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(54) Title: INSTALLATION METHOD FOR AN OFFSHORE STRUCTURE

(57) Abstract: This invention relates to a method of installing an offshore structure comprising the steps of providing one or more anchor lines connected to an anchor that is placed at an anchor position on the sea bed, storing the anchor line length in a data storage unit, pulling an upper end of the anchor line with an installation vessel at the water surface with a predetermined force at a surface position, measuring a tension in the anchor line at or near the water surface and recording the tension and the position of the anchor line upper end in a data storage unit, retrieving anchor line data from the data storage unit, determining on the basis of the retrieved data and the measured tension and position a mooring anchor line length L_m resulting in an anchor line connection position, determining an actual anchor line length L , and removing an over length $L - L_m$ from the anchor line end.



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Installation method for an offshore structure

Field of the invention

5 The present invention relates to an installation method for an offshore structure. The method involves accurately determining the over length of a an anchor line part of a mooring line for mooring an offshore system, and removing said over length in order to ensure that the mooring system is installed with a line tension that is within predefined tolerances.

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Background of the invention

 The international patent application WO2006101401 describes a method for anchoring of a vessel offshore, preferably in deep water, with the use of a system in
15 which a pulling wire is paid out from a winch on the vessel and fastened to the coupling part of an anchoring line, the anchoring line is pulled in by the winch to where the coupling part is in position over a crib, the coupling part is laid down into the crib. The operation is repeated for each anchoring line. In this prior art method a locking means is preferably fastened in place for each crib only after the actual anchoring line
20 having been laid into position. However with such a method, an additional tightening and/or adjustment step of the anchoring line is still needed, which is time consuming and as it is done offshore, is an expensive activity.

 Another patent, US3422783 describes a device for anchoring a floating system such as a platform or a ship. It disclose a precise offshore positioning of a floating
25 system combined with the utilization of a plurality of anchors fixed to the water bottom around the system and connected to the latter through mooring lines (chains and/or ropes or cables) under strong tension at the beginning of the anchoring process. In this patent the upper end of the mooring line is fixed to the floating system, for example by winding it on a winch which is used to put the mooring rope under tension and locked it
30 when the desired mooring line tension is obtained. Again, with this device an additional adjustment of the tension in the mooring line is required before the length of the moorings can be exactly determined, so that it will stay within the predefined tolerances.

A well known calculation method often used is the seabed measurement method. This method consists in physically measuring a reference point along the anchoring line once it is laid in a straight line down onto the seabed. Comparison of the derived end point position and theoretical one gives the length adjustment to be performed. The calculation of length correction to a future line length variation has to be taken into account. However, although this method is based on a simple calculation and operation, it requires an accurate positioning and subsea measurement means which are difficult to obtain in deep water. Further, for taut mooring line systems, the variation due to change in buried length of the mooring line part near the anchor, should not be just added to the over length; in fact the effect of a variation between the calculated anchor point and the installed anchor point, has also to be taken into account. In addition, an uneven shape of the seabed or any seabed irregularities, will also lead to an underestimated length of the mooring line.

It is an object of the present invention to provide a method of installing an offshore structure at an anchor line connection position, in which the influence of inaccuracies in determining the required length for obtaining the desired anchor line connection are reduced in a simple manner. It is a further object of the invention to carry out an accurate anchor line connection procedure that does not require any additional offshore checks to be performed.

Summary of the invention

Hereto the method according to the invention comprises the steps of:

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- providing one or more anchor lines connected to an anchor that is placed at an anchor position on the sea bed,
- storing the anchor line length in a data storage unit,
- pulling an upper end of the anchor line with an installation vessel at the water surface with a predetermined force (F) at a surface position (x_1, y_1, z_1),
- measuring a tension (T) in the anchor line at or near the water surface and recording the tension (T) and the position (x_1, y_1, z_1) of the anchor line upper end in a data storage unit,

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- retrieving anchor line data from the data storage unit,
- determining on the basis of the retrieved data and the measured tension (T) and position(x_1, y_1, z_1) a mooring anchor line length $L_m(x_2, y_2, z_2)$ resulting in an anchor line connection position (x_2, y_2, z_2),
- 5 - determining a actual anchor line length L, and
- removing an over length $L - L_m(x_2, y_2, z_2)$ from the anchor line end.

Each floating and anchored offshore system is to be installed and moored to the seabed within a certain target box and with the correct tensions in its anchor lines. To
10 accommodate the as-built characteristics of the anchor lines and to remain within the installation tolerances, each mooring line is connected to the sea bed with a certain over length. This over length is adjusted on site to achieve the target position and the target mooring line tensions. According to one embodiment the upper end of the mooring line comprises a chain section, and a “reference link” calculation may be performed to
15 define the correct adjustment of the mooring line by cutting it at the reference link of the chain section.

This calculation uses data relating to the anchor lines that are stored in the data storage unit and that may be based on offshore subsea measurements which are taken during anchor line installation. The anchor line over length calculation according to
20 present invention prevents inaccuracies arising from the known installation methods and may for instance comprise collecting the as-built data of each anchor line component from the various suppliers (for the chain, shackle, wire, polyester, tri-plate, etc) in the data storage unit and providing the data with an identification number. Thereafter the anchors may be positioned in the seabed and the as-installed positions
25 recorded in the data storage unit. Identification numbers of each anchor line component during offshore anchor line assembling and installation are recorded. Next, in case an upper end in the form of a chain section is used, a reference link assessment operation may be carried out followed by a reference link calculation, cutting the extra length of anchor line upper end (chain) at the reference link and completing hook up to the
30 offshore structure.

The reference link assessment operation consists of pulling on the anchor line with the installation vessel to achieve a specific anchor line tension (as close as possible to the final hook up tension) while recording tension with a calibrated load

cell placed at or near the installation vessel as well as the exact position (x_1, y_1, z_1) of the load cell with a known high-accuracy GPS system.

The method according to the invention preferably assess the impact on the anchor line tensions (for both intact and damaged conditions) of all inaccuracies of the anchor line components that are supplied before going offshore and of the positioning measurement systems during the offshore installation phase, combined in the most unfavourable configuration.

The method according to the invention provides a very accurate calculation as it depends on as-built data. Precision of the surface method depends mainly on the measurement accuracies and the precision of anchor line over length cutting. Furthermore, mooring line tensioning measurements can be performed from any point on the anchor line. An accurate and definite mooring line configuration reduces the uncertainties that need to be compensated, for instance by a calibration parameter.

An advantage of the method according to the invention is that it removes the inaccuracy of subsea acoustic positioning systems while at the same time it avoids offshore operations like deploying multiple expensive subsea transponder arrays. Another advantage of the method according to the invention is that it avoids the measurement error due to irregular seabed shapes and that it also takes into account the actual catenary shape of the anchor lines (by for instance including the as-built mass linear factor).

It should be understood that when referring to a reference link, applicant refers to the final point (or more precise the chain link) where the mooring line length will be adjusted by cutting off the measured and calculated over length part.

In one embodiment a load cell is connected between the anchor line end and the installation vessel for measuring the tension T . Providing the load cell at the anchor line upper end provides an easy access for taking tension measurements on the installation vessel and for providing the measured data to the data storage unit on the installation vessel.

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The anchor line may comprise a synthetic line section, wherein the anchor position (x_0, y_0, z_0) is stored in the data storage unit and the anchor line length is calculated on the bases of the position (x_1, y_1, z_1) of the anchor line upper end and the anchor position

x_0, y_0, z_0 in the sea bed. This may provide a more accurate determination of the mooring anchor line length for obtaining the desired anchoring position than that based on the actual length of the synthetic anchor line.

- 5 Preferably the position (x_1, y_1, z_1) in which the tension in the anchor line is measured corresponds to the desired anchor line connection position (x_2, y_2, z_2) , and the tension is about equal to the operating tension in the anchor line during mooring of the offshore structure.
- 10 Although there may be a lapse of time between cutting the anchor lines to their desired operative lengths and the attaching of an offshore structure to the upper end of each anchor line, it is preferred that the offshore structure is attached immediately following cutting off the over length of the anchor line.

An embodiment of a method of anchoring an offshore structure in accordance with the present invention will be described in detail in conjunction with the accompanying drawings.

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Brief description of the drawings

Fig. 1 schematically shows a known seabed measurement calculation method for a mooring line and the data required,

10 Fig. 2 schematically shows a reference link calculation method and the data required, and

Fig. 3 shows one embodiment of the application of the surface measurement method near a mooring line installation vessel.

15 Description of the preferred embodiments

Fig 1 illustrates a known method of how to calculate the anchoring line length adjustment to by using a “seabed measurement method”. This method consist of the following steps:

20 - By positioning the anchoring line in a straight line on the seabed and measuring its total length (l nominal), the theoretical end link position on seabed can also be calculated (P2).

- After tensioning, the reference point position is measured (P1).

25 - The distance L between P1 and the extremity of the anchoring line, based on as-built data, is calculated. The length correction to future line length variation (S) is calculated. This calculation takes into account factors such as (but not limited to), the long term creep of the mooring line (when using polyester ropes for instance), the permanent elongation due to higher loads to be experienced, the change in buried configuration (near anchor) due to soil relaxation.

30 - It is then possible to calculate the over length, derived from the distance P between P1 and P2 such that:

$$\text{Over length} = L - P + S$$

As stated before this known method lacks accuracy in several points, for example when measuring a length along the anchoring line once laid down on seabed can lead to important mistake depending on the how flat the seabed is, how straight from the mooring point the anchoring line is laid as from the mooring point or anchor, etc.

Fig 2 shows the anchoring line length adjustment according to the present invention, which is hereafter referred to as “the reference link calculation method”. An anchor line 10 is attached to the sea bed 11 in a position (x_0, y_0, z_0) via a suction anchor 12. The anchor line 10 is formed by a bottom chain 13, a spiral strand part 14 and an upper end part 15 also in the form of a chain. The upper end part 15 is attached to an installation vessel 1 at the water surface 17 via a load cell 16 for measuring the tension in the anchor line 10. The tension data from the load cell 16 may be stored in a data storage unit 20 on the vessel 1.

The data required for the calculation of the mooring anchor line length L_m which results in the desired anchor line connection position (x_1, y_1, z_1) and stored in the data storage unit 20 is based on data delivered by mooring line parts suppliers and data measured and received during the offshore installation of the anchoring and mooring line. The data measured during mooring line installation comprise for instance the water depth at the anchor point touch down point (TDP) on the seabed, the axial mooring line tension, the position of the stern roller of the installation vessel 1, the exact surface position of the installation vessel 1 with High Precision DGPS. The supplier has provided beforehand the data of each mooring line component such as the length and weight of the bottom chains 13, the length and weight of the spiral strands 14, etc.

Hence, as the length of the anchor line parts constituting anchor line 10 are accurately known beforehand, the tension T measured in the load cell 16 and the position x_1, y_1, z_1 of the mooring line 14 allows for an accurate pre-calculation of an anchor position (x_2, y_2, z_2) . Once the anchor position is calculated, it is possible to (re)-calculate the anchor line length L_m that is required to match the target criteria, i.e. to obtain an anchoring position (x_2, y_2, z_2) at a predetermined tension T .

It could be considered to re-calculate with another parameter. For instance if the length of the polyester mooring line part is less accurate than the position of the anchor, then based on the anchor position and surface measurement, the polyester length is re-

calculated and used to assess the required line length. By taking into account different accurate parameters, an efficient way to double check the accuracy of the results can be obtained as well via this calculation method.

5 Fig 3 illustrates one embodiment of the application of a surface measurement method according to the invention. In this figure a simplified back view of an installation vessel 1 is shown. Measurements of the tension and position of anchoring line 4 are made near the stern of the installation vessel 1. The reference link assessment operation consists of pulling on the anchor line 4 with the installation vessel to achieve
10 a specific anchor line tension T as close as possible to the final hook up tension, while recording at the same time the mooring line tension with a load cell and the recording the position (x_1, y_1, z_1) of the load cell with a known high-accuracy GPS, which can be performed on the installation vessel 1.

 Then the calculation method enables to calibrate a pre-calculated and pre-
15 designed anchor line model with the offshore measured data and the over length of the upper chain part of the mooring line can be derived real time, in order to install the mooring lines and consequently the offshore system 2 within a pre-defined target box and with line tensions that are within the tolerances on the floating system chain stopper. In fact, the calculation shifts (see arrow 3) the reference link assessment from
20 the stern of the installation vessel 1 to its connection on the offshore system 2. In figure 3, the offshore system 2 is a FPSO (Floating and Production , Storage and Offloading system), but this method can be used for the installations of other floating systems as well like Calm buoys, deepwater buoys, Semi-sub, Spars, Tension Line Platforms, spread or turret moored barges, etc.

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 The improved accuracy of this new calculation method, enables to provide an installed mooring line is within specifications without the need for any further time consuming mooring line adjustment activities after the mooring line hook up procedure has been finalized, as is the case with known calculation and installation methods.

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 Although particular embodiments of the invention have been described and illustrated herein, it is recognized that modifications and variations may readily occur

to those skilled in the art, and consequently, it is intended that the claims be interpreted to cover such modifications and equivalents.

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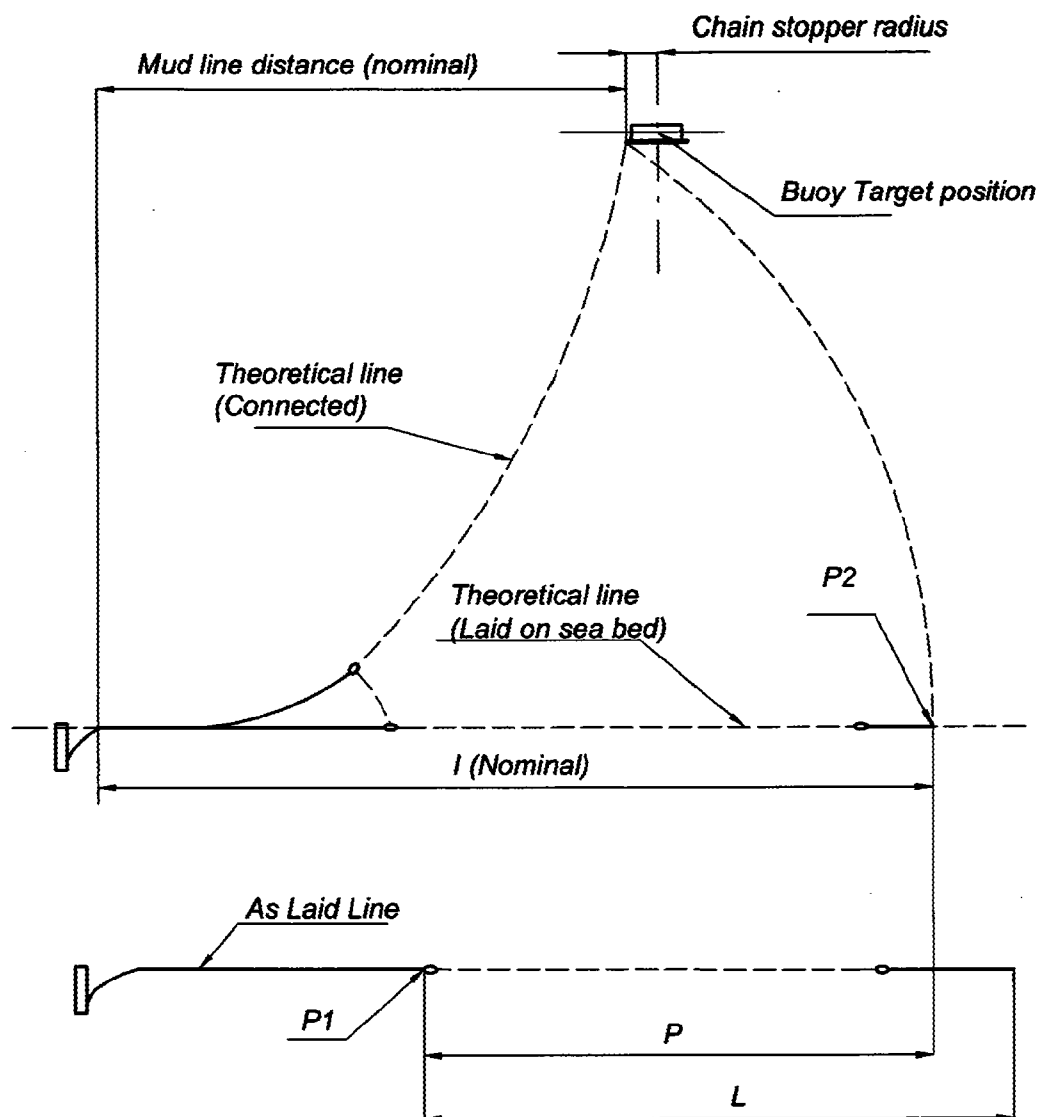
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Claims

1. Method of installing an offshore structure comprising the steps of:
 - 5 - Providing one or more anchor lines connected to an anchor that is placed at an anchor position on the sea bed,
 - Storing the anchor line length in a data storage unit,
 - Pulling an upper end of the anchor line with an installation vessel at the water surface with a predetermined force (F) at a surface position (x_1, y_1, z_1) ,
 - 10 - Measuring a tension (T) in the anchor line at or near the water surface and recording the tension (T) and the position (x_1, y_1, z_1) of the anchor line upper end in a data storage unit,
 - Retrieving anchor line data from the data storage unit,
 - Determining on the basis of the retrieved data and the measured tension (T) and position (x_1, y_1, z_1) a mooring anchor line length $L_m(x_2, y_2, z_2)$ resulting in an anchor line connection position (x_2, y_2, z_2) ,
 - 15 - Determining a actual anchor line length L, and
 - Removing an over length $L - L_m(x_2, y_2, z_2)$ from the anchor line end.
- 20 2. Method according to claim 1, wherein a load cell is connected between the anchor line end and the installation vessel for measuring the tension (T).
3. Method according to claim 1 or 2, wherein the anchor line comprises a synthetic line section, wherein the anchor position (x_0, y_0, z_0) is stored in the data storage unit and the anchor line length is calculated on the bases of the position
 - 25 - (x_1, y_1, z_1) of the anchor line upper end and the anchor position (x_0, y_0, z_0) .
4. Method according to any of the preceding claims, wherein the position (x_1, y_1, z_1) corresponds to the anchor line connection position (x_2, y_2, z_2) .
- 30 5. Method according to any of the preceding claims, followed by attaching the anchor line upper end to an offshore structure for mooring said offshore structure to the sea bed.

