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(54) **Noise suppression apparatus**

Rauschunterdrückungsvorrichtung

Appareil de suppression du bruit

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Description

[0001] The present invention relates to an apparatus and method for noise suppression during driving of support piles, and relates particularly, but not exclusively, to an apparatus for noise suppression during driving of support piles of an offshore wind turbine into the seabed.

[0002] Installation of offshore wind turbines is typically carried out by gradually hammering a large monopile (generally 5 meters to 7 meters in diameter) into the seabed until it forms a solid support base or foundation on which to install a wind turbine generator. The hammering or piling operation generates large amounts of emitted energy, generally in the form of sound energy propagated into the local environment, which can cause harm to marine animals.

Bubble curtains have been used in an attempt to alleviate this problem. These entail the deploying one or more perforated hoses around the pile and/or the ship. Air under pressure is then pumped through the hoses causing a large number of bubbles of air to escape the perforations in the hose. In theory the bubbles then rise to the surface forming a barrier of high impedance spheres (air bubbles) around the pile/ship which scatter, reflect, and refract the pile noise, thus damping the pulse and reducing the peak intensity. However, this arrangement suffers from the disadvantage of the cost of another ship to lay the hose/deploy the system, breakdown of various equipment, waiting for suitable weather, causing downtime and thus very high cost), since the second ship operates to a generally lower weather limit than the piling ship, but waiting for one of them to be operable means that both are idle. Also, currents and waves break up the current and cause bubbles to drift and the curtain to break down, bubbles tend to chaotically join together creating larger bubbles as they progress, thus changing the impedance of curtain, and water depth varies effectiveness so that when operating well, noise suppression is typically insufficient at approximately 10-12dB.

[0003] Cofferdams have also been used in an attempt to alleviate the problem. A cofferdam comprises a cylinder taller than the water depth and at least 1m wider than the monopile on a supporting frame. It is lowered to the seabed, generally penetrating a short distance in the seabed to form a seal, with its top above the waves. Water is then pumped out from the cofferdam prior to a pile being inserted within it. Piling of the monopile is then undertaken in 'dry' conditions with an air gap between the monopile and the cofferdam, thereby generating noise in air, the noise being poorly transmitted through the cofferdam into the surrounding water. However, this arrangement suffers from the disadvantage that it is very difficult to achieve an effective seal on the sea bed in most soil conditions and without this, the cofferdam does not work effectively. Also, it is usually necessary to carry out sea bed levelling prior to installation. Furthermore, the cofferdam is a heavy construction and occupies a significant element of the useable area of an installation

vessel, and its weight requires 2 extra heavy lifts per monopile installation (with risks associated) and significantly slows down the installation process, thereby increasing costs.

5 Hydro sound dampers (also known as bubble nets) have also been used. These consist of a series of balloons located periodically on a net or other supporting structure draped around the monopile and extending to the sea floor. Each bubble can be designed to absorb a specific wavelength of noise. However, these installations suffer from the disadvantage that installation of these systems generally requires the use of another vessel to wrap the net around the monopiles in situ, which takes considerable time, effort and cost. The nets can also be subject to motion caused by waves and currents, thus limiting their effectiveness, and the system to unwrap and install the nets is generally complex, which in a dynamic environment causes tangles and thus expensive delays. It is believed that when operating well, inadequate noise suppression of typically 12dB is achieved.

20 One further attempt to alleviate the problem consists of isolation casings, which are generally a casing around the piling operation comprising one or more shells. Between adjacent shells air or sound absorbing material can be inserted to create a high impedance barrier to noise transmission. Additionally within the casing an additional air bubble release systems (similar to the bubble curtain discussed above) can be introduced to create further noise mitigation. However, this arrangement suffers from the disadvantage that these systems are very heavy (sometimes heavier than the monopile itself), particularly where multiple skins are involved. As a result, 2 additional heavy lifts per installation are required, with attendant risks and costs. The systems are also generally very expensive, and the additional time (and thus vessel cost) required for their use is significant. Also, many installation vessels may not be able to lift and/or manoeuvre these devices, and thus their operations severely restrict vessel choice and thus increase costs. Furthermore, each monopile diameter will require a different size casing.

30 **[0004]** In addition to the specific problems outlined above, generally none of these known arrangements is capable of delivering the level of noise suppression required. They are expensive to install, and slow down marine operations as their deployment lies on critical path and thereby significantly increase operational cost.

