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(54) Benævnelse: **APPARAT OG FREMGANGSMÅDE TIL INSTALLATION AF OFFSHORE-FUNDAMENTER**

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The present invention relates to an arrangement and a method for installing offshore foundations, in particular offshore foundations for wind turbines and substation platforms.

In the prior art various techniques are known (such as, for example, from document DE-A1-102012021001) for building offshore foundations for wind turbines. It is known *inter alia* to transport a foundation member prefabricated on land by floating it by means of attached buoyancy bodies to its final place of use. At the place of use the foundation is then released and - if it does not already provide a sufficient foundation due to its mass – is secured if necessary with foundation piles.

Since prior art offshore foundations from the prior art do not have sufficient floating stability, especially when released, a corresponding foundation can only be released by using a crane construction. The use of suitable heavy duty floating cranes suitable for this purpose is however extremely costly and, on account of the limited availability of suitable floating cranes, is not always possible. Furthermore, it is known to improve the floating stability by special geometries or the use of certain materials, which is however generally complicated and costly.

The object of the invention is to provide an arrangement and a method for installing offshore foundations, in which the disadvantages known from the prior art no longer occur or only to a lesser extent.

This object is achieved by an arrangement according to the main claim as well as a method according to the independent claim 15. Advantageous developments are the subject matter of the dependent claims.

Accordingly, the invention relates to an arrangement for the installation of offshore foundations comprising a floatable foundation body with at least one air-filled ballast in the floating state, which can be filled with ballast to lower the foundation body, wherein at least one anchor arranged on the ground in the region of the desired installation site of the foundation body anchor and at least one cable pull device are provided, wherein each of the at least one cable pull devices is designed to hold in each case under tensile stress a pull cable guided between a common or in each case separate anchor(s) and the foundation body during the lowering of the foundation body, so that a tensile force that increases the floating stability acts on the foundation body.

Furthermore, the invention relates to a method for installing offshore foundations with an arrangement according to the invention, wherein the at least one pull cable is tensioned during the lowering of the foundation body by the cable pull device to a predetermined nominal tension.

Various advantages are achieved by the at least one pull cable provided according to the invention, which is stretched between the foundation body and an anchor and is held under tension during the lowering operation.

On the one hand a sufficient floating stability of the foundation body during the lowering operation is achieved on account of the tensile stress permanently maintained by the at least one cable pull device. Since the at least one pull cable is in fact held under tension, the foundation body is constantly pulled downwards by a tensile force, whereby the point of engagement for the buoyancy force from an otherwise resulting equilibrium position with the point of engagement for the weight force in the direction opposite to the tensile force introduced by the at least one pull cable in the foundation body is displaced, so that the foundation body is stably aligned, taking into account the point or points at which the at least one pull cable engages at the foundation body. In this connection it should be noted that the at least one pull cable provided according to the invention does not have to overcome the buoyancy force of the foundation body itself in air-filled ballast chambers. Rather, the actual lowering procedure, as already known from the prior art, is carried out by filling the air-filled ballast chamber with ballast, such as for example water, sand or concrete. The tensile force to be applied by the at least one pull cable or the cable pull device therefore only has to be sufficient so as to ensure the afore-described stabilisation of the floating position of the foundation body during the lowering procedure.

In addition, with the arrangement according to the invention it is ensured that the foundation body is installed at the position predetermined by the anchor. By maintaining the at least one pull cable under tensile stress by the cable pull device during the lowering of the foundation body, the foundation body can be guided towards the at least one anchor. Thus, if the at least one anchor is located at the desired position for the foundation body, it is ensured in the arrangement according to the invention that the foundation body actually also comes to lie at the desired position.

It is preferred if at least one anchor is a ballast anchor comprising a ballast body. A "ballast anchor" is an anchor whose anchoring effect is based essentially on its weight or the weight of the ballast body. The ballast anchor in the state of use thus simply rests on the bottom and in particular has no flukes that can dig into the ground or become wedged there. The ballast anchor can preferably be held at a distance from the bottom by the at least one pull cable on the floating foundation body and can be released from there via the at least one cable pull device. In other words, the ballast anchor can first of all be carried along with the floating base body, while this is brought floating independently for example from a port to the final installation site. At the desired installation site, the ballast anchor can then be lowered down to the bottom. In particular, under slack water conditions - i.e. when the tidal current is still - and in calm weather, the position on the bottom at which the ballast anchor comes to rest can be well influenced by the positioning of the floating foundation body.

A ballast anchor has a maximum vertical anchor retention force for a vertical pulling on the anchor, which in the simplest case correlates directly with the weight of the ballast anchor. The vertical tensile force acting on the ballast tank due to the tension in the at least one pull cable starting from the at least one cable pull device during the lowering of the foundation body is less than if the maximum vertical anchor holding force were chosen, since otherwise the ballast anchor would be raised.

