



(51) International Patent Classification:

E02D 13/04 (2006.01) E02D 27/52 (2006.01)

(21) International Application Number:

PCT/NL2020/050109

(22) International Filing Date:

21 February 2020 (21.02.2020)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

2022625 22 February 2019 (22.02.2019) NL

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN,

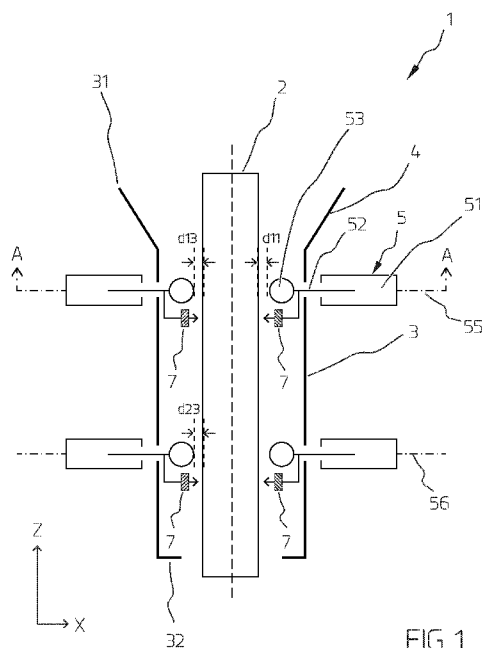
HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

(54) Title: ADJUSTABLE PILE GUIDE AND METHOD OF PILING



(57) Abstract: Adjustable pile guide for offshore pre-piling, comprising a tubular frame for receiving a pile to be installed in the sea bottom; a guiding mechanism comprising at least one movable guide for guiding the pile, wherein the movable guide is movable in a radial direction towards the pile in the tubular frame; a pile detection system for detecting a distance between the pile and the movable guide; a control system for driving the guiding system, wherein the control system is arranged for driving the movable guide on the basis of the detected distance between the pile and the movable guide.



Adjustable pile guide and method of piling

The present invention relates to an adjustable pile guide and a method of piling.

- 5 Many offshore structures, such as offshore platforms and offshore wind turbines, require foundations for transferring induced wind and wave loads into the ground, or in other words, the seabed. In order to firmly secure these structures to the seabed, piles are often used to anchor the structures. Certain offshore foundations, such as offshore jackets or tripods, require a number of piles to secure them to the seabed. These piles need to be accurately placed with respect to each
10 other to ensure that the interface of the offshore structure matches the piles installed.

Generally, two types of main approaches exist to ensure this fit. In the first approach, one first lifts the offshore structure, or foundation, in place after which the piles are installed through purposely manufactured sleeves. Grout is then often applied to fix the piles into the sleeves of the structure.

- 15 The advantage of this approach is that, as the structure is directly fixed in place, the piles will not be miss-placed with respect to each other. A downside is that placement of offshore structures typically involves larger, more expensive installation equipment, which, due to the slower installation process need to be leased for a longer period, leading to a cost-increase.

- 20 In the second approach, the piles are first installed into the seabed using smaller and more inexpensive installation equipment. In a next step, larger installation equipment places the structure over the installed piles and connects the piles and the structure, often using grout. This approach, also referred to as pre-piling, although typically cheaper, requires that the piles are precisely placed in the seabed, as otherwise the offshore structure intended to connect to the piles might not fit the
25 pre-installed piles. The challenge is then obviously how to accurately position and install piles into the seabed, while at the same time disturbing forces due to e.g. waves and currents are acting on the piles, thereby disturbing the positioning and installation process.

- In order to ensure a precise placement of the piles in the seabed, so called pre-piling templates are
30 typically used. These pre-piling templates are built to match the footprint of the offshore structure that is to be installed and comprise a number of pile guides for maintaining the position and tilting of the pile during piling. Nonetheless, these pre-piling templates are typically also expensive pieces of equipment, hence making them adjustable and, at least partially, reusable saves costs on the longer term.

Adjustable and reusable piling guides exist, for instance international patent application WO 2016 / 169923 A1 discloses a method of installing a pile in the sea bottom by means of a pile guide which has a frame and at least an upper and a lower pair of cooperating guide members, wherein the upper pair and the lower pair are located at a distance from each other in vertical direction, wherein
5 each pair of guide members comprises a passive guide member and an active guide member, the passive guide member and the active guide member are moved towards the pile after placing the pile between each of the pairs of guide members. The passive guide members are moved to respective fixed initial guiding positions with respect to the frame and the active guide members are moved to the pile until the passive and the active guide members engage the pile. The
10 engagement of the pile is detected by the guide member. After detection of the engagement, the pile is clamped between the upper pair of guide members and between the lower pair of guide members during driving the pile into the sea bottom, during which the actual forces between the pile and the respective guide members are determined.

15 The downside of this method for installing piles by means of such an adjustable pile guide is that, as the guide members are to engage and clamp the pile, it introduces large additional forces on the pile, but thereby also on the piling guide itself, resulting in an increased loading and wear of the pile guide and can necessitate that the construction of the pile guides is made stronger than necessary to overcome just the disturbing forces.

20 It is a goal of the present invention, next to other goals, to obtain an adjustable pile guide and a method for installing piles that is less susceptible for wear, wherein at least one of the above-mentioned problems is at least partially alleviated.

25 This goal, amongst other goals, is met by an adjustable pile guide for offshore pre-piling, comprising:

- a tubular frame for receiving a pile to be installed in the sea bottom;
- a guiding mechanism comprising at least one movable guide for guiding the pile, wherein the movable guide is movable in a radial direction towards the pile in the tubular frame;
- 30 - a pile detection system for detecting a distance between the pile and the movable guide;
- a control system for driving the guiding system, wherein the control system is arranged for driving the movable guide on the basis of the detected distance between the pile and the movable guide.

35 Such an adjustable pile guide can detect the position of the pile with respect to the movable guide by means of the pile detection system and the control of the movable guide is based on the detected

position of the pile. This allows an accurate placement of the pile with respect to the pile guide.

Preferably, the pile detection system is arranged to detect the distance between a movable guide in the pile without the movable guide and the pile making contact. For detecting the pile it is thus no longer required to engage the pile, for instance between opposing guides. It is thus possible to

control the movement of the guiding system in a controlled manner, based on the detected position of the pile with respect to a movable guide. It is preferred if the pile detection system detects the pile in a non-contact manner. This further reduces any friction between the pile and the pile guide and increases the durability of the system.

In a preferred embodiment, the control system is arranged for driving the movable guide towards the pile until a predefined nonzero distance between the movable guide and the pile is reached. Once the pile is lowered into the pile guide, the movable guide is driven towards the centre, i.e. towards the longitudinal axis, of the tubular frame. As the control system is arranged for driving the movable guide until the predefined nonzero distance is reached between the movable guide and the pile, there will remain a gap between the guiding mechanism, or at least the movable member of which the distance is being detected, and the pile, such that unnecessary clamping cannot occur, and the forces acting on the movable guide remain lower. Preferably, the control system is arranged for driving movable guide such that a gap is maintained between the movable guide and the pile.

As described above, only when a movable member engages a pile in the prior art, the relative position of the movable member and the pile were known. The clamping of the pile by the adjustable guide according to the prior art however introduces additional forces onto the pile, but also onto many parts of the adjustable guide, such as the movable guides themselves. As a result of this friction the wear of the movable parts tend to increase, leading to a reduced life-time of the piling guide. In addition, during piling one also needs to overcome the additional frictional forces between the guide and the pile, resulting in either larger forces for installing the pile into the seabed or in an increased installation time. The adjustable guide according to the invention does not increase forces on the movable guides, such that friction, wear installation time can be reduced.

The predefined nonzero distance is preferably larger than 0 mm and smaller than 30 mm, more preferably between 5 mm and 20 mm, most preferably around 10 mm. Hereby, the pile is not clamped by the adjustable pile guide, while at the same time the distance, or gap, between the movable guide and the pile is narrow enough to accurately guide the pile during installation.

In order to be able to correctly guide the pile to the predetermined location, it is preferred if also the position of the pile with respect to the pile guide, in particular the tubular frame thereof, is known. It is then preferred if the movable guide is movable from an initial outer position, wherein the movable guide extends at or near the inner wall of the tubular frame and wherein the relative position of the movable guide and the tubular frame is known, to an inner position in closer proximity to the pile. The movable guide, or generally the pile guide, is then preferably provided with a length detection system for detecting the movement length of the movable guide, preferably with respect to said initial position. Based on the distance the guide has travelled and the detected position of the movable guide with respect to the pile, the control system can then determine the position of the pile and control the driving of the guiding system in accordance therewith, for instance for accurately aligning the pile. Thus, in a preferred embodiment, the control system is arranged for determining the distance the movable guide has travelled from an initial position, wherein the initial position is defined with respect to the tubular frame, wherein the control system is, preferably, arranged for determining a position of the pile with respect to the tubular frame on the basis of the travelled distance of the movable guide and the detected distance between the pile and the movable guide. Hereby a relative distance between the pile and the tubular frame can be determined, such that, if the position of the tubular frame with respect to the pile target location is known, the distance between the pile and the pile target location can also be determined. The control system can then be arranged to drive the guiding mechanism on the basis of the detected pile location and the pile target location.

In a preferred embodiment, the pile detection system comprises a distance sensor for determining a distance between the movable guide and the pile. A distance sensor, such as a magnetic, inductive, optical, or touch-sensor, allows direct measurement of the distance. It is preferred if the pile detection system is arranged to exert no more than a negligibly small force on the pile compared to the disturbing forces. It is more preferred, as mentioned above, if the distance sensor is arranged for detecting the distance between the movable guide and the sensor in a non-contact manner between the movable guide and the pile. More preferably, the distance sensor is arranged on, or arranged to move with, the movable guide. By arranging the sensor on, or to move with, the movable guide, a more direct measurement between the movable guide and the pile can be obtained. This direct measurement can also lead to more reliable measurements and a more reliable operation of the adjustable pile guide. Preferably, the distance sensor is arranged for determining a distance parallel to the direction of motion of the movable guide.

In a preferred embodiment, the guiding mechanism comprises a first set of at least two movable guides, wherein the movable guides are arranged on the tubular frame at a first axial position of the

tubular frame, wherein the movable guides are movable in a radial direction towards the pile, preferably in directions that substantially intersect at, or near, a centre of the tubular frame. This allows approaching the pile from at least two sides, allowing a more efficient and/or accurate guiding procedure. A stable guidance of the pile is achieved when the movable guides are provided around the pile to be received in the tubular frame. Preferably, the movable guides are substantially equally divided around a circumference of the tubular frame. By providing the guiding mechanism to enclose the pile from at least two sides, preferably from three sides or more, the length of travel of the movable guides is reduced, resulting in a time savings during installation.

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- 10 More preferably, the guiding mechanism comprises a second set of at least two movable guides, wherein the movable guides are arranged on the tubular frame at a second axial position of the tubular frame that is different from the first axial position and are, preferably, also substantially equally divided around the circumference of the tubular frame, such that the movable guides are arranged to move in directions that substantially intersect at, or near, a centre of the tubular frame.
- 15 A second set of movable guides allows positioning the pile at two axial positions at the tubular frame, such that also a tilting of the pile can be set by the adjustable pile guide.

In a preferred embodiment, the control system is arranged for driving, preferably synchronously driving, at least one set of movable guides until a largest distance between a movable guide and the pile is equal to a predefined nonzero distance. For accurately guiding the pile during installation, the pile is preferably enclosed by the movable guides in such a manner that they do not all engage the pile, as this would lead to clamping the pile, which is to be prevented. Hence, a trade-off is to be made between sufficiently accurately enclosing the pile while not clamping the pile. An effective trade-off is obtained by (synchronously) driving the movable guide until the largest

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25 distance between a movable guide and the pile is equal to the predefined distance. Hereby, the distances between the rest of the movable guides and the pile is less than the predefined distance, but one ensures that a minimum of one movable guide is always at a distance of the pile, thereby not fully locking the pile in a clamped position.

- 30 In a preferred embodiment, the control system is arranged for synchronously driving at least one set of movable guides until a sum of distances between the movable guides of the set and the pile is nonzero and substantially equal to or smaller than a predefined nonzero total distance. This ensures a controlled clearance between the movable guides and the pile, such that the pile is properly guided while still allowed to make small displacements with respect to the guiding mechanism. At the same time, an efficient control mechanism is obtained. According to this embodiment, it is possible that one of the movable guides makes contact with the pile when the sum of the detected
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distance is not yet equal to or smaller than the nonzero total distance. The control system may be arranged to stop movement of a movable guide when a distance between said movable guide and the pile is smaller than a predetermined nonzero distance as mentioned above. The other movable guides may then continue to move inwardly until the sum of distances between the movable guides is nonzero equal to or smaller than the predefined nonzero total distance. Preferably, the nonzero total distance is larger than 0 mm and smaller than 40 mm, more preferably between 5 mm and 30 mm, most preferably around 10 mm. Hereby, the pile is not clamped by the adjustable pile guide, while at the same time the distance, or gap, between the movable guide and the pile is narrow enough to accurately guide the pile during installation.

In a preferred embodiment, the control system is arranged for determining a position of the pile, based on the determined distances between the movable guides and the pile, with respect to the frame in a plane substantially parallel to the radial direction. As the length of travel of the movable guides may be registered by for instance a length detection system as mentioned above, and the distances between the movable guides and the pile are known, the control system can accurately determine a position of the pile with respect to the tubular frame in this plane. Also, if redundant measurements (more than three per set of movable guide) are taken around the circumference of the pile, the control system can also be arranged to determine an ovality, or another degree of non-circularity, of the pile.

In a preferred embodiment, the control system is arranged for determining a tilting of the pile, based on the determined distances between the movable guides of the first and second sets and the pile, with respect to the tubular frame in a plane substantially perpendicular to the radial direction. As the distance between the pile and the second set of movable guides can be determined and the length of travel of the movable guides can also be determined by the control system, the tilting in a plane substantially parallel to the axial direction of the tubular frame can be determined by taking into account the pile-positioning differences at the first and second, or upper and lower, sets of movable guides into account and dividing this by the length with which the sets of movable guides are spaced apart from one and another, a metric for a tilting can be determined.

In a preferred embodiment, the control system is arranged to adjust the position of the pile by synchronously moving the moving guides, such that the pile is displaced in the plane substantially parallel to the radial direction, while maintaining a nonzero distance between the pile and at least one movable guide, or while maintaining the sum of distances between the movable guides and the pile to be nonzero and substantially equal to, or smaller than, a predefined distance. If, for instance, after determining the position of the pile with respect to the tubular frame, it appears that the pile

does not substantially align with a pile target location in the seabed, the movable guides can be used to re-position the pile to the correct pile target location. As the control system is arranged to maintain the nonzero distance, the pile can also be displaced without clamping it between the movable guides.

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In a preferred embodiment, the control system is arranged to adjust the tilting of the pile by synchronously moving the moving guides of the first set independent of synchronously moving the moving guides of the second set, while maintaining a nonzero distance between the pile and at least one movable guide of the first set and maintaining a nonzero distance between the pile and at least one movable guide of the second set, or while maintaining the sum of distances between the movable guides of the first and second sets and the pile to be nonzero and substantially equal to, or smaller than, a predefined distance. If, for instance, after determining a tilting of the pile, it turns out that the pile needs an adjustment to compensate a tilting, the first and second sets of movable guides can be driven independently with respect to each other, such that the control system is able to adjust the tilting. As the control system is arranged to maintain the nonzero distance, the pile can also be tilted without clamping it between the movable guides.

In a preferred embodiment, the movable guide is arranged at the end of a linear actuator, such as a piston of a hydraulic cylinder. This allows for a relatively simple construction of the driving means for the movable guides. The movable guide may then be arranged to move in a single, straight line.

In a preferred embodiment, the movable guide is arranged at a first end of a pivoting arm, wherein the pivoting arm is coupled to the tubular frame at a second end and wherein a linear actuator, such as a hydraulic cylinder, is arranged to move the pivoting arm from a initial position, wherein the movable guide is close to the inner wall of the tubular frame, and a second position, wherein the pivoting arm is moved outwardly with respect to the initial position. Hereby an arrangement of the movable guides is obtained that can be made more compact in the first position, as the arms and linear actuator, can be mounted such that they are positioned close to an inner wall of the tubular frame and the actuating means do not have to protrude through the wall of the tubular frame. In the initial position, the pivoting arm may substantially parallel to, or make a small angle with, the axial direction of the tubular frame. In the second position, the pivoting arm may be substantially perpendicular to the axial direction of the tubular frame or at least makes a larger angle with respect to the axial direction of the tubular frame.

Preferably, the distance sensor is mounted on the pivoting arm near the movable guide in a preferably fixable manner. This allows for the sensor to follow the guiding member, such that the

distance between the guiding member and the movable guide can be reliably determined at least when the movable guide is near the pile. Or in other words, in this embodiment the sensor can be used over a limited part of the mechanical reach of the movable guide. When the intended reach changes. e.g. because the pile diameter changes with the different foundations, the sensor position and orientation relative to the pivoting arm can be adjusted by modifying the mounting on the pivoting arm, preferably by adjusting the angle between the distance sensor and the pivoting arm.

An efficient measurement is possible if the distance sensor is coupled to the pivoting arm using a parallelogram configuration. This allows maintaining a proper orientation of the distance sensor and the pivoting arm over the full range of movement of the movable guide. Thus, in a preferred embodiment, a distance sensor is arranged on a coupling bar, that is pivotally connected to the pivoting arm, preferably at or near the first end, and which is pivotally connected to a first end of a secondary pivoting arm, that is arranged to move substantially parallel to the pivoting arm, such that the coupling bar is arranged to remain substantially parallel to the axial direction of the tubular frame. By arranging the sensor to the coupling bar that is arranged to remain substantially parallel to the axial direction, and thereby to the pile, distance measurements can be taken that are substantially perpendicular to the axial direction, thereby enabling a more direct determination of the (shortest) distance between a movable guide and the pile. Alternatively, the distance sensor is pivotally, and freely rotatably, mounted on the pivoting arm, preferably near the movable guide, and is arranged with a pendulum weight to bias the distance sensor to measure a distance substantially perpendicular to the pile.

In a preferred embodiment, at least one guiding member comprises a guiding wheel that is arranged to freely rotate and/or wherein at least one guiding member comprises a sliding member that is arranged to slidably support the pile. A free-rotating wheel as guiding member allows for a reduced friction when guiding the pile. Also, it can also ensure a better handling of potential unevenness in the outer wall of the pile. A sliding member provides for a simple and robust solution for guiding the pile.

The goal, amongst other goals, is also met by a method of installing a pile into a seabed, comprising the steps of:

- inserting the pile to be installed into a tubular frame of an adjustable pile guide;
- moving at least one movable guide of a guiding mechanism in a radial direction towards the pile;
- detecting, during the movement of the movable guide, a distance between the pile and the movable guide by means of a pile detection system;

- maintaining a predefined distance between the movable guide and the pile to be installed during installing of the pile into the seabed on the basis of the determined distance.

As discussed above, this method for installing a pile using an adjustable guide according to the invention does not increase forces on the movable guides, such that friction, wear and installation time can be reduced.

In a preferred embodiment, the method also comprises the step of positioning the pile with respect to the tubular frame, by, preferably at least partly synchronously, moving at least two movable guides, wherein the position of the pile is maintained between the movable guides, and maintaining the predefined distance between the pile and at least one movable guide, or by maintaining the sum of distances between the pile and the movable guides to be nonzero and substantially equal to, or smaller than, the predefined total distance. As has been discussed above, if, after determining the position of the pile with respect to the tubular frame, it appears that the pile does not substantially align with a pile target location in the seabed, the movable guides can be used to re-position the pile to the correct pile target location. As the control system is arranged to maintain the nonzero distance, the pile can also be displaced without clamping it between the movable guides.

In a preferred embodiment, the method also comprises the steps of:

- providing movable guides at two axial positions in the tubular frame, wherein the two axial positions are provided at a certain axial distance from each other;
- tilting the pile with respect to the tubular frame, by synchronously moving at least two movable guides of the first and/or second axial position, wherein the movement of the movable guides at the first axial position is different from the movement of the movable guides at the second axial position, wherein the position of the pile is maintained between the movable guides, and maintaining the predefined distance between the pile and at least one movable guide at each position, or by maintaining the sums of distances between the pile and each set of movable guides to be nonzero and substantially equal to, or smaller than, the predefined total distance.

As discussed above, if, after determining a tilting of the pile, it turns out that the pile needs an adjustment to compensate a tilting, the first and second sets of movable guides can be driven independently with respect to each other, such that the control system is able to adjust the tilting. As the control system is arranged to maintain the nonzero distance, the pile can also be tilted without clamping it between the movable guides.

The present invention is further illustrated by the following figures, which show preferred embodiments of the adjustable pile guide according to the invention, and are not intended to limit the scope of the invention in any way, wherein:

- 5 - Figure 1 shows a schematic front view of an embodiment of the adjustable pile guide according to the invention.
- Figure 2 shows a schematic cross-sectional view of the adjustable pile guide at the set of movable guide assemblies at the upper axial position.
- Figure 3 shows in more detail a schematic front view of the embodiment of the adjustable pile guide according to the invention.
- 10 - Figure 4A and 4B show different embodiments of movable guides and sensors for detecting a distance between the movable guide and the pile.

Figure 1 shows a schematic front view of an embodiment of the adjustable pile guide 1 according to the invention wherein a pile 2 is inserted. The pile 2 is arranged to be installed into the seabed.
15 The adjustable pile guide 1 that is placed on the seabed comprises a tubular frame, or sleeve, 3, which is fitted with an insert guide 4. Multiple movable guide assemblies 5 are arranged along the outer circumference of the tubular frame 3. The movable guide assemblies 5 are arranged in sets at two axial positions 55, 56, whereby the set at upper axial position 55 is located near an upper side 31 of the tubular frame and the set at lower axial position 56 is located near a lower side of the
20 tubular frame 3. Movable guide assemblies 5 comprise a linear actuator, such as a hydraulic cylinder 51 that is arranged to extend and retract piston 52. At the end of the piston 52, a movable guide, such as a free-rolling wheel 53 or a sliding bearing, is arranged.

In the current embodiment distance detection sensors 7 that are suitable for underwater, offshore
25 conditions, such as inductive, magnetic or simple touch-sensors, are mounted with the movable guides 53, such that the distance detection sensors 7 are arranged for determining the distances d11, d13 between the free-rolling wheel 53 and pile 2.

Figure 2 shows a schematic cross-sectional view of the adjustable pile guide 1 at the set of
30 movable guide assemblies 5 at the upper axial position 55. In this embodiment of the adjustable pile guide 1 four movable guide assemblies 5 are arranged at the upper axial position 55 such that the movable guide assemblies 5 that can comprise the piston 52 and free rolling wheel 53 are equally divided around a circumference of the tubular frame 3 and are movable in the radial direction towards a centre 6 of the tubular frame 3. Preferably, all free-rolling wheels 53 are
35 associated with a distance detection sensor 7 that is arranged to move with the free-rolling wheels 53. Thereby, the distances d11, d12, d13, d14 between pile 2 and movable guides 53 can be

determined, such that the, as is seen in figure 2, an in-plane position in the X, and Y coordinates with respect to the tubular frame 3, i.e. the plane parallel to the radial directions, can be determined based on the measurements performed by the distance detection sensors 7.

5 Figure 3 shows in more detail a schematic front view of the embodiment of the adjustable pile guide 1 according to the invention. The hydraulic cylinders 51 are fitted with a sensor 54 for measuring the length travelled by the piston 52. In addition, distance detection sensors 7 have been mounted with the free-rolling wheels 53. Sensors 54 and distance detection sensors 7 are both connected to controller 100 and pass the measured signals onto the control system comprising
10 controller 100. Controller 100 in turn is connected to hydraulic cylinders 51 and controls the driving of the hydraulic cylinders 51 and thus the movement of the free-rolling wheels 53.

The pile 2 needs to be precisely installed at the right location, i.e. the target pile location, in the seabed, in order to achieve this, the following steps are taken. The sleeve 3 is positioned by a
15 crane-vessel on the seabed, after which the position of the sleeve 3 is determined. The sleeve 3 obviously needs to be positioned with such accuracy that it encloses the target location of the pile 2. All the movable guides 53 are retracted, after which the pile 2 is lowered and inserted into the sleeve 3. The free-rolling wheels 53 are now synchronously driven, by means of hydraulic cylinders 51, which are controlled by controller 100 to move in the direction of the pile 2. As soon
20 as the distance detection sensors 7 are able to determine the distances d_{11} , d_{13} between the sensor 7 and the pile 2, the X-position of the pile 2, with respect to the sleeve 3 can be determined by the controller 100, as the controller 100 has registered the length of travel, by means of sensor 7, of both pistons 52 and knows the distance between the free-rolling wheels 53 and the pile 2. The controller 100 keeps on driving the free-rolling wheels 53 until a predefined distance, or until the
25 sum of the measured distances d_{11} , d_{13} is nonzero and equal to, or smaller than, a certain predefined total distance, preferably greater than 0 mm and smaller than 30 mm, more preferably around 10 mm.

Hereby the adjustable pile guide 1 is able to accurately guide the pile 2 while the pile 2 is installed,
30 at the same time, as the pile 2 is not all free-rolling wheels 53 engage the pile 2, the pile 2 is not clamped between the free-rolling wheels 53, hence the guiding mechanism adds little additional friction in the process of installing the pile 2. As a result, the pile 2 can be installed with less force and, typically, it can also be installed faster, at least when compared to a traditional pile guide that clamps the pile 2 in between its guiding members.

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Assuming now that the adjustable pile guide 1 is not exactly centred onto the target location, the pile 2 needs to be positioned in the sleeve 3, such that it aligns with the target location in the seabed. Hereto, the movable guide assemblies 5 can reposition the pile 2 within the sleeve 3. By synchronously driving the left movable guide assembly 58 and the right movable guide assembly 57 in opposite directions, the pile 2 can be repositioned in the sleeve 3, while again maintaining the sum of the measured distances d_{11} , d_{13} to be, preferably nonzero and, equal to, or smaller than, a certain predefined total nonzero distance, such that the pile 2 is not clamped between the free-rolling wheels 53, as explained before.

- 10 If this action is performed synchronously between the sets of movable guide assemblies at lower and upper axial position 56, 55, the orientation of the pile 2 with respect to the sleeve 3 is maintained, such that a pure X, Y - positioning of the pile 2 within, and with respect to, the sleeve 3 is obtained. If the lower set of movable guide assemblies 56 is driving differently from the upper set of movable guide assemblies 55, or if only one of the sets 55, 56 is driven, the orientation, or
15 tilting angle of the pile 2 with respect to the sleeve 3 can be adjusted. Suppose sleeve 3 is, due to local seabed conditions, not exactly vertical after placement, but pile 2 needs to be installed exactly vertically, then the tilting of the pile 2 with respect to sleeve 3 can be adjusted such that pile 2 is substantially vertically oriented. Again, as the pile 2 is not clamped between the free-rolling wheels 53 during this process or afterwards, hence the guiding mechanism adds little additional friction in
20 the process of installing the pile 2.

In figure 4A an alternative embodiment of the movable guide assembly 200 is shown. The free-rolling wheel 53, which acts as the movable guide, can be mounted at the end of a first pivoting arm 202 that can be pivotally coupled by means of hinge 203 to an inner wall 31 of sleeve 3. Piston
25 52 of cylinder 51 is pivotally coupled to the first pivoting arm for moving the first pivoting arm 202 from a first position, wherein the first pivoting arm 202 is pointing downwards and is substantially parallel, or at a small angle, with the axial direction of the sleeve 3, to a second direction, wherein the pivoting arm 202 moves upwards such that free-rolling wheel 53 moves towards pile 2. In order to accommodate the relative rotations, cylinder 51 can be pivotally coupled
30 to the sleeve 3 by means of hinge 201.

A second pivoting arm 204 that can be pivotally coupled by means of hinge 205 to an inner wall 31 of sleeve 3 is provided, such that the first and second pivoting arm 202, 204 remain substantially parallel to each other. At the end of the pivoting arms 202, 204 that, in the second positions, point
35 towards pile 2, an additional linkage 206 is provided between the arms 202, 204.

Hereby, a parallelogram configuration or a so-called four-bar mechanism is obtained. This linkage, or coupling bar, 206 is arranged such that it remains parallel to the axial direction of the sleeve 3. The sensor 7 can be arranged to this linkage 206, such that the distance detection sensor 7, such as an inductive or magnetic sensor, will, in any position of the arms 202, 204, measure the distance to the pile 2 in a direction substantially perpendicular to the axial direction of the pile 2. Hereby, reliable and consistent distances can be measured by the distance detection sensors 7.

In figure 4B another alternative embodiment of the movable guide assembly 300 is shown. Hereby, the cylinder 51 is mounted substantially perpendicular to the axial direction of the pile 2. At the end of piston 52 a sliding guide member 353, with a low-friction contact surface 354 is provided. Arranged with piston 52 is an alternative distance detection sensor, a touch-sensor 307, provided. Touch-sensor 307 can be arranged with contacting member 308, that is arranged to contact the pile 2, and wherein the touch-sensor 307 determines the distance based on the amount with which the contacting member 308 is pressed in.

The different components with similar functions as displayed in figures 4A, 4B, but also figures 1 - 3 can be exchanged to form further embodiments from the combinations. Furthermore, cylinders 51 that are shown in figures 4A and 4B, can also be fitted with sensor 54 for measuring the length travelled by the piston 52.

The present invention is not limited to the embodiment shown, but extends also to other embodiments falling within the scope of the appended claims.

Claims

1. Adjustable pile guide for offshore pre-piling, comprising:
 - a tubular frame for receiving a pile to be installed in the sea bottom;
 - 5 - a guiding mechanism comprising at least one movable guide for guiding the pile, wherein the movable guide is movable in a radial direction towards the pile in the tubular frame;
 - a pile detection system for detecting a distance between the pile and the movable guide without the movable guide and the pile making contact;
 - 10 - a control system for driving the guiding system, wherein the control system is arranged for driving the movable guide on the basis of the detected distance between the pile and the movable guide.
2. Adjustable pile guide according to claim 1, wherein the control system is arranged for
15 driving the movable guide towards the pile until a predefined nonzero distance between the movable guide and the pile is reached.
3. Adjustable pile guide according to claim 1 or 2, wherein the control system is arranged for
20 determining the distance the movable guide has travelled from an initial position, wherein the initial position is defined with respect to the tubular frame, wherein the control system is arranged for determining a position of the pile with respect to the tubular frame on the basis of the travelled distance of the movable guide and the detected distance between the pile and the movable guide.
- 25 4. Adjustable pile guide according to any of the preceding claims, wherein the pile detection system comprises a distance sensor for determining a distance between the movable guide and the pile.
5. Adjustable pile guide according to claim 4, wherein the distance sensor is arranged on, or
30 arranged to move with, the movable guide and wherein the distance sensor is arranged for determining a distance parallel to the direction of motion of the movable guide.
6. Adjustable pile guide according to any of the preceding claims, wherein the guiding
35 mechanism comprises a first set of at least two movable guides, wherein the movable guides are arranged on the tubular frame at a first axial position of the tubular frame and are substantially equally divided around a circumference of the tubular frame, and wherein the

movable guides are arranged to move in substantially radial directions that substantially intersect at, or near, a centre of the tubular frame.

- 5 7. Adjustable pile guide according to claim 6, wherein the guiding mechanism comprises a second set of at least two movable guides, wherein the movable guides are arranged on the tubular frame at a second axial position of the tubular frame that is different from the first axial position and are substantially equally divided around the circumference of the tubular frame, such that the movable guides are arranged to move in directions that substantially intersect at, or near, a centre of the tubular frame.
- 10 8. Adjustable pile guide according to claim 6 or 7, wherein the control system is arranged for driving at least one set of movable guides until a largest distance between a movable guide and the pile is equal to a predefined nonzero distance.
- 15 9. Adjustable pile guide according to any of the preceding claims 6 - 8, wherein the control system is arranged for synchronously driving at least one set of movable guides until a sum of distances between the movable guides of the set and the pile is substantially equal to a predefined nonzero total distance.
- 20 10. Adjustable pile guide according to any of the preceding claims, wherein the control system is arranged for determining a position of the pile, based on the determined distances between the movable guides and the pile, with respect to the frame in a plane substantially parallel to the radial direction.
- 25 11. Adjustable pile guide according to any of the preceding claims 7 - 10, wherein the control system is arranged for determining a tilting of the pile, based on the determined distances between the movable guides of the first and second sets and the pile, with respect to the tubular frame in a plane substantially perpendicular to the radial direction.
- 30 12. Adjustable pile guide according to any of the preceding claims 5 - 11, wherein the control system is arranged to adjust the position of the pile by synchronously moving the moving guides, such that the pile is displaced in the plane substantially parallel to the radial direction, while maintaining a non-zero distance between the pile and at least one movable guide, or while maintaining the sum of distances between the movable guides and the pile to
35 be substantially equal to a predefined distance.

13. Adjustable pile guide according to any of the preceding claims 7 - 12, wherein the control system is arranged to adjust the tilting of the pile by synchronously moving the moving guides of the first set independent of synchronously moving the moving guides of the second set, while maintaining a non-zero distance between the pile and at least one movable guide of the first set and maintaining a non-zero distance between the pile and at least one movable guide of the second set, or while maintaining the sum of distances between the movable guides of the first and second sets and the pile to be substantially equal to a predefined distance.
- 10 14. Adjustable pile guide according to any of the preceding claims, wherein the movable guide is arranged at the end of a linear actuator, such as a piston of a hydraulic cylinder, and is arranged to move in a single, straight line.
- 15 15. Adjustable pile guide according to any of the preceding claims, wherein the movable guide is arranged at a first end of a pivoting arm, wherein the pivoting arm is coupled to the tubular frame at a second end and wherein a linear actuator, such as a hydraulic cylinder and piston, is arranged to move the pivoting arm from a initial position, wherein the pivoting arm is substantially parallel to the axial direction of the tubular frame and a second position, wherein the pivoting arm is substantially perpendicular to the axial direction of the tubular frame.
- 20 16. Adjustable pile guide according to claim 15, wherein a distance sensor is arranged on a coupling bar, that is pivotally connected to the pivoting arm at the first end and pivotally connected to a first end of a secondary pivoting arm, that is arranged to move substantially parallel to the pivoting arm, such that the coupling is arranged to remain substantially parallel to the axial direction of the tubular frame.
- 25 17. Adjustable pile guide according to any of the preceding claims, wherein at least one guiding member comprises a guiding wheel that is arranged to freely rotate and/or wherein at least one guiding member comprises a sliding member that is arranged to slidably support the pile.
- 30 18. Method of installing a pile into a seabed, comprising the steps of:
- inserting the pile to be installed into a tubular frame of an adjustable pile guide;
 - 35 - moving at least one movable guide of a guiding mechanism in a radial direction towards the pile;

- detecting, during the movement of the movable guide, a distance between the pile and the movable guide by means of a pile detection system;
- maintaining a predefined distance between the movable guide and the pile to be installed during installing of the pile into the seabed on the basis of the determined distance.

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19. Method according to claim 18, comprising the step of positioning the pile with respect to the tubular frame, by synchronously moving at least two movable guides, wherein the position of the pile is maintained between the movable guides, and maintaining the predefined distance between the pile and at least one movable guide.

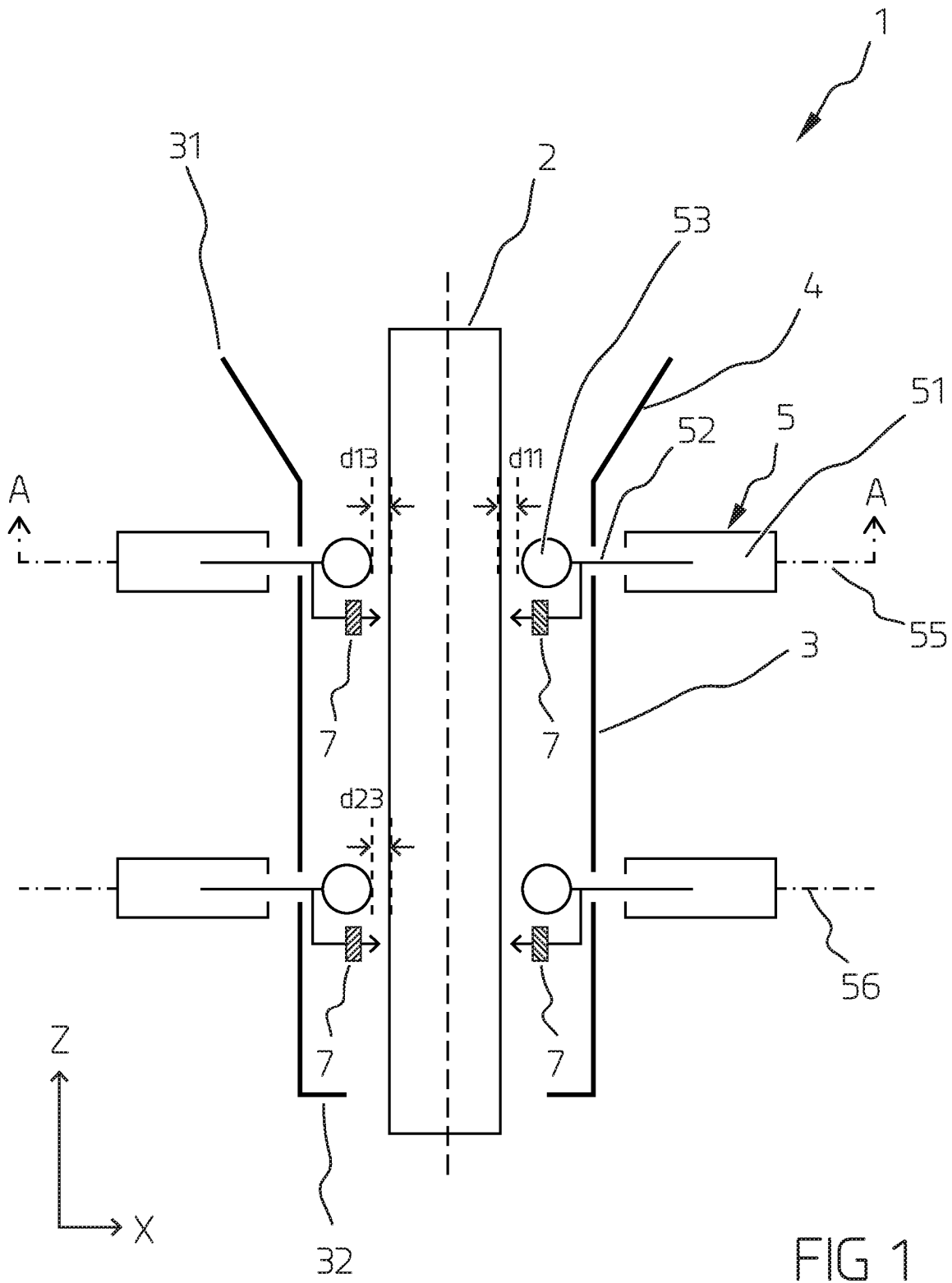
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20. Method according to claim 18 or 19, comprising the steps of:

- providing movable guides at two axial positions in the tubular frame, wherein the two axial positions are provided at a certain distance from each other;
- tilting the pile with respect to the tubular frame, by synchronously moving at least two movable guides of the first and/or second axial position, wherein the movement of the movable guides at the first axial position is different from the movement of the movable guides at the second axial position, wherein the pile is maintained between the movable guides, and maintaining the predefined distance between the pile and at least one movable guide at each position.