35 **[0005]** Preferred embodiments of the present invention seek to overcome one or more of the above disadvantages of the prior art.

40 **[0006]** According to the present invention, there is provided a noise suppression apparatus for suppressing noise during driving of at least one support pile of an offshore structure into the seabed, the noise suppression apparatus comprising at least one first vibration damping member adapted to be mounted to at least one support pile of an offshore structure and to at least partially attenuate transmission of vibrations generated in said support pile, as a result of hammering of said support pile

into the seabed, through water adjacent said support pile.

[0007] By providing at least one first vibration damping member adapted to be mounted to at least one support pile of an offshore structure and to at least partially attenuate transmission of vibrations generated in the support pile, as a result of hammering of the support pile into the seabed, through water adjacent the support pile, this provides the advantage of providing a more cost effective system which is much easier to install and handle, minimises delay in piling operations or handling, and does not require power or air supply or an additional boat for deployment.

[0008] At least one said first vibration damping member may be adapted to at least partially attenuate transmission of vibrations when in contact with a surface of at least one said support pile.

[0009] At least one said first vibration damping member may include at least one respective inflatable member.

[0010] At least one said first vibration damping member may be adapted to be brought into contact with a surface of at least one said pile by means of inflation of at least one said inflatable member.

[0011] The apparatus may further comprise constraining means for limiting expansion of at least one said inflatable member.

[0012] This provides the advantage of enabling the apparatus to withstand higher inflation pressures.

[0013] The constraining means may comprise at least one flexible member adapted to be brought into engagement with a said support pile by means of inflation of at least one said inflatable member.

[0014] The apparatus may further comprise fluid flow control means for controlling flow of fluid into and/or out of the interior of said support pile.

[0015] This provides the advantage of enabling the amount of water in the interior of the support pile to be controlled, thereby enabling the resonant frequencies damped by the apparatus to be adjusted.

[0016] The fluid flow control means may comprise at least one valve.

[0017] At least one said first vibration damping member may be adapted to allow air to escape therefrom.

[0018] This provides the advantage of enhancing the damping effect.

[0019] At least one said first vibration damping member may have at least one air outlet for allowing adjustable quantities of air to escape therefrom.

[0020] At least one said first vibration damping member may be adapted to engage an external surface of at least one said support pile.

[0021] At least one said first vibration damping member may be adapted to engage an internal surface of at least one said support pile.

[0022] The apparatus may further comprise a plurality of said first vibration damping members and at least one second vibration damping member adapted to be mounted to a pair of said first vibration damping members.

[0023] This provides the advantage of enhancing the

vibration damping effect.

[0024] At least one said second vibration damping member may comprise at least one sheet of material.

[0025] At least one said second vibration damping member may comprise at least one pair of sheets of material for receiving air therebetween.

[0026] Preferred embodiments of the invention will now be described, by way of example only and not in any limitative sense, with reference to the accompanying drawings in which:-

Figure 1 is a schematic side cross sectional view of part of a support pile for an offshore wind turbine having a noise suppression apparatus of a first embodiment of the present invention mounted to an internal surface thereof;

Figure 2 is a side cross sectional view of the noise suppression apparatus of Figure 1;

Figure 3 is a side view of the noise suppression apparatus of Figure 1;

Figure 4 is a side view of a first embodiment of a vibration damping member of the apparatus of Figures 2 and 3;

Figure 5 is a cross sectional view along the line A-A in Figure 4 in an uninflated condition of the vibration damping member;

Figure 6 is a cross sectional view along the line A-A in Figure 4 in an inflated condition of the vibration damping member;

Figure 7 is a plan view of the apparatus of Figure 2 in an uninflated condition thereof;

Figure 8 is a plan view of the apparatus of Figure 2 in an inflated condition thereof;

Figure 9 is a side view of a second embodiment of a vibration damping member of the apparatus of Figure 2 in a first condition thereof;

Figure 10 is a side view of the vibration damping member of Figure 9 in a second condition thereof;

Figure 11 is a schematic side cross sectional view of part of a support pile having a noise suppression apparatus of a second embodiment of the present invention mounted to an internal surface thereof;

Figure 12 is a plan view of the noise suppression apparatus of Figure 11; and

Figure 13 is a schematic side cross sectional view of part of a support pile having a noise suppression

apparatus of a third embodiment of the present invention mounted to internal and external surfaces thereof.

[0027] Referring to Figures 1 to 8, a noise suppression apparatus 2 of a first embodiment of the present invention is mounted to an internal surface 4 of a support pile 6 for an offshore wind turbine (not shown) to attenuate transmission of vibrations, generated as the pile 6 is driven into the seabed (not shown) through the water surrounding the pile 6. The noise suppression apparatus 2 comprises a generally cylindrical body 8 containing a rigid framework 10 of square cross section and a plurality of horizontally arranged first vibration damping members 12 arranged horizontally around the circumference of the cylindrical body 8 and vertically arranged first vibration damping members 14. Each of the first vibration damping members 12, 14 is mounted to the external surface of the cylindrical body 8 and has constraining means in the form of a rigid steel housing 16 forming a gap 18, and a flexible member 20 of durable resilient material located in the gap 18 and which can be urged into engagement with the internal surface 4 of the pile 6 by means of inflation of an inflatable member in the form of an inflatable inner tube 22 arranged between the flexible member 20 and the rigid housing 16. This enables the first vibration damping members 12, 14 to withstand higher inflation pressures than would be the case if the inner tube 22 was not constrained. Such flexible member 20 may be comprised of material(s) which themselves have sound absorbing qualities. Such inflatable inner tube 22 may be inflated with air, other gas, liquid or liquid foam to further enhance its noise suppression qualities.

[0028] As shown in more detail in Figure 2, the first vibration damping members 12, 14 are shown in various stages from the uninflated condition at the top of Figure 2 to the fully inflated condition at the bottom of Figure 2. Wheels 24 are provided for engaging the inner wall 4 of the pile 6 when the vibration damping members 12, 14 are in their uninflated condition, and are prevented from coming into engagement with the inner surface 4 of the pile 6 when the vibration damping members 12, 14 are in their fully inflated condition.

[0029] A second embodiment of a first vibration damping member 26 is shown in Figures 9 and 10. Instead of being formed from a single piece of metal, as in the case of the first vibration damping member 12, 14 of figure 4, the housing 28 of the vibration damping member 26 in Figures 9 and 10 includes three metal body members 30 hinged together so that differences in diameter of the cylindrical body 8 can be accommodated, from the smaller diameter body 8 as shown in Figure 9 to the larger diameter body 8 as shown in Figure 10. A resilient rubber mount 32 is located between the metal body members 30 and the outer surface of the cylindrical body 8 to accommodate differences in curvature between the outer surface of the cylindrical body 8 and the adjacent surfaces of the metal body members 30.

[0030] A noise suppression apparatus 102 of a second embodiment of the present invention is shown in Figures 11 and 12, in which part common to the embodiment of Figures 1 to 10 are denoted by like reference numerals but increased by 100. The cylindrical body 108 of the noise suppression apparatus 102 supports first vibration damping members 112 and is provided with a top plate 134 having a hole or valve 136 to allow controlled flow of air and/or water through the monopile 6 as it is installed in the seabed. In this way, the weight or buoyancy of the monopile 6 in water can be controlled, as a result of which the pile dominant frequency can be adjusted to enable resonant peaks to be avoided. It is also possible to provide two apparatus 102 as shown in Figures 11 and 12, one at the top and one at the bottom of the monopile 6, to seal both ends of the monopile 6 to enable it to be floated and towed to its desired location prior to installation in the seabed.

[0031] Referring to Figure 13, a noise suppression apparatus 202 of a third embodiment of the present invention, in which parts common to the embodiment of Figures 1 to 10 are denoted by like reference numerals but increased by 200, includes first noise suppression members 212 which can be brought into engagement with the inner surface 4 of the pile 6 (four viscoelastic rings 4 are shown in Figure 3) and outer inflatable viscoelastic rings 138 which can be brought into engagement with an outer-surface 7 of the pile 6. The external viscoelastic rings 138 are connected together by second noise suppression members in the form of pairs of sheets 140 of material having apertures allowing air bubbles 142 to pass there-through, and weights 144 are attached to the lowermost external viscoelastic ring 138.

[0032] In order to install the pile 6 to provide a support for an offshore wind turbine generator (not shown), the pile 6 is supported by a crane (not shown) and maneuvered by means of a manipulator arm (not shown) to its desired position over the seabed. An anvil 146 is then located in position at the top of the pile 6 and the pile 6 is hammered into the seabed by means of a suitable hammering apparatus (not shown). As the pile 6 is hammered into the seabed, transmission of noise through the water is suppressed by the noise suppression apparatus 202.

[0033] It will be appreciated by persons skilled in the art that the above embodiment has been described by way of example only and not in any limitative sense, and that various alterations and modifications are possible without departure from the scope of the invention as defined by the appended claims.

Claims

1. A noise suppression apparatus (2) for suppressing noise during driving of at least one support pile (6) of an offshore structure into the seabed, the noise suppression apparatus (2) comprising at least one first vibration damping member (12) adapted to be

mounted to at least one support pile (6) of an offshore structure and to at least partially attenuate transmission of vibrations generated in said support pile (6), as a result of hammering of said support pile (6) into the seabed, through water adjacent said support pile.

2. An apparatus according to claim 1, wherein at least one said first vibration damping member is adapted to at least partially attenuate transmission of vibrations when in contact with a surface of at least one said support pile. 5
3. An apparatus according to claim 1 or 2, wherein at least one said first vibration damping member includes at least one respective inflatable member. 10
4. An apparatus according to claim 3, wherein at least one said first vibration damping member is adapted to be brought into contact with a surface of at least one said pile by means of inflation of at least one said inflatable member. 15
5. An apparatus according to claim 3 or 4, further comprising constraining means for limiting expansion of at least one said inflatable member. 20
6. An apparatus according to claim 5, wherein the constraining means comprises at least one flexible member adapted to be brought into engagement with a said support pile by means of inflation of at least one said inflatable member. 25
7. An apparatus according to any one of the preceding claims, further comprising fluid flow control means for controlling flow of fluid into and/or out of the interior of said support pile. 30
8. An apparatus according to claim 7, wherein the fluid flow control means comprises at least one valve. 35
9. An apparatus according to any one of the preceding claims, wherein at least one said first vibration damping member is adapted to allow air to escape therefrom. 40
10. An apparatus according to claim 9, wherein at least one said first vibration damping member has at least one air outlet for allowing adjustable quantities of air to escape therefrom. 45
11. An apparatus according to any one of the preceding claims, wherein at least one said first vibration damping member is adapted to engage an external surface of at least one said support pile. 50
12. An apparatus according to any one of the preceding claims, wherein at least one said first vibration damping member is adapted to engage an internal surface

of at least one said support pile.

13. An apparatus according to any one of the preceding claims, further comprising a plurality of said first vibration damping members and at least one second vibration damping member adapted to be mounted to a pair of said first vibration damping members.
14. An apparatus according to claim 13, wherein at least one said second vibration damping member comprises at least one sheet of material.
15. An apparatus according to claim 14, wherein at least one said second vibration damping member comprises at least one pair of sheets of material for receiving air therebetween.

Patentansprüche

1. Rauschunterdrückungsvorrichtung (2) zur Rauschunterdrückung während des Rammens von wenigstens einem Stützpfehl (6) einer Offshore-Konstruktion in den Meeresboden, wobei die Rauschunterdrückungsvorrichtung (2) wenigstens ein erstes Vibrationsdämpfungselement (12) aufweist, das zur Anbringung an wenigstens einem Stützpfehl (6) einer Offshore-Konstruktion und zum wenigstens teilweisen Dämpfen der Übertragung von Vibrationen, die in dem genannten Stützpfehl (6) infolge von Hämmern des genannten Stützpfehls (6) in den Meeresboden erzeugt werden, durch an den genannten Stützpfehl angrenzendes Wasser ausgeführt ist.
2. Vorrichtung nach Anspruch 1, wobei wenigstens ein genanntes erstes Vibrationsdämpfungselement ausgeführt ist, um die Übertragung von Vibrationen wenigstens teilweise abzuschwächen, wenn es mit einer Oberfläche von wenigstens einem genannten Stützpfehl in Kontakt ist.
3. Vorrichtung nach Anspruch 1 oder 2, wobei wenigstens ein genanntes erstes Vibrationsdämpfungselement wenigstens ein jeweiliges aufblähbares Element beinhaltet.
4. Vorrichtung nach Anspruch 3, wobei wenigstens ein genanntes erste Vibrationsdämpfungselement ausgeführt ist, um durch Aufblähen des wenigstens einen genannten aufblähbaren Elements mit einer Oberfläche von wenigstens einem genannten Pfehl in Kontakt gebracht zu werden.
5. Vorrichtung nach Anspruch 3 oder 4, das ferner ein Beschränkungsmittel zur Begrenzung der Ausdehnung von wenigstens einