 30, and can likewise be raised, by means of a jack-up device 16 or other lifting device. Guide pillar 15 comprises on an underside thereof a conical contact surface 27 with underwater bottom 30, whereby the underside of guide pillar 15 penetrates partially into underwater bottom 30 and wherein contact surface 27 tapers in the direction of underwater bottom 30.

[0049] The conical contact surface 27 on the one hand provides sufficient fixation of the underside of guide pillar 15 to underwater bottom 30, but on the other allows a rotation of guide pillar 15 around axes X and Y running perpendicularly of a longitudinal axis 15a of guide pillar 15. A rotation Ry around the Y-axis is shown in figure 7, while figure 8 shows a rotation Rx around the X-axis. The rotations Rx and Ry can be obtained by tightening and/or paying out traction cables 12, whereby pontoon 21 is displaced through a relatively small distance and guide pillar 15 rotates around the X-axis and/or the Y-axis. Guide pillar 15 can in this way be placed in a precisely determined vertical position, wherein longitudinal axis 15a runs parallel to the vertical direction Z.

[0050] At variance with the embodiment described in figures 1-4, positioning framework 1 is connected for displacement along the longitudinal axis 15a of guide pillar 15 to pontoon 21, wherein positioning framework 1 is situated under pontoon 21. Positioning framework 1 can for this purpose be lowered or raised along the peripheral surface of guide pillar 15 by means of a central sleeve 22, which encloses guide pillar 15 in sliding manner, using a system 24 of hoisting cables and pulleys, this system 24 being connected on one side to positioning framework 1 by means of pulleys 25 and on another side to pontoon 21 by means of pulleys 26. Figures 5 and 7 show both a raised rest position, in which positioning framework 1 is located against pontoon 21, and an operating position in which positioning framework 1 is located in the vicinity of underwater bottom 30.

[0051] Guide pillar 15 is connected to pontoon 21 in a central position of work deck 13 of pontoon 21 by means of the cardan suspension (18a, 18b, 18c, 19a, 19b) which has already been described above and which is arranged in a central opening 18 which provides access to the water mass and through which guide pillar 15 runs. The cardan coupling allows guide pillar 15 to rotate around two axes X and Y running perpendicularly of longitudinal axis 15a of guide pillar 15.

[0052] As shown in figure 5, the connection (18a, 18b, 18c, 19a, 19b) between guide pillar 15 and pontoon 21 is configured such that it allows substantially no rotation of guide pillar 15 around an axis Z running parallel to longitudinal axis 15a of guide pillar 15. Such a movement of guide pillar 15 can be realized by rotating pontoon 21 around an axis running in vertical direction Z using traction cables 12, as already noted above.

[0053] The positioning framework 1 shown in figures 5-8 comprises four cylindrical guide tubes (2a, 2b, 2c, 2d) placed at corner points and configured to receive and guide a pile 40. Guide tubes (2a, 2b, 2c, 2d) are connected rigidly to central sleeve 22 and to each other by a lattice constructed from tubular structural elements. The lattice is provided if desired with female docking stations (5a, 5b) which co-act with male docking stations (20a, 20b) provided on an underside of pontoon 21 for the purpose of docking positioning framework 1 against the underside of combi-float 11 in a rest position. Longitudinal axis 15a of guide pillar 15 extends substantially parallel to a central axis of guide tubes (2a, 2b, 2c,2d).

[0054] Guide tubes (2a, 2b, 2c, 2d) are held in a fixed position relative to each other by the lattice, this such that guide tubes (2a, 2b, 2c, 2d) are arranged in a geometric pattern, this pattern being a quadrilateral in the embodiment shown in figure 1. In this embodiment each guide tube (2a, 2b, 2c, 2d) can if desired also be supported by a foot (not shown) and extend above water surface 32 during use. Guide tubes (2a, 2b, 2c, 2d) can also take a sound-damping form. Guide tubes (2a, 2b, 2c, 2d) are further provided on an upper side with inlet funnels (6a, 6b, 6c, 6d) for a pile 40 to be received.

[0055] In an embodiment of the method according to the invention a floating device (not shown) is provided in the vicinity of pontoon 21 or combi-float 11. The floating device is provided with hoisting means (not shown) in the form of a lifting crane with which foundation piles 40 to be arranged in the underwater bottom from a rack can be suspended in vertical position above a guide tube (2a, 2b, 2c, 2d) of positioning framework 1.

[0056] Guide pillar 15 is first lowered from pontoon 21 or combi-float 11 until contact surface (17a, 27) of guide pillar 15 has penetrated at least partially into underwater bottom 30. In the embodiment shown in figures 1-4 positioning framework 1 descends here together with guide pillar 15 from a rest position to an operating position in the vicinity of underwater bottom 30. Guide pillar 15 is then brought into a substantially vertical position by slightly displacing the pontoon 21 or combi-float if desired in the transverse directions X and Y, wherein guide pillar 15 rotates around its contact surface (17a, 27) with underwater bottom 30. Positioning frame 1 is simultaneously hereby aligned substantially horizontally. Once guide pillar 15 has been brought into the desired position, in the embodiment shown in figures 5-8 positioning frame 1 is lowered via hoisting system 24 into the vicinity of or onto underwater bottom 30 in an operating position. Positioning frame 1 can in this way be placed precisely in the desired operating position relative to underwater bottom 30.

[0057] Once positioning frame 1 has been positioned on or preferably at a certain height above underwater bottom 30 as according to the above described embodiments, foundation piles 40 are placed through guide tubes (2a, 2b, 2c, 2d) of positioning frame 1 into the position of use in bottom 30. This can take place for instance by a foundation pile 40 being picked up by the lifting crane from a storage rack located on work deck 13 and being lowered until the underside of pile 40 is located at the level of the upper side of one of the guide tubes (2a, 2b, 2c, 2d), and subsequently being lowered therein and being carried into underwater bottom 30 under its own weight, in which process foundation pile 40 is guided through the associated guide tube. Pile 40 is then driven further into underwater bottom 30 until the top of foundation pile 40 has penetrated far into the guide tube. Foundation pile 40 can for instance be driven into bottom 30 by means of a hydraulic hammer.

[0058] The above described sequence of method steps is then repeated a number of times, depending on the desired number of foundation piles 40 which must be arranged in underwater bottom 30. Because guide tubes (2a, 2b, 2c, 2d) of positioning frame 1 are automatically situated in the correct positions, all piles can be driven in efficient manner into bottom 30 without losing time in determining the position for each individual pile. Because device 10, and therefore also positioning frame 1, has buoyancy, this frame 1 need not rest on underwater bottom 30 during arranging of foundation piles 40 in underwater bottom 30. This avoids positioning framework 1 sinking into the upper layer of underwater bottom 30.

[0059] Once all foundation piles 40 have been arranged in underwater bottom 30, positioning frame 1 can optionally be removed by raising positioning framework 1 by means of hoisting system 24 and/or by means of raising guide pillar 15. Support base 17 can if desired be filled with air here. The buoyancy of positioning framework 1 is hereby reduced, whereby it will make its way more easily to water surface 32. Prior to removal of positioning framework 1 the position of foundation piles 40 and/or the vertical position of the top of each of the foundation piles 40 can if desired be checked using optical means suitable for the purpose, such as cameras.

[0060] Referring to figure 9, a jacket 150 of a wind turbine 151 can be placed on the foundation realized as described above. This can take place for instance by arranging legs 152 of jacket 150 in or around piles 40 and anchoring the legs 152 to piles 40 by means of grouting.

[0061] The device and method according to the invention allow a pile foundation to be provided in efficient manner in an underwater bottom, at least an upper layer of which has a reduced load-bearing capacity.