The ballast anchor preferably has at least one ballast chamber and / or ballast trough that can be filled with ballast. If these ballast chambers and/or ballast troughs are filled on the bottom with ballast (e.g. water, sand or concrete), for example after successful release of the ballast anchor, the weight of the ballast anchor and thus its maximum vertical anchor holding force can thereby be increased.

It is preferred if the ballast anchor has a circumferential skirt and a negative pressure module on its underneath side formed so as to rest on the bottom, wherein the negative pressure module is designed to generate a negative pressure between the ballast anchor and bottom within the skirt during or after the ballast anchor has been laid on the bottom. If a corresponding negative pressure is generated, the ballast anchor is sucked to the bottom according to the suction-bucket principle. Also, the maximum vertical anchor holding force of a ballast anchor can be increased in this way. The negative pressure module can be a pump. However, it may also be sufficient to provide a check valve as negative pressure module, whose forward direction leads from the underneath side within the skirt to a region outside the skirt.

The ballast anchor preferably has on its upper side facing towards the foundation body a shaping centring the foundation body, which cooperates with a correspondingly inverted shaping of the foundation body at its underneath side facing the ballast anchor. For example, the ballast anchor can have a conical-shaped elevation on its upper side, which can cooperate with a conical-shaped depression in the foundation body. The accuracy of the positioning of the foundation body at the position predetermined by the ballast anchor can thereby be improved.

The ballast anchor can preferably have on its upper side facing towards the foundation body a connection element, with which after the complete lowering of the foundation body the ballast anchor can be fastened to the latter in such a way that at least part of the weight of the ballast anchor is introduced into the foundation body via the connection element. In this way it is ensured that after the foundation body has been successfully lowered the ballast anchor is no longer needed as an aid for the release, although its mass can contribute at least partially as an additional weight in securing the foundation body.

As an alternative to a ballast anchor, at least one of the anchors may be a ground anchor or rock anchor. A corresponding anchor can be installed in a known manner on the bottom in order to be used subsequently in the arrangement according to the invention.

It is preferred if the at least one anchor has for each pull cable that is guided via the latter, a guide pulley in the form of a loose pulley for the guidance of the pull cable. If the anchor has one or more corresponding guide pulleys, a pull cable can be guided from the foundation body via the guide pulley at the anchor to the cable pull device, whereby the force required by the cable pull device to produce the desired tension is reduced, in particular halved.

A lifting tackle distributing the carrying capacity of the pull cable is preferably provided between a pull cable and the anchor. By means of a corresponding lifting tackle, which for example can resemble a lifting harness, the floating stability of the ballast anchor can be improved during its lowering, especially if only one pull cable is provided.

It is possible that the cable pull device is a ship, which moves away from the anchor so as to tension the pull cable. It is however preferred if at least one of the at least one cable pull devices is a cable winch. The winch is in this connection preferably attached to the foundation body itself.

Furthermore, it is preferred if at least three tension cables spaced from one another are provided in the region between the foundation body and the anchor. By providing at least three tension cables the position of the foundation body during the lowering can be controlled in a regulated manner.

The foundation body preferably has multiple ballast chambers that can be filled separately from one another with ballast, wherein the ballast chambers can be formed in the foundation body itself or in buoyancy bodies connected to the foundation body. If multiple ballast chambers are provided, which can be filled separately with ballast, it is possible to control more effectively the position of the foundation body during the lowering procedure. If the ballast chambers are provided in separate buoyancy bodies, the separate buoyancy bodies can be removed after the successful release of the foundation body and then be reused.

A control unit is preferably provided, which is designed to control the filling of the at least one ballast chamber of the foundation body and/or the at least one cable pull device, so that during the lowering procedure of the foundation body the at least one pull cable is subjected to a force below a predetermined nominal tensile stress. By an appropriate control procedure, the lowering of the foundation body can be precisely controlled, in order to avoid for example an undesirable change in position of the foundation body.

It is preferred if the foundation body is designed for pad foundation or deep foundation and/or the foundation body is produced in concrete, steel or hybrid construction. In the case of a pad foundation the foundation takes place solely on account of the weight of the foundation body and possibly its ballast and / or a ballast anchor fastened thereto, while for a deep foundation piles are driven into the ground, with which the foundation body is fastened to the bottom.

To explain the method according to the invention, reference is made to the above implementations.

The invention will now be described by way of example with the aid of advantageous embodiments and with reference to the accompanying drawings, in which:

Figs. 1a-d:	show a schematic representation of an installation procedure of a first exemplary embodiment of an arrangement according to the invention for installing offshore foundations;
Fig. 2a-b:	shows schematic detailed representations of the arrangement according to Figs 1a-d;
Fig. 3:	shows a schematic representation of a second exemplary embodiment of an arrangement according to the invention for installing offshore foundations; and
Fig. 4:	shows a schematic representation of a third exemplary embodiment of an arrangement according to the invention for installing offshore foundations.

Figs. 1a-d show a first exemplary embodiment of an arrangement 1 according to the invention for installing offshore foundations. The arrangement 1 comprises a floatable foundation body 10 with multiple ballast chambers 11. The ballast chambers 11 are filled with air in the floating state but can be filled with ballast to lower the foundation body 1.

The arrangement 1 further comprises a ballast anchor 20 with a ballast chamber 21 arranged in a ballast body. In the illustrated exemplary embodiment, the ballast chamber 21 is formed so that even in the air-filled state the weight of the ballast anchor 20 is greater than the buoyancy of the ballast anchor 20. By filling the ballast chamber 21 with ballast, in particular only the weight of the ballast anchor 20 can thus be increased.

The ballast anchor 20 is connected via a pull cable 30 to a cable winch 40 arranged on the foundation body 10 and can thus be held on the foundation body 10 in a position spaced from the bottom 90, as is illustrated in Fig. 1a. As a result, the foundation body 10 can be brought together with the ballast anchor 20 by a transport ship 91 to the desired installation site.

At the desired installation site, the ballast anchor 20 is lowered by means of the winch 40 to the bottom 90 (see Fig. 1b), wherein the release preferably taking place under still water conditions and in calm weather. In order to prevent the ballast anchor 20 behaving unstably during the lowering procedure, on the one hand the lowering speed should be chosen correspondingly low. On the other hand, a lifting tackle 31 in the form of a lifting harness is provided between the pull cable 30 and the ballast anchor 20, with which the tensile force of the pull cable 30 is distributed to multiple connection points on the ballast anchor 20.

When the ballast anchor 20 rests on the bottom 90, the ballast chamber 21 of the ballast anchor 20 is filled with ballast so as to increase the weight of the ballast anchor 20. This is correspondingly indicated in Figure 1b, in which the ballast chamber 21 is already partially filled.

The foundation body 10 in which the ballast chambers 11 of the foundation body 10 are filled with ballast, is then released (see Fig. 1c). During the lowering procedure the pull cable 30 is held under tension by the cable winch 40 so that a tensile force acts towards the bottom 90 on the foundation body 10, which contributes to increasing the floating stability. At the same time this pulling force is less than the maximum vertical anchor holding force of the ballast anchor 20, so as to ensure that it does not come loose from the bottom 90.

In addition to increasing the floating stability, it is ensured in the arrangement according to the invention 1 illustrated in Figs. 1a-d that the foundation body 10 is installed at the predetermined position by the ballast anchor 20 (see Fig. 1d). In addition to the positioning due to the connection of the ballast anchor 20 to the foundation body 10 via the pull cable 30, the ballast anchor 20 and foundation body 10 have a centring shape, with which the relative position of the two components with respect to each other in the installation state of the foundation body (Fig. 1d) is determined. This centring shaping is shown in more detail in Figs. 2a-b.

The ballast anchor 20 has a cone-shaped elevation 23 on its upper side 22 facing towards the foundation body 10. At the same time the foundation body 10 has a corresponding cone-shaped recess 13 on its lower side 12 facing the ballast anchor 20. The cone-shaped surfaces 13, 23 act as centring surfaces when the foundation body 10 approaches the ballast anchor 20 during the last phase of the lowering of the foundation body 10.

A further exemplary embodiment of an arrangement according to the invention is shown in Fig. 3. Since this exemplary embodiment essentially corresponds to that of Figs. 1a-d, in particular with regard to the installation process that can be realised therewith, and also has the shape explained in connection with Figs. 2a-b, reference is made to the implementations there for purposes of explanation. In the following only the differences compared to the above will be discussed.

In the exemplary embodiment according to Fig. 3, three pull cables 30 are provided, which are guided parallel and spaced apart from each other in the region between the foundation body 10 and the ballast anchor 20. Each of the three pull cables 30 has its own independently controllable cable winch 40, which are fixed distributed uniformly over the circumference to the foundation body 10.

A guide pulley 24 is provided on the ballast body 20 for each of the pull cables 30. The pull cables 30 are each guided by a guide pulley 24 and fastened directly to the foundation body 10 with their end remote from the winch 40. By providing the guide pulleys 24, the force to be applied by the cable winch 40 can be reduced.