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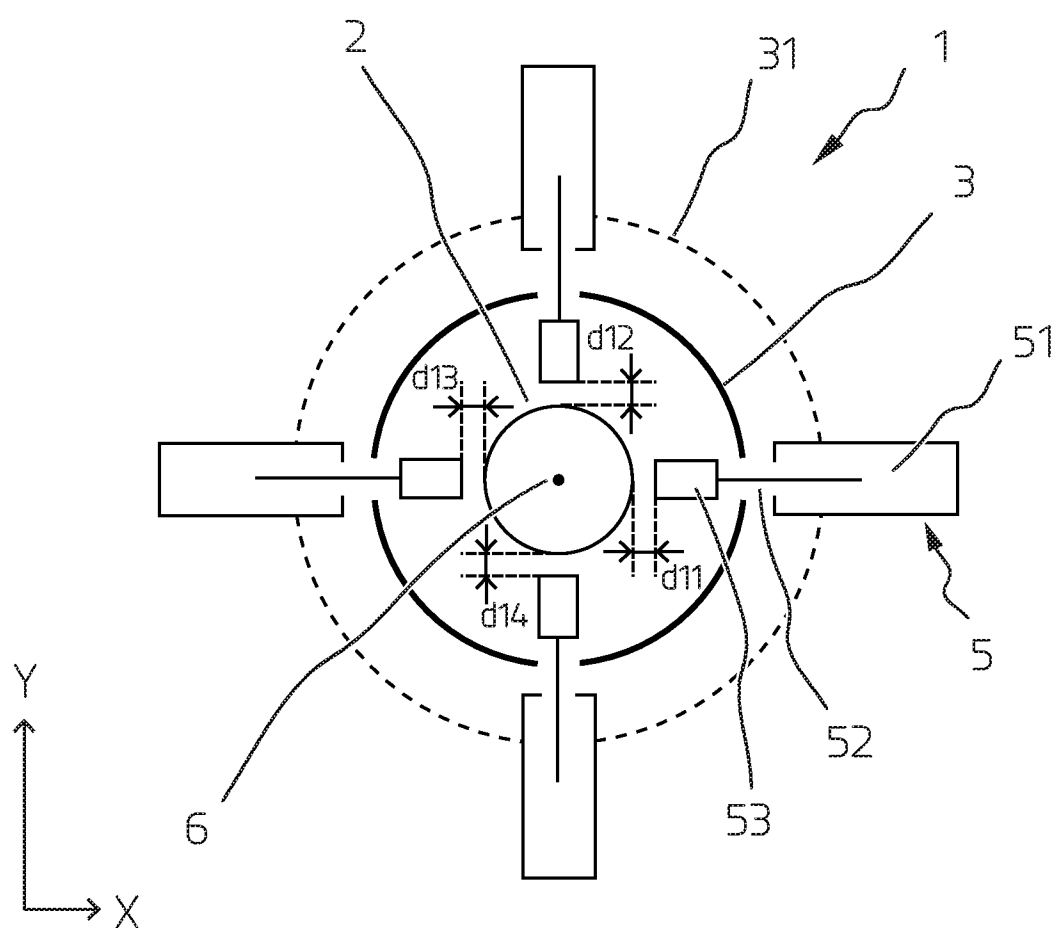
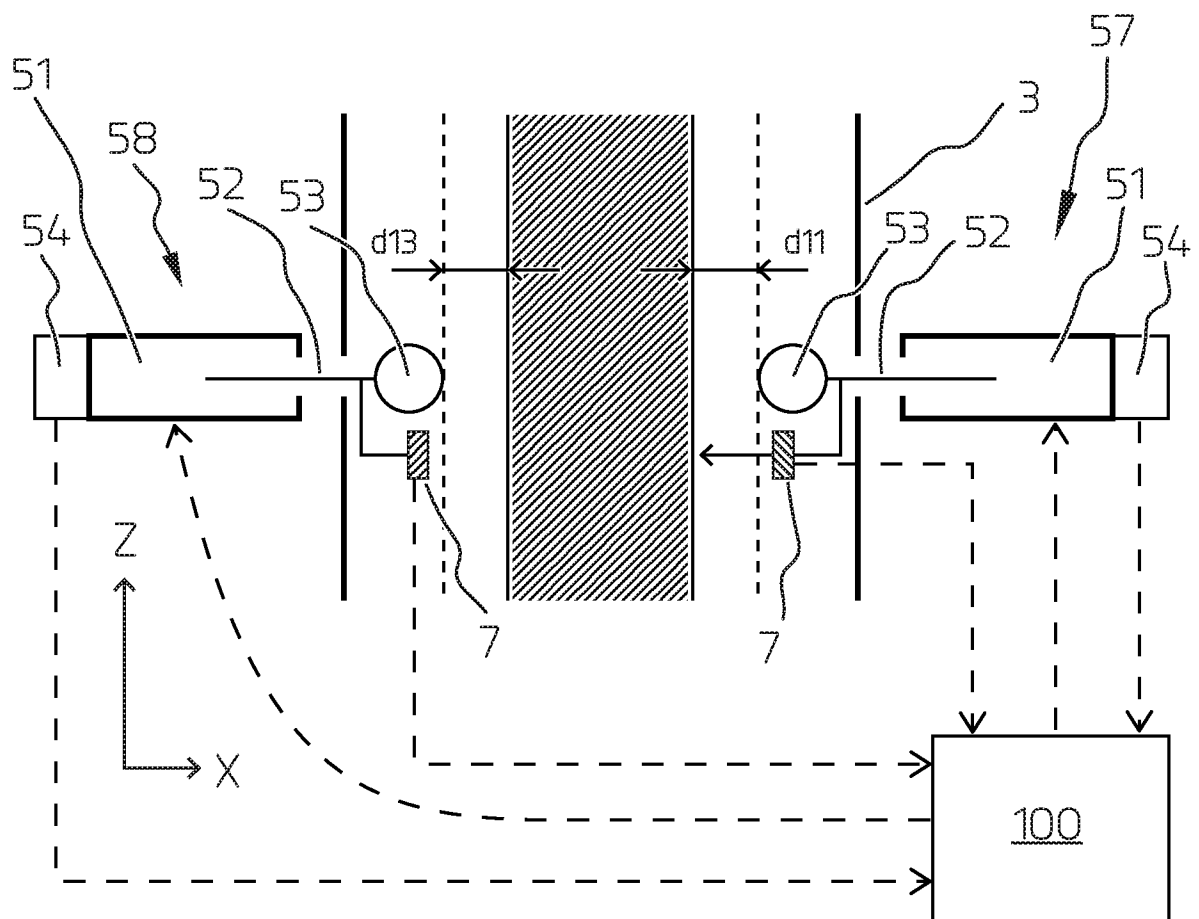
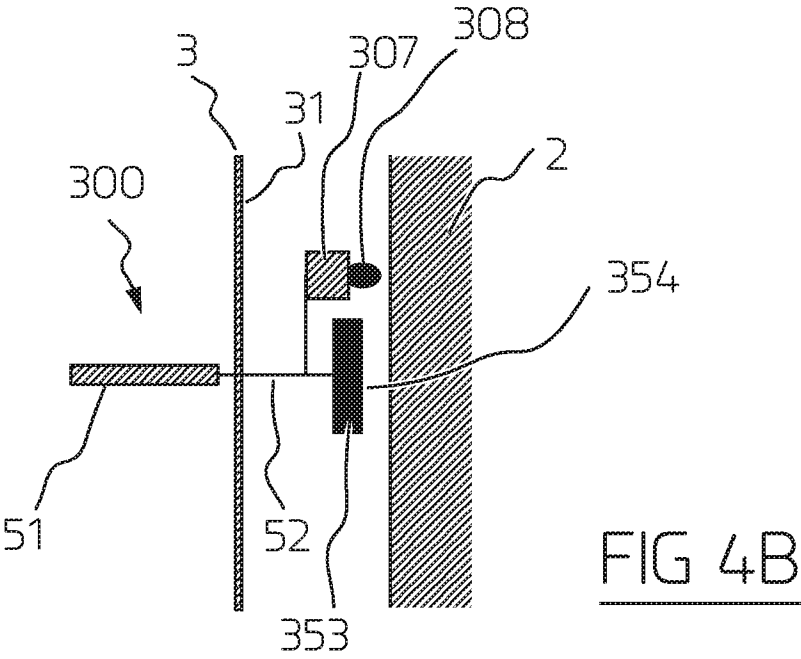
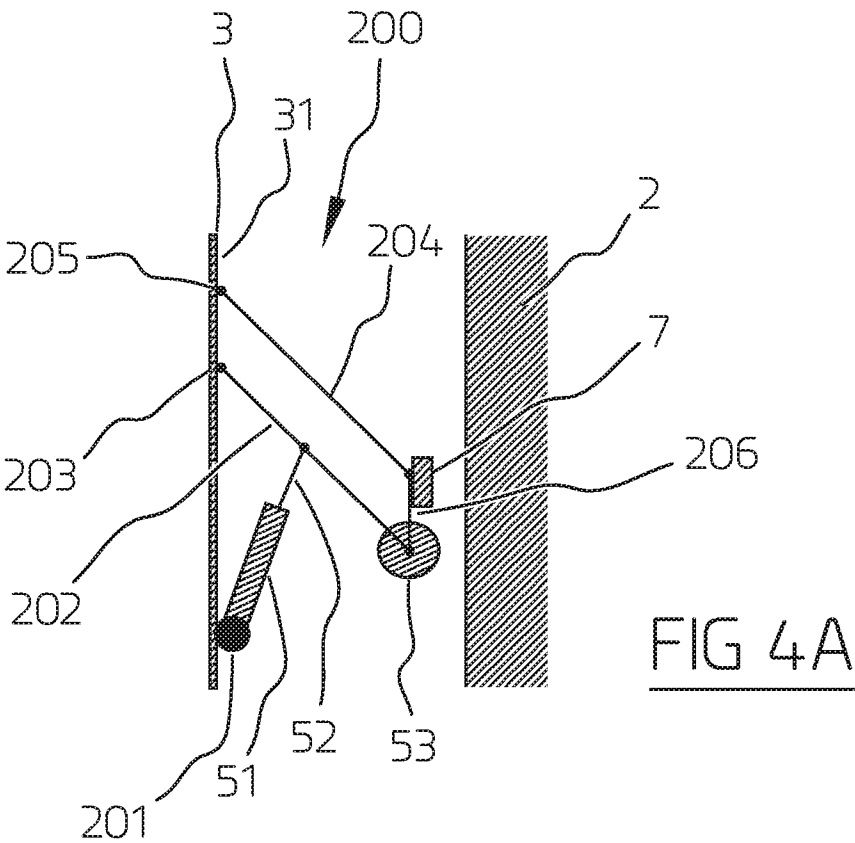


FIG 2

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FIG 3

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INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2020/050109

A. CLASSIFICATION OF SUBJECT MATTER
INV. E02D13/04 E02D27/52
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
E02D E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 108 104 123 A (TAIZHONG TIANJIN HEAVY EQUIPMENT TECH DEVELOPMENT CO LTD) 1 June 2018 (2018-06-01) the whole document	1-20
A	----- WO 2012/177131 A1 (IHC HOLLAND IE BV [NL]; JUNG BOUDEWIJN CASPER [NL] ET AL.) 27 December 2012 (2012-12-27) page 6, line 6 - page 8, line 22; figures 1,3,4	1,15,16,18
A	----- WO 2016/169923 A1 (IHC IQIP UK LTD) 27 October 2016 (2016-10-27) cited in the application the whole document -----	1,18



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

25 May 2020

Date of mailing of the international search report

03/06/2020

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/NL2020/050109

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
CN 108104123	A	01-06-2018	NONE
WO 2012177131	A1	27-12-2012	NONE
		AU 2012273589 A1	16-01-2014
		AU 2017204523 A1	20-07-2017
		CN 103620122 A	05-03-2014
		EP 2723947 A1	30-04-2014
		JP 2014517178 A	17-07-2014
		NL 2006982 C2	02-01-2013
		US 2014154015 A1	05-06-2014
		WO 2012177131 A1	27-12-2012
WO 2016169923	A1	27-10-2016	NONE