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- US4378178A [0004]

Patentkrav

1. Apparat (10) til transport under vand af et rammeværk (1), og som er således udformet, at det kan positionere fundamentspæle (40) i et geometrisk mønster på en under vand stående bund (30), hvilket apparat (10) omfatter et flydende legeme (11), som har tilstrækkelig flydeevne til at kunne flyde på en vandoverflade (32), og som er forsynet med forankringsorganer (12), som kan holde det flydende legeme (11) i stilling i forhold til den under vand stående bund (30), og en aflang føringskonstruktion (15) til positionering af rammeværket (1) – som er forbundet med det flydende legeme (11) – og som kan sænkes ned på den under vand stående bund, **kendetegnet ved, at** føringskonstruktionen på sin underside omfatter et understøtningsorgan (17), som kan fastgøre en underside til den under vand stående bund (30), og som tillader en drejning omkring en akse (x, y), der forløber vinkelret på en længdeakse (15a) i føringskonstruktionen (15).

2. Apparat ifølge krav 1, det positionerende rammeværk er stift forbundet med føringskonstruktionen og anbragt under det flydende legeme.

3. Apparat ifølge krav 1, hvor det positionerende rammeværk er forbundet med føringskonstruktionen med henblik på at kunne forskydes langs føringskonstruktionens længdeakse og er anbragt under det flydende legeme.

4. Apparat ifølge ethvert af de foregående krav, hvor føringskonstruktionen er forbundet med det flydende legeme ved hjælp af en forbindelse, som kan dreje omkring en akse, der forløber vinkelret på en længdeakse i føringskonstruktionen.

5. Apparat ifølge krav 4, hvor føringskonstruktionen er forbundet med det flydende legeme ved hjælp af en forbindelse, som kan dreje omkring to akser, der forløber vinkelret på en længdeakse i føringskonstruktionen.

6. Apparat ifølge ethvert af de foregående krav, hvor føringskonstruktionen er forbundet med det flydende legeme ved hjælp af en forbindelse, som tillader i hovedsagen ingen rotation af føringskonstruktionen i forhold til det flydende legeme, omkring en akse parallelt med længdeaksen for føringskonstruktionen.

7. Apparat ifølge ethvert af de foregående krav, hvor føringskonstruktionen er forbundet med det flydende legeme i en central stilling af et arbejdsdæk på det flydende legeme.

8. Apparat ifølge ethvert af de foregående krav, hvor understøtningsorganet på føringskonstruktionen tillader en rotation omkring to akser, som forløber vinkelret på længdeaksen i føringskonstruktionen.

9. Apparat ifølge ethvert af de foregående krav, hvor forankringsorganerne er således udformet, at de kan dreje føringskonstruktionen omkring en akse vinkelret på føringskonstruktionens længdeakse.

10. Apparat ifølge krav 9, hvor forankringsorganerne omfatter trækkabler, som er forsynet med ankre, og som kan strammes ved hjælp af spil, der er monteret på det flydende legeme, og hvor resultanten af trækkablernes spændinger ikke går gennem længdeaksen for føringskonstruktionen.

11. Apparat ifølge ethvert af de foregående krav, hvor understøtningsorganet omfatter en konisk berøringsflade vis-a-vis den under vand stående bund.

12. Apparat ifølge ethvert af de foregående krav, hvor understøtningsorganet omfatter en kugleformet berøringsflade vis-a-vis den under vand stående bund.

13. Apparat ifølge krav 2 eller 3, hvor det positionerende rammeværk omfatter indbyrdes forbundne føringsrør for funderingsrør, som er anbragt i et geometrisk mønster.

14. Apparat ifølge krav 13, hvor længdeaksen i føringskonstruktionen strækker sig i hovedsagen parallelt med en central akse i føringsrørene.

15. Apparat ifølge krav 13 eller 14, hvor føringsrørene omfatter et aflangt legeme med en sådan længde, at de under brugen kan strække sig op over vandoverfladen.