1/3

Fig 1



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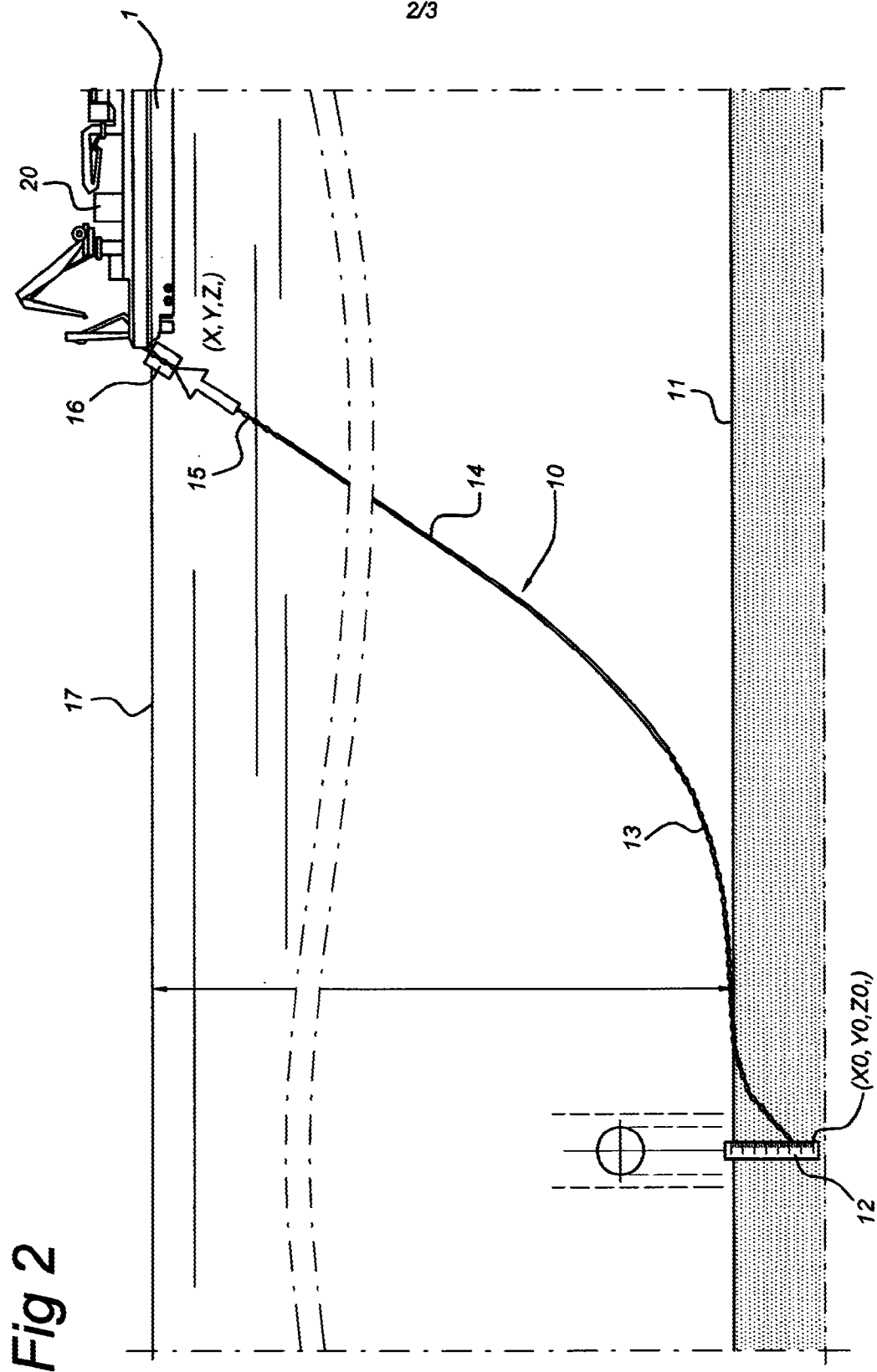


Fig 3