The ballast anchor 20 has a circumferential skirt 26 on its underneath side 25 formed to rest on the bottom 90. In addition, a pump is provided as a negative pressure module 27, with which within the skirt 26 a negative pressure can be generated between the ballast anchor 20 and bottom 90 after the ballast anchor 20 has been laid on the bottom 90, so as to increase the vertical anchor holding force of the ballast anchor 20. In other words, a suction of the ballast anchor 20 to the bottom 90 takes place according to the suction-bucket principle.

On its upper side 22 facing the foundation body 10 the ballast anchor 20 has a connection element 28. The ballast anchor can be fastened with this connection element 28 to the foundation body 10 after the latter has been lowered, so that at least part of the weight of the ballast anchor 20 is introduced into the foundation body 10 via the connection element 28. The weight of the ballast anchor 20 can then contribute at least partially as an additional weight to secure the foundation body 10.

By providing three separate pull cables with three separately controllable cable winches 40, the lowering procedure of the foundation body 10 can be controlled very precisely via a control unit, not shown, whereby in particular undesirable changes in position of the foundation body 10 can be counteracted. If the foundation body 10 has ballast chambers 11 which can be separately filled with ballast, the control unit can also control the filling of the individual ballast chambers 11 during the lowering procedure.

Fig. 4 shows a further exemplary embodiment of an arrangement 1 according to the invention, which basically is directed on the exemplary embodiment according to Figs. 1a-d. Only the differences from this embodiment will therefore be discussed hereinafter, reference otherwise being made to the previous implementations.

In the embodiment according to Fig. 4, instead of a ballast anchor 20, a ground anchor 20’ is provided, which is fastened in a known manner to the bottom 90 and has a guide pulley 24. A pull cable 30 is guided over this guide pulley 24, the pull cable being fixedly connected at one end to the foundation body 10. At its other end the pull cable is attached to a towboat 40'. During the lowering procedure of the foundation body 10, which takes place similarly to that of Figs. 1a-b by filling the ballast chambers 11 of the foundation body 10 with ballast, the towboat 40' moves away from the installation site for the foundation body 10 so that the tension on the pull cable 30 always remains below a predetermined value.

In all the illustrated embodiments the foundation body 10 is formed for pad foundation. However, it is of course also possible that the foundation body 10 is designed for deep foundation and has for example sleeves for accommodating foundation piles. The foundation body 10 can be produced in concrete, steel or hybrid construction. Water, sand or concrete can for example be used as ballast.

Patentkrav

1. Apparat (1) til installation af offshore-fundamenter omfattende et flydedygtigt fundamentlegeme (10) med mindst et i flydende tilstand luftfyldt ballastkammer (11), der kan fyldes med ballast til nedsænkning af fundamentlegemet (10),
kendetegnet ved, at
der er tilvejebragt mindst et på bunden (90) i området ved det ønskede installationssted for fundamentlegemet (10) anbragt anker (20, 20') og mindst en kabeltrækindretning (40, 40'), idet hver af den mindst ene kabeltrækindretning (40, 40') er udformet til at holde et mellem et fælles eller særskilte anker/re (20, 20') og fundamentlegemet (10) styret trækkabel (30) således under trækspænding under nedsænkningen af fundamentlegemet (10), at en trækkraft, der forøger flydestabiliteten, virker på fundamentlegemet (10).

2. Apparat ifølge krav 1,
kendetegnet ved, at
mindst et af ankrene (20, 20') er et ballastanker (20) omfattende et ballastlegeme, der fortrinsvis kan holdes i afstand fra bunden gennem det mindst ene trækkabel (30) ved det flydende fundamentlegeme (10) og kan sænkes fra det flydende fundamentlegeme (10) ved hjælp af den mindst ene kabeltrækindretning (40, 40').

3. Apparat ifølge krav 2,
kendetegnet ved, at
ballastankeret (20) har mindst et ballastkammer (21) eller ballasttrug, som kan fyldes med ballast.

4. Apparat ifølge krav 2 eller 3,
kendetegnet ved, at
ballastankeret (20) på sin til at ligge på bunden (90) udformede underside (25) har et omløbende skørt (26) og et undertryksmodul (27), fortrinsvis en tilbageslagsventil og/eller en pumpe, idet undertryksmodulet (27) er udformet til frembringelse af et undertryk under eller efter nedlægningen af ballastankeret (20) på bunden (90) mellem ballastanker (20) og bund (90) inden for skørtet

(26).

5. Apparat ifølge et af kravene 2 til 4,

kendetegnet ved, at

ballastankeret (20) på sin mod fundamentlegemet (10) vendende overside (22) har en fundamentlegemet (10) centrerende form, som samvirker med en tilsvarende inverteret form på fundamentlegemet (10) ved dettes mod ballastankeret (20) vendende underside (22).

6. Apparat ifølge et af kravene 2 til 5,

kendetegnet ved, at

ballastankeret (20) på sin mod fundamentlegemet (10) vendende overside (22) har et forbindelseselement (28), med hvilket ballastankeret (20) efter fuldstændig nedsænkning af fundamentlegemet (10) kan fastgøres således til dette, at i det mindste en del af ballastankerets (20) vægt via forbindelseselementet (28) indføres i fundamentlegemet (10).

7. Apparat ifølge et af de foregående krav,

kendetegnet ved, at

mindst et af ankrene (20, 20') er et jordanker (20') eller et indstøbningsanker.

8. Apparat ifølge et af de foregående krav,

kendetegnet ved, at

det mindst ene anker (20, 20') for hvert over dette ført trækkabel (30) har en trisse (24) til gennemføring af trækkablet (20) som løs trisse.

9. Apparat ifølge et af kravene 1 til 7,

kendetegnet ved, at

der mellem et trækkabel (30) og ankeret (20, 20') er tilvejebragt et anslagsmiddel (31), der fordeler trækkablets (30) bærekraft.

10. Apparat ifølge et af de foregående krav,

kendetegnet ved, at

mindst en af den mindst ene kabeltrækindretning (40, 40') er en kabelvinde (40), idet kabelvinden (40) fortrinsvis er fastgjort til fundamentlegemet (10).

11. Apparat ifølge et af de foregående krav,
kendetegnet ved, at
der er tilvejebragt mindst tre trækkabler (30) i afstand fra hinanden i området mellem fundamentlegemet (10) og ankeret (20, 20').

12. Apparat ifølge et af de foregående krav,
kendetegnet ved, at
fundamentlegemet (10) har flere ballastkamre (11), der separat fra hinanden kan fyldes med ballast, idet ballastkamrene (11) kan være udformet i fundamentlegemet (10) selv eller i med fundamentlegemet (10) forbundne opdriftslegemer.

13. Apparat ifølge et af de foregående krav,
kendetegnet ved, at
der er tilvejebragt en styringsenhed, som er udformet til styring af fyldningen af det mindst ene ballastkammer (11) i fundamentlegemet (10) og den mindst ene kabeltrækindretning (40, 40'), således at det mindst ene trækkabel (30) under fundamentlegemets (10) nedsænkning står under en forudbestemt nominel trækspænding.

14. Apparat ifølge et af de foregående krav,
kendetegnet ved, at
fundamentlegemet (10) er udformet til overfladefundering eller til dybdefundering, og/eller fundamentlegemet (10) er fremstillet som beton-, stål- eller hybridkonstruktion hergestellt ist.

15. Fremgangsmåde til installation af offshore-fundamenter med et apparat ifølge et af de foregående krav, idet det mindst ene trækkabel (30) under fundamentlegemets (10) nedsænkning holdes under en forudbestemt nominel trækspænding af kabeltrækindretningen (40, 40').

Fig. 1a

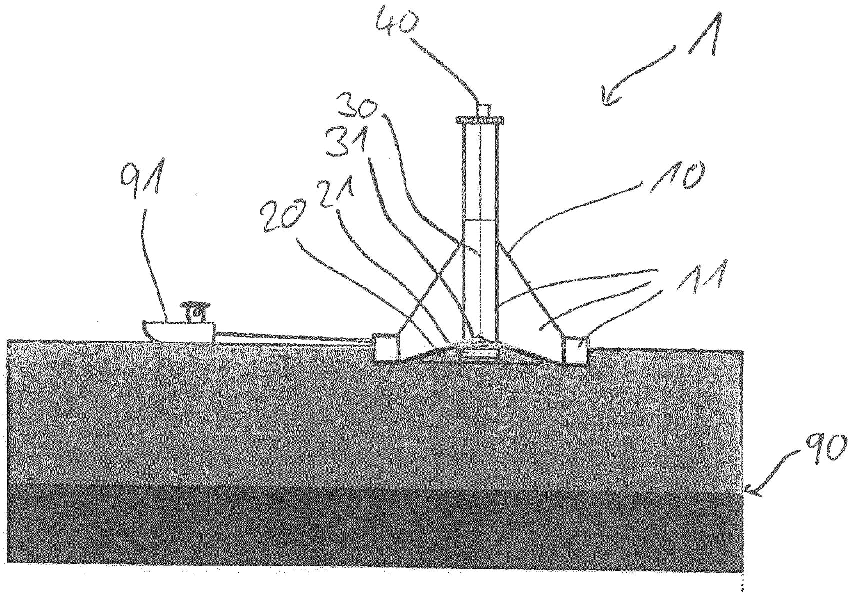

Fig. 1b

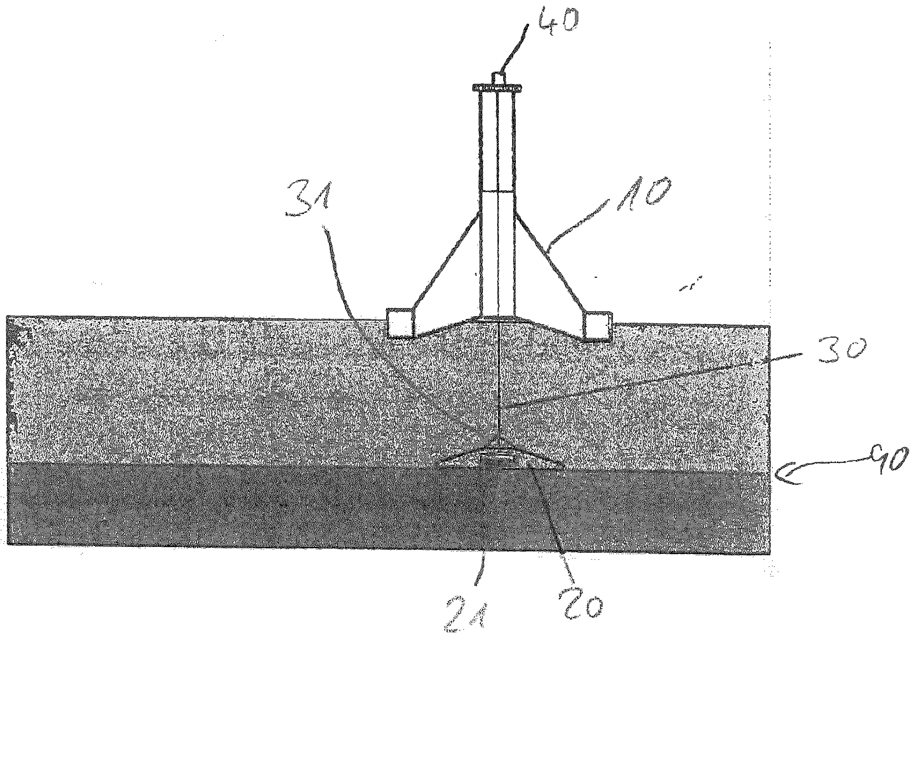

Fig. 1c

