DEVICE FOR ASSISTING IN INSTALLING A PILE IN THE SEABED, OFFSHORE FOUNDATION STRUCTURE AND METHOD OF ESTABLISHING AN OFFSHORE FOUNDATION

A method of establishing an offshore foundation (1) on the seabed, in particular of establishing an offshore foundation for a wind turbine installation on the seabed, is provided. In this method, an offshore foundation structure (1) comprising at least one leg (7) is set on the seabed (3) and anchored in the seabed (3) by means of a pile (10) extending from the leg into the seabed (3). The anchoring is done by flushing the pile (10) into the seabed (3).
Device for assisting in installing a pile in the seabed, offshore foundation structure and method of establishing an offshore foundation

The present invention relates to device for assisting in installing a pile in the seabed. In addition, the present invention relates to an offshore foundation structure and a method of establishing an offshore foundation.

It is known to establish mono piles, jacket constructions or tripod constructions on the seabed as foundations in particular for offshore wind turbine installations. A mono pile construction is, for example, described in WO 2009/026933 A1, US 5,988,949 and EP 2 067 914 A2, for example, describe jacket constructions, and DE 10 2004 042 066 A1, for example, describes a tripod construction.

A typical method for establishing a foundation, in particular a foundation based on a jacked construction or a tripod construction, is to prepare the seabed prior to establishing the foundation which includes levelling out variations of the high of the seabed in order to achieve a construction in level. Furthermore, the method comprises establishing piles very accurately positioned in the seabed such as by means of a pre-fabricated and pre-positioned pile positioning template structure on the seabed. The piles function as anchor of the offshore foundation.

The piles are established by using e.g. hydraulic drifting means which literally hammer the pile down into the seabed. When the pile is established, a jacket or a tripod construction is set over a part of the pile (or piles in case of a tripod construction or a jacket construction) and the space between the leg and the pile is grouted to establish a secure connection.

With respect to the mentioned state of the art it is an objective of the present invention to provide an advantageous
device for assisting in installing a pile in the seabed. It is further objective to provide an advantageous offshore foundation structure and a method of establishing an offshore foundation.

The first objective is solved by a device for assisting in installing a pile to be used for anchoring an offshore foundation in the seabed. The further objective is solved by an offshore foundation structure as claimed in claim 7 and by a method of establishing an offshore foundation as claimed in claim 11. The depending claims contains further developments of the invention.

An inventive device for assisting in installing a pile to be used for anchoring an offshore foundation in the seabed comprises nozzles and means for generating water jets ejected out of the nozzles. The water jets eddy the material of the seabed and, thereby, create low resistance for the pile to be positioned. The device may be integrated into a pile to be used for anchoring an offshore foundation. In this case, the pile may comprises a tip with the nozzles of the device being located in the tip. Alternatively, the device may be a separate device which creates eddies in the material of the seabed. The pile then follows closely to the device so as to penetrate the flushed material.

The device for assisting in installing a pile in the seabed may comprise a flush control means being connected to the nozzles, e.g. by one or more hoses. In particular, if the device is integrated into a pile to be used for anchoring an offshore foundation in the seabed the flush control means may be integrated into the pile. Alternatively, it may be external to the pile.

The inventive device facilitates drifting the piles into the seabed. In particular, with using the inventive device the installation of the piles does not require specialised vessels or heavy equipment. Moreover, two or more inventive de-
vices may be operated in parallel so that two or more piles can be drifted into the seabed at the same time, which is time saving and, hence, also cost saving.

In addition, the inventive device offers the opportunity to install a whole construction like a tripod or jacket construction at a time, thereby minimizing the time for occupying expensive specialised vessels for the installation.

An inventive offshore foundation structure, in particular an offshore foundation structure for a wind turbine, which is to be installed on the seabed comprises at least one foot and a pile for anchoring the offshore foundation structure in the seabed. The offshore foundation structure, for example the pile of the offshore foundation structure, comprises an inventive device for assisting in installing a pile in the seabed. With the so designed foundation structure the advantages mentioned with respect to the device for assisting in installing a pile in the seabed can be achieved with the offshore foundation structure.