16. Apparat ifølge ethvert af kravene 13-5, hvor føringsrørene er lyddæmpende.

17. Fremgangsmåde til på en bund under vand at anbringe fundamentspæle i et geometrisk mønster, og som omfatter følgende trin:

- at man tilvejebringer et apparat som ifølge ethvert af de foregående krav;
- at man holder det flydende legeme i stilling i forhold til den under vand stående bund ved hjælp af ankerorganerne;
- at man sænker et positionerende rammeværk i retning af den under vand stående bund, og dette til en driftsstilling, hvor understøtningsorganet fastgør undersiden af føringskonstruktionen til den under vand stående bund; og
- at man driver pælene ned i den under vand stående bund gennem føringsrør i det positionerende rammeværk på arbejdsstedet.

DRAWINGS

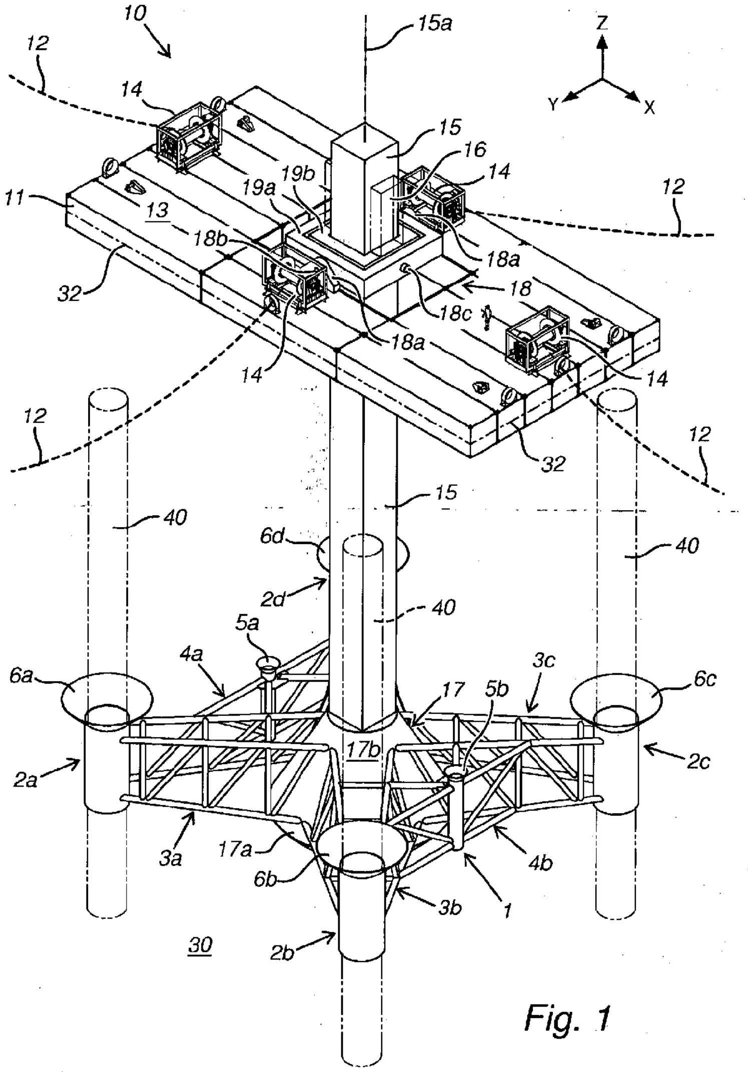
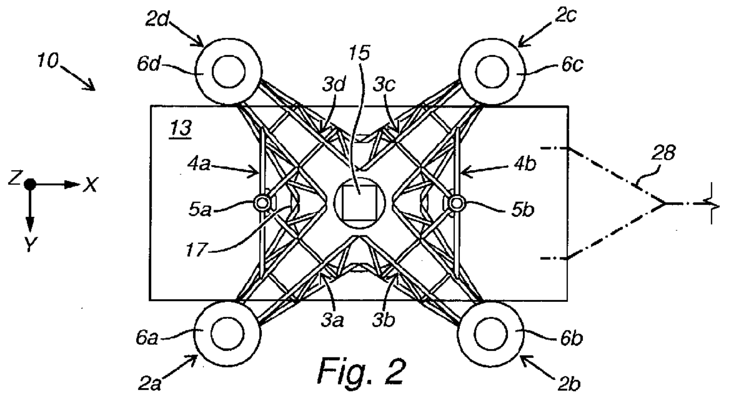
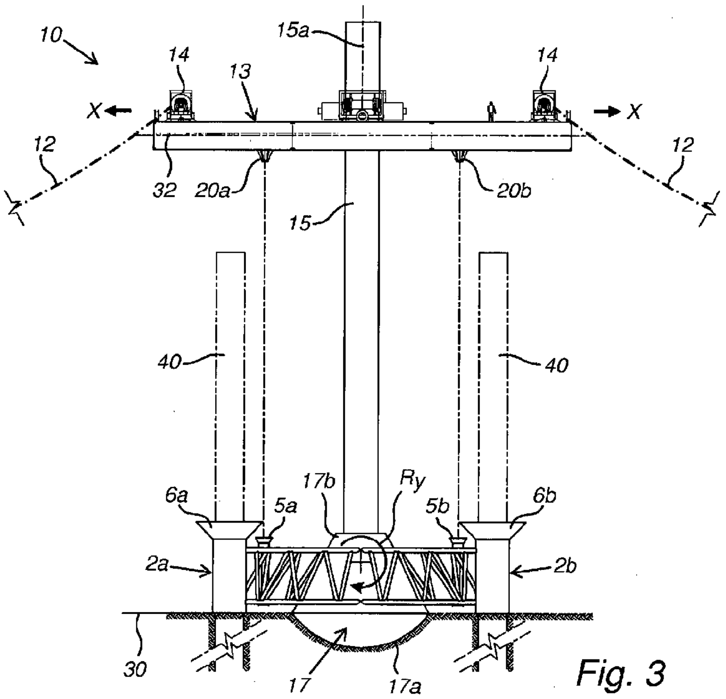