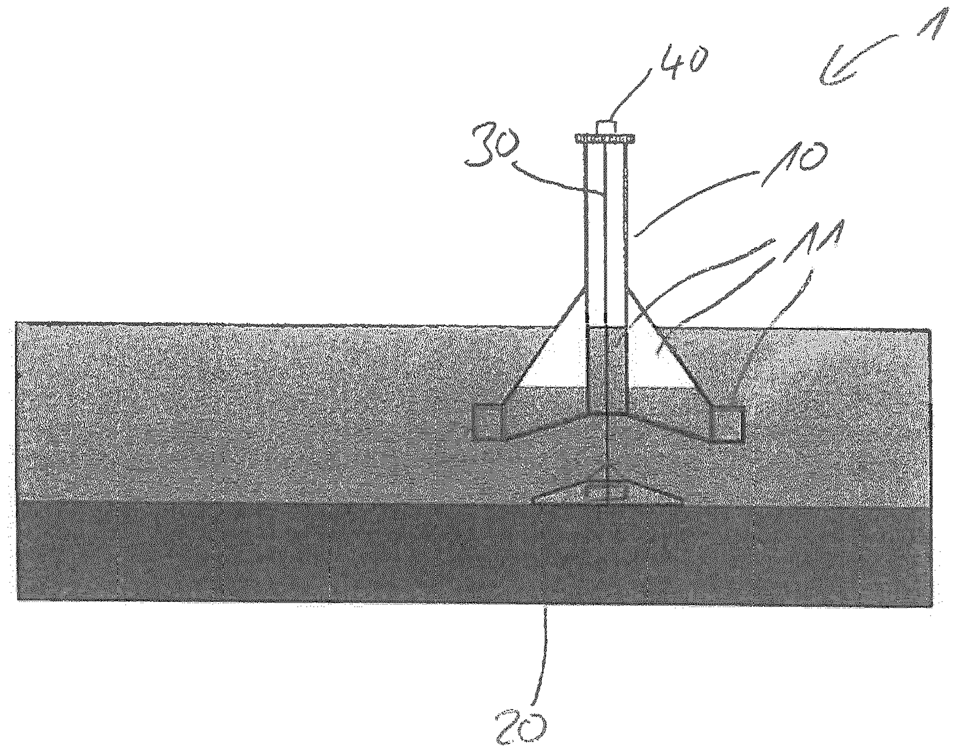

Fig. 1d

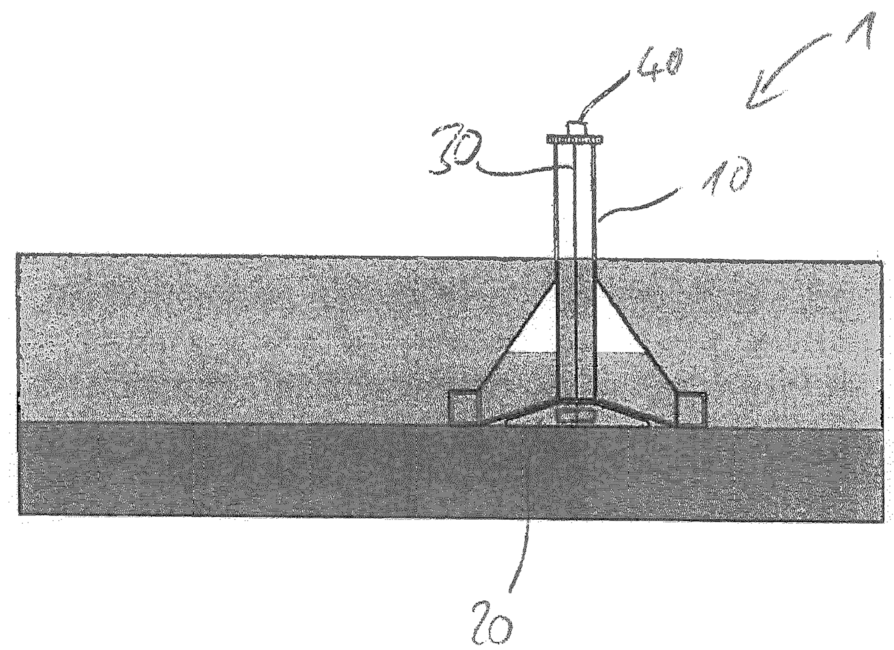

Fig 2a

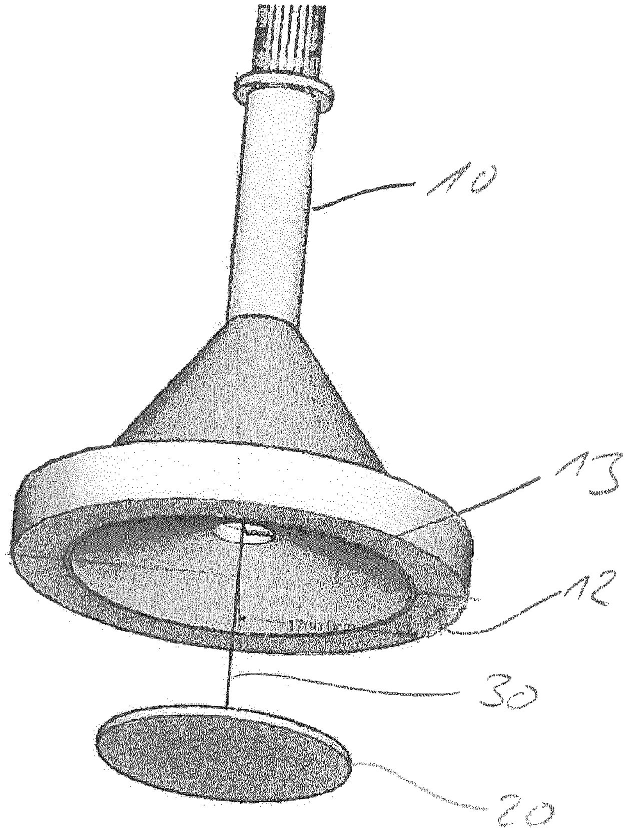