In a first concrete implementation of the offshore foundation structure the structure comprises at least one hollow leg with an interior hollow space. The pile is located inside the hollow space. Such a foundation structure can be positioned with the feed on the seabed, and afterwards anchored by drifting the piles into the seabed. The inventive offshore foundation structure therefore overcomes the need for pre-installing piles in the seabed onto which the structure has to be set. Pre-installed piles would need to be positioned very accurately so that the typically three or more legs of a tri-pod or jacket structure can be placed over the ends of the piles projecting from the seabed. Hence, pre-installing the piles is very elaborate. With the inventive offshore foundation structure according to the described implementation the anchoring procedure can be simplified in that it is not necessary to accurately pre-install the piles for anchoring the structure.
In a further implementation, the offshore foundation structure comprises at least one leg with a foot and a pile that extends from the foot. In other words, the pile is fixed to the foot so as to project from the foot towards the seabed. The pile is then drifted into the seabed by means of the device for assisting in installing a pile in the seabed together with the foundation structure to which the pile is connected. This means that a whole offshore foundation structure can be placed on and anchored in the seabed by a single process step, which is time saving and, hence, also cost saving. It may even be possible to settle the foundation onto the seabed driven by the weight of the structure, due to the low resistance of the flushed seabed material.

In the inventive method of establishing an offshore foundation on the seabed, in particular of establishing an offshore foundation for a wind turbine installation on the seabed, an offshore foundation structure comprising at least one leg is set on the seabed and anchored in the seabed by means of a pile extending from the leg into the seabed. According to the inventive method, the at least one leg is anchored in the seabed by flushing the pile into the seabed. For flushing the pile into the seabed an inventive device for assisting in installing a pile in the seabed is used. The device may be integrated into the pile or may be an external device which eddies the material of the seabed so that the pile can be drifted into the seabed by closely following the device so as to penetrate the flushed material.

In a first implementation of the inventive method a pile is flushed into the seabed out of the interior hollow space of an offshore foundation structure leg after the offshore foundation structure has been set on the ground.

In an alternative implementation, an offshore foundation structure with a pile extending from the at least one foot is used. In this implementation, the offshore foundation struc-
tue is set on the ground with the pile and the pile is flushed into the seabed whereupon the offshore foundation structure settles with the at least one foot on the seabed. In this implementation of the method anchoring an offshore foundation structure and settling the structure on the seabed is performed in a single process step which is time saving and cost saving since the time for occupying expensive specialised vessels for in the installation can be reduced. To the low resistance of the flushed seabed material it may even be possible to drive the settling process by the weight of the structure.

In any implementation of the inventive method, the inventive device for assisting in installing a pile in the seabed can be used for flushing the pile into the ground. The device may be integrated into the pile or may be an individual device which flushes the material of the seabed. In the letter case the pile follows closely the individual device to penetrate the flushed material.

Further features, properties and advantages of the present invention will become clear from the following description of embodiments in conjunction with the accompanying drawings.

Figure 1 shows a jacket or tripod structure of an offshore wind turbine foundation in a highly schematic view.

Figure 2 shows a mono pile structure of an offshore wind turbine foundation in a highly schematic view.

Figure 3 shows a section of a first embodiment of the inventive offshore foundation structure.

Figure 4 shows a section of a second embodiment of the inventive offshore foundation structure.
Typical offshore foundations for wind turbines which can realise the present invention, are shown in Figures 1 and 2 in highly schematic views. While Figure 1 shows a foundation using a jacket structure or tripod structure as foundation structure Figure 2 shows a foundation using a mono pile as foundation structure.

The jacket or tripod structure 1 shown in Figure 1 comprises three hollow legs 7 each forming a tubular hollow foundation member. Each leg 7 is equipped with an open longitudinal end 5 located in a foot 4 which is placed on the seabed 3 such that the open longitudinal end 5 shows towards the seabed 3. The legs 7 are slightly tilted with respect to the vertical direction. Piles 10 project through the open longitudinal ends 5 of the legs 7 into the seabed 3 to form anchors for the foundation structure 1. The interior of the legs 7 may be grouted, in particular the space between the piles 10 and the inside wall of the legs 7, in order to increase stability of the structure.

A mono pile structure used as foundation structure is shown in Figure 2. This foundation structure comprises as one of the main elements a tubular hollow foundation member 14 with a foot 4 which rests on the seabed 3 and an open longitudinal end 5 located in the foot 4. A pile 10 extends from the tubular hollow foundation member 14 through the open longitudinal end 5 in the foot 4 into the seabed 3 so as to form an anchor for the tubular hollow foundation member 14. The space inside the tubular hollow foundation member 14, in particular the space between the section of the pile 10 which is located inside the tubular hollow foundation member 14 and the inner wall of the tubular hollow foundation member 14, may be grouted to increase stability of the foundation.

The present invention will now be described by way of exemplary embodiments. These embodiments are depicted in Figures 3 and 4 and relate in general to an advantageous wind turbine tower offshore foundation structure and an advantageous
method of establishing an offshore wind turbine tower foundation such as, for example, a tripod or jacket structure on the seabed.