Fig. 1



2d
2c
10
6d
6c
15
3d
3c
13
28
Z
X
Y
4a
4b
5a
5b
17
3a
3b
6a
6b
2a
2b

Fig. 2



10
15a
14
13
14
X
X
12
12
32
20a
20b
15
40
40
17b
Ry
6a
5a
5b
6b
2a
2b
30
17
17a

Fig. 3

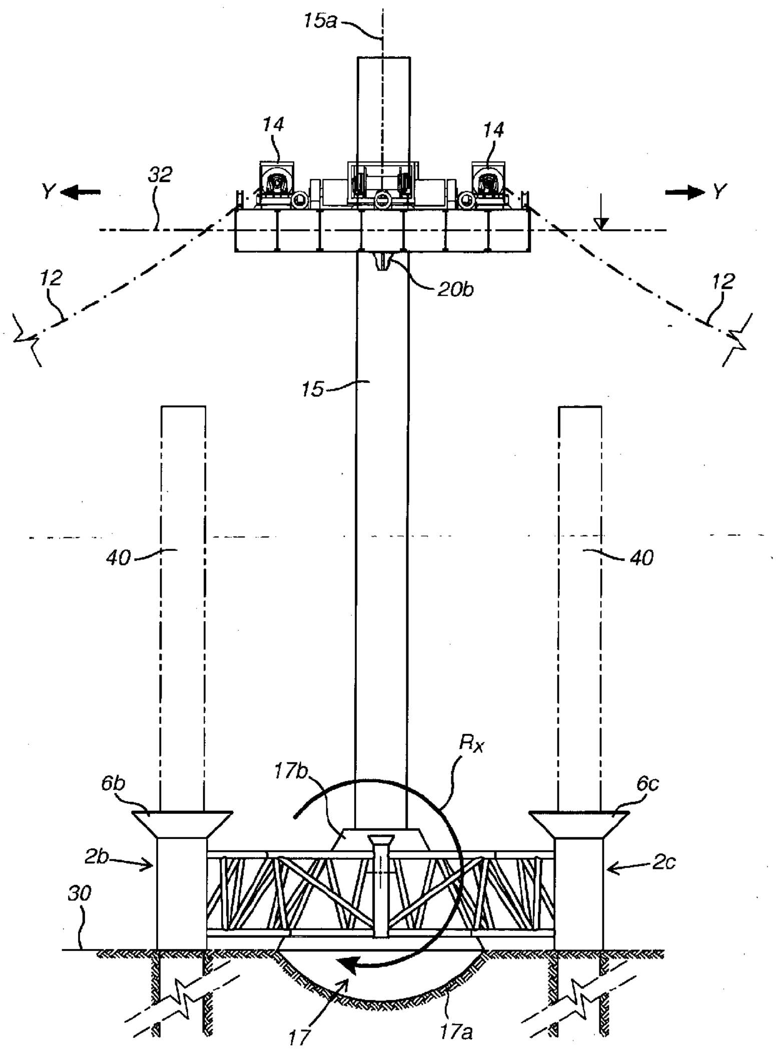
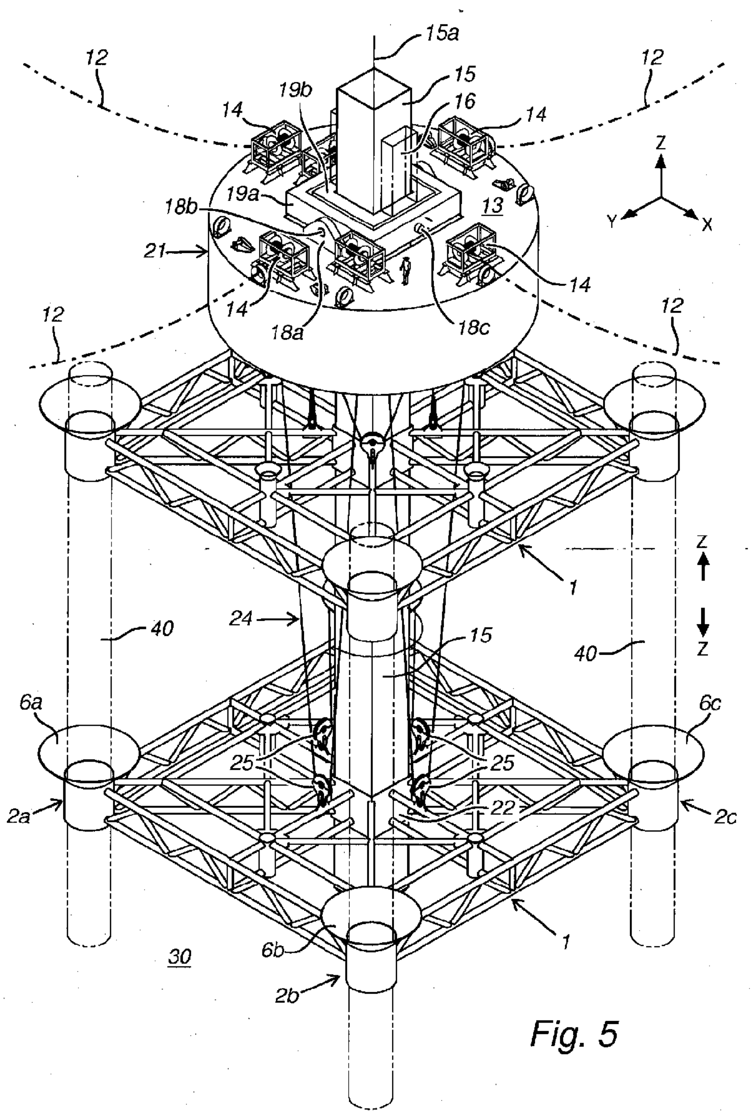


Fig. 4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12
19b
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16
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14
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Y
X
19a
13
18b
21
14
14
18a
18c
12
12
1
Z
Z
24
40
15
40
6a
6c
25
25
22
2a
2c
1
30
6b
2b

Fig. 5

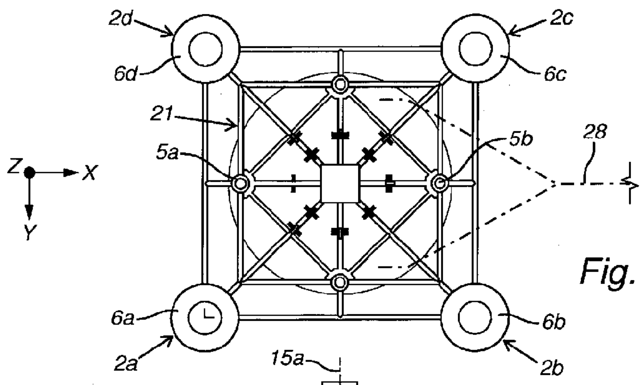
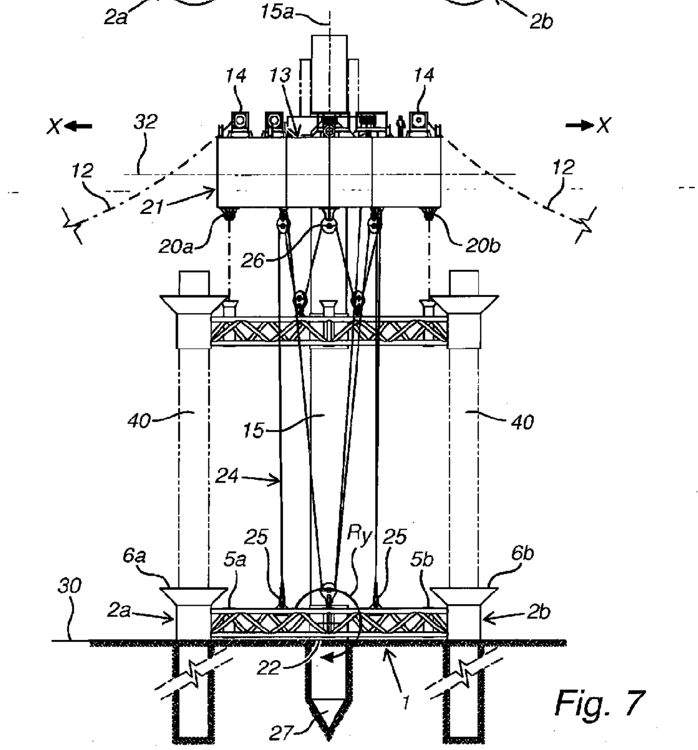