Fig 2b

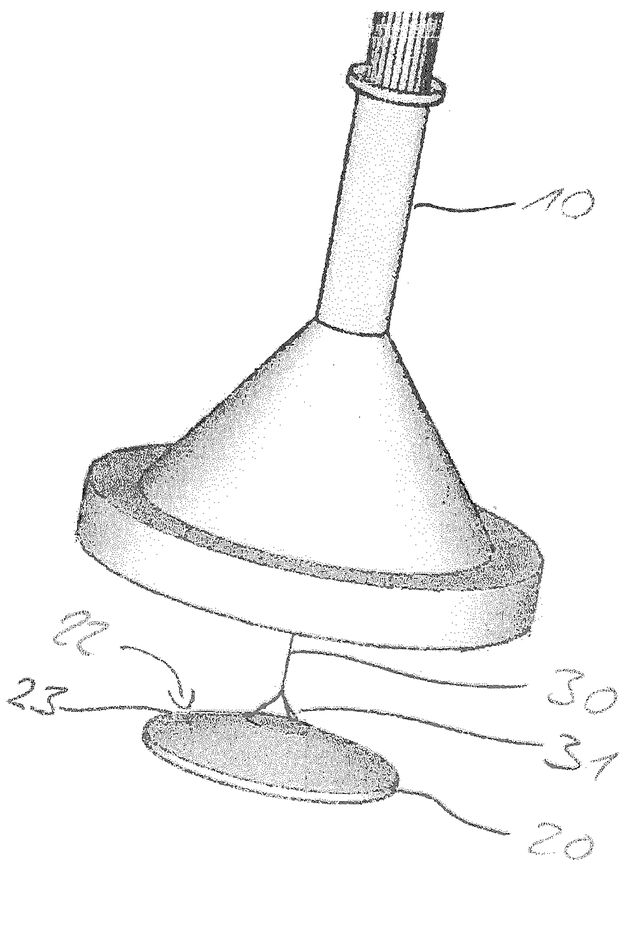

Fig. 3

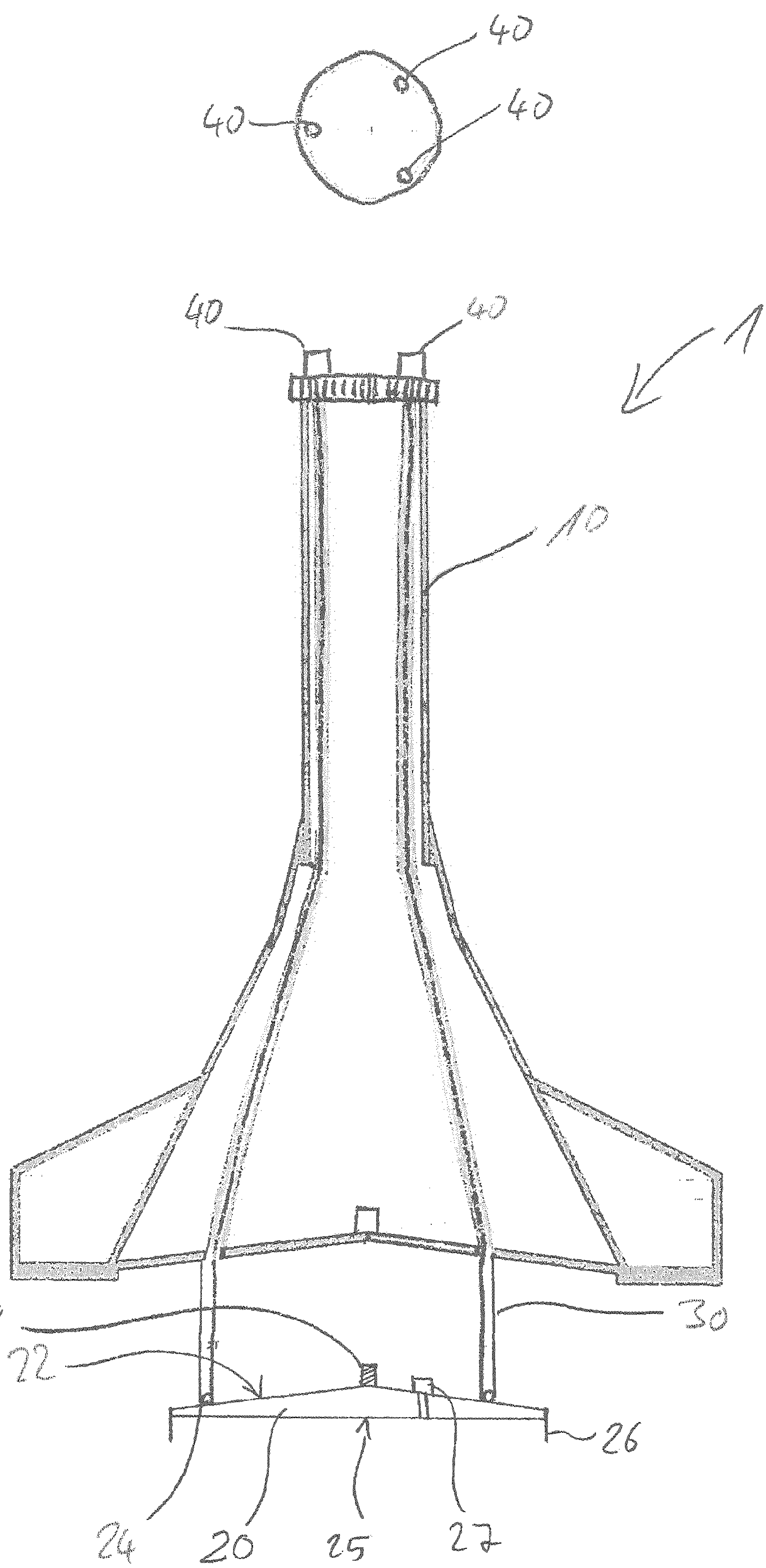

Fig. 4