A first embodiment of the invention is schematically illustrated in Figure 3. In this embodiment, as an illustrative example, a jacket structure 1 is established on the seabed 3. The structure 1 is held in secure position on the seabed 3 by means of one or more piles 10 which are installed in the seabed 3 through legs 7 of the structure.

As for this embodiment of the invention, the piles 10 are flushed to penetrate and being positioned into the seabed 3.

The pile 10 of this embodiment comprises a plurality of nozzles 8 in the tip 6 of the pile 10, which are able to make water jets 9 which eddies the material of the seabed 3 and thereby create low resistance for the pile 10 to be positioned.

For another embodiment of the invention, the flush to eddy the material of the seabed 3 is managed by flush-means external to the pile i.e. separate flush-means eddies the material of the seabed and the pile follows closely to penetrate the flushed material.

For various embodiments of this invention, the flush is controlled by flush control means 11 being connected to the nozzles 8 by e.g. one or more hoses 12. The flush control means 11 may be integrated in the pile 10 or may be external.

Consequently, this embodiment of the invention is characterized in that the foundation structure (e.g. jacket or tripod) is secured to the seabed by one or more piles which have been installed in the seabed by flushing.

The embodiment is advantageous in that it is easy to establish. Furthermore the installation does not require special-
ized vessels or heavy equipment to the installation. Even further for an installation, more than one pile can be operated at the same time and consequently the process is time saving.

A second embodiment of the invention is schematically illustrated in Figure 4. In this embodiment, as an illustrative example, a jacket structure 1 is to be established on the seabed 3. The structure 1 comprises one or more piles 13 which are connected to the structure 1, in particular to the feet 4 located at the lower ends of the legs 7. The piles 13 further comprise one or more nozzles 8 with a function as already described with respect to the first embodiment.

According to the second embodiment of the invention, the piles 13 are connected to the structure 1 before positioning it on the seabed 3. During installation the piles 13 are driven into the seabed 3 by flushing while carrying the structure 1. This means that the flush of each pile 13 must be coordinated in order to drive the whole construction in a correct upright position.

Consequently this embodiment of the invention is characterized in that the foundation structure (e.g. jacket or tripod) is established on the seabed by driving one or more connected piles into the seabed by flushing.

The embodiment is advantageous in that a whole construction can be installed at the same time thereby minimizing the time for occupying expensive specialized vessels for the installation.

Although driving one or more piles into the seabed by flushing has been described in the context of a jacket or tripod structure, driving a pile into the seabed by flushing can also be done in the context of a mono pile structure as shown in Figure 2, e.g. by using a pile as it has been described with respect to Figure 3, for anchoring the mono pile struc-
ture. Alternatively, like with the jacket or tripod structure, a separate flush-means that eddies the material of the seabed may be used when driving the pile into the seabed.
Claims

1. A device for assisting in installing a pile (10, 13) to be used for anchoring an offshore foundation (1) in the seabed characterized in that it comprises nozzles (8) and a means for generating water jets (9) ejected out of the nozzles (8).

2. The device as claimed in claim 1, characterized in that it comprises a flush control means (11) being connected to the nozzles (8).

3. The device as claimed in claim 2, characterized in that the flush control means (11) is connected to the nozzles by means of one or more hoses (12).

4. The device as claimed in any of the claims 1 to 3, characterized in that the device is integrated into the pile (10) to be used for anchoring an offshore foundation (1).

5. The device as claimed in claim 4, characterized in that the pile (10) comprises a tip (6) with the nozzles (8) of the device being located in the tip (6).

6. The device as claimed in claim 2 or claim 3 and as claimed in claim 4 or claim 5, characterized in that the flush control means (11) is integrated into the pile (10).

7. An offshore foundation structure (1), in particular an offshore foundation for a wind turbine, which is to be installed on the seabed (3) and comprises at least one foot (4).
and pile (10, 13) for anchoring the offshore foundation structure (1) in the seabed, characterised in that the foundation structure comprises a device as claimed in any of the claims 1 to 6.

8. The offshore foundation structure as claimed in claim 7, characterised in that the pile (10) is a pile as claimed in any of the claims 4 to 6.

9. The offshore foundation structure (1) as claimed in claim 7 or claim 8, characterised in that the offshore foundation structure (1) comprises at least one hollow leg (7) with an interior hollow space and the pile (10) is located inside the hollow space.

10. The offshore foundation structure (1) as claimed in claim 7 or claim 8, characterised in that the offshore foundation structure (1) comprises at least one leg (7) with a foot (4) and the pile (13) extends from the foot (4).

11. A method of establishing an offshore foundation (1) on the seabed, in particular of establishing an offshore foundation for a wind turbine installation on the seabed, in which an offshore foundation structure (1) comprising at least one leg (7) is set on the seabed (3) and anchored in the seabed (3) by means of a pile (10, 13) extending from the leg into the seabed (3), characterised in that the at least one leg (7) is anchored in the seabed (3) by flushing the pile (10, 13) into the seabed (3).