2d
2c
6d
6c
21
5a
5b
28
Z
X
Y
6a
6b
2a
2b

Fig. 6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X
X
32
12
12
21
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20b
26
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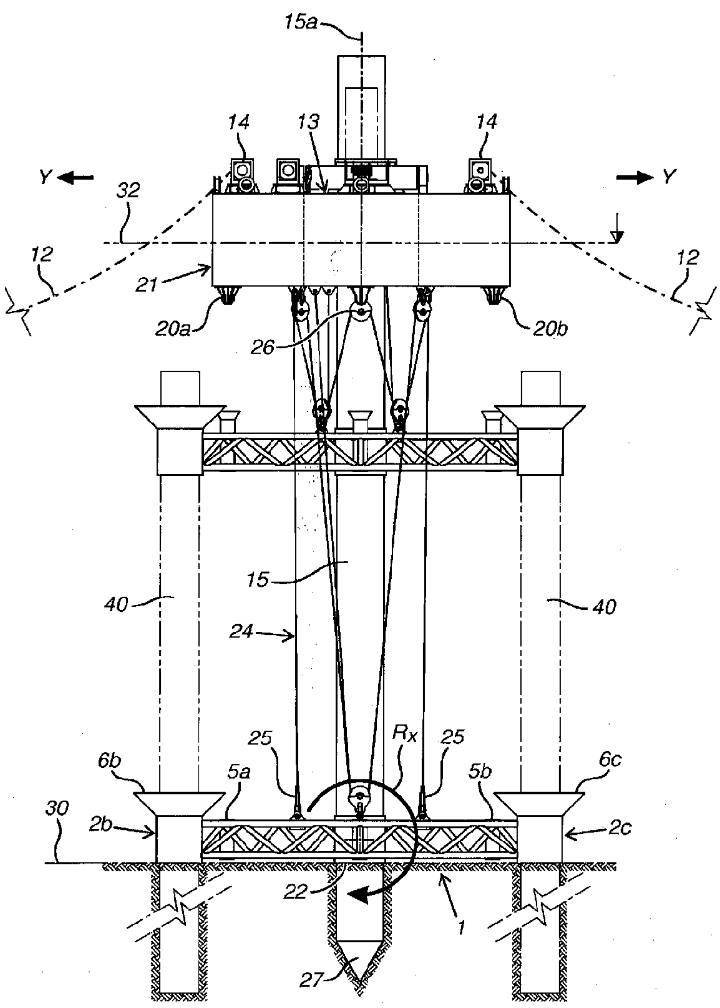
40
15
24
25
Ry
25
6a
5a
5b
6b
30
2a
2b
22
1
27

Fig. 7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13
14
Y
Y
32
12
12
21
20a
20b
26
15
40
40
24
25
Rx
25
6b
5a
5b
6c
30
2b
2c
22
1
27

Fig. 8

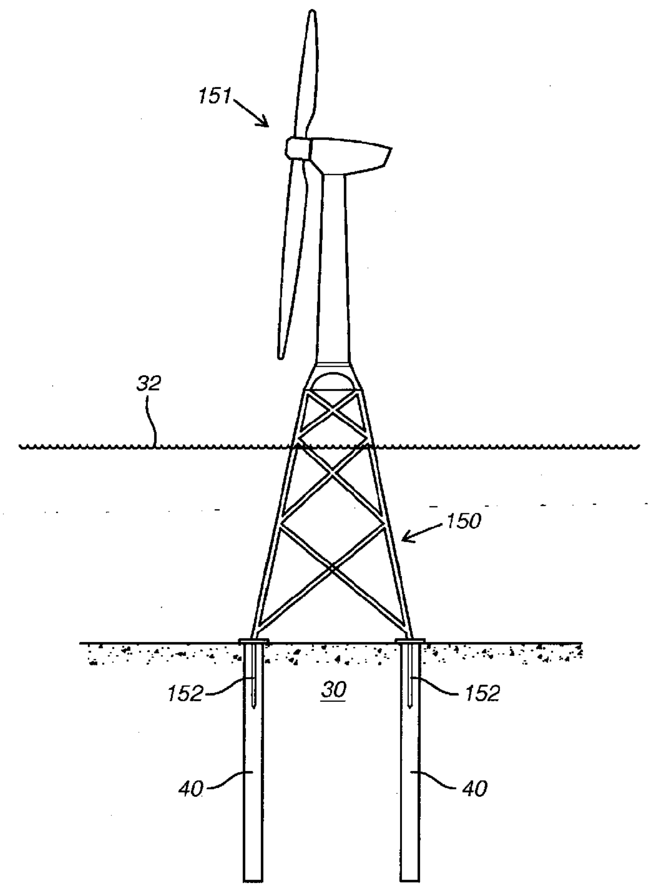

Fig. 9