12. The method as claimed in claim 11, characterised in that
an offshore foundation structure (1) as claimed in claim 9 is used and the pile (10) is flushed into the seabed (3) out of the interior hollow space after the offshore foundation structure (1) has been set on the ground,

13. The method as claimed in claim 11, characterised in that an offshore foundation structure (1) as claimed in claim 10 is set on the ground with the pile extending from the at least one foot and the pile (13) is flushed into the seabed (3) whereupon the offshore foundation structure (1) settles with the at least one foot (4) on the seabed (3).

14. The method as claimed in any of the claims 11 to 13, characterised in that a device for assisting in installing a pile (10, 13) as claimed in any of the claims 1 to 6 is used for flushing the pile into the ground.

15. The method as claimed in claim 14, characterised in that the device for assisting in installing a pile (10, 13) is an individual device which flushes the material of the seabed and the pile (10, 13) follows closely the individual device to penetrate the flushed material.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

INV. E02D5/80 E02D27/52 E02D7/24 E02D27/42 F03D1/00
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 B63B F03D E02B

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 practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>JP 60 230430 A (KUWABARA KI NJI) 15 November 1985 (1985-11-15) * abstract; f i g u r e 1</td>
<td>1-14</td>
</tr>
<tr>
<td>X</td>
<td>NL 7 902 690 A (TOA HARBOR WORKS CO LTD) 9 October 1979 (1979-10-09) page 6, l i n e s 26-35 ; f i g u r e s 1, 5</td>
<td>1-6</td>
</tr>
<tr>
<td>X</td>
<td>US 2003/072620 AI (LONG WALTER DANI EL [US]) 17 April l 2003 (2003-04-17) f i g u r e 6</td>
<td>1-3</td>
</tr>
<tr>
<td>X</td>
<td>NL 39 429 C (W0UTER EGAS, PETER MANS) 15 June 1936 (1936-06-15) page 2; f i g u r e s 5-6</td>
<td>1</td>
</tr>
<tr>
<td>X</td>
<td>US 2 979 910 A (CRAKE WILFRED S) 18 April l 1961 (1961-04-18) col um n 3, l i n e s 25-41 ; f i g u r e s 5-6</td>
<td>1, 11</td>
</tr>
</tbody>
</table>

Further documents are listed in the continuation of Box C.

See patent family annex.

* Special categories of cited documents :
  "A" document defining the general state of the art which is not considered to be of particular relevance
  "E" earlier document but published on or after the international filing date
  "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
  "O" document referring to an oral disclosure, use, exhibition or other means
  "P" document published prior to the international filing date but later than the priority date claimed

"I" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"D" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"V" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"A" document member of the same patent family

Date of the actual completion of the international search

14 February 2011

Date of mailing of the international search report

22/02/2011

Name and mailing address of the ISA/
European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040
Fax: (+31-70) 340-3016

Authorized officer

Leroux, Corentine

Form PCT/ISA/210 (second sheet) (April 2005)
<table>
<thead>
<tr>
<th>Patent document cited in search report</th>
<th>Publication date</th>
<th>Patent family member(s)</th>
<th>Publication date</th>
</tr>
</thead>
<tbody>
<tr>
<td>JP 60230430</td>
<td>15-11-1985</td>
<td>NONE</td>
<td></td>
</tr>
<tr>
<td>NL 7902690</td>
<td>09-10-1979</td>
<td>DE 2913433 A1</td>
<td>18-10-1979</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FR 2421993 A1</td>
<td>02-11-1979</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GB 2022660 A</td>
<td>19-12-1979</td>
</tr>
<tr>
<td></td>
<td></td>
<td>JP 1124662 C</td>
<td>30-11-1982</td>
</tr>
<tr>
<td></td>
<td></td>
<td>JP 54155607 A</td>
<td>07-12-1979</td>
</tr>
<tr>
<td></td>
<td></td>
<td>JP 57013690 B</td>
<td>18-03-1982</td>
</tr>
<tr>
<td></td>
<td></td>
<td>US 4257722 A</td>
<td>24-03-1981</td>
</tr>
<tr>
<td>US 2003072620</td>
<td>17-04-2003</td>
<td>NONE</td>
<td></td>
</tr>
<tr>
<td>NL 39429</td>
<td></td>
<td>NONE</td>
<td></td>
</tr>
<tr>
<td>US 2979910</td>
<td>18-04-1961</td>
<td>NONE</td>
<td></td>
</tr>
</tbody>
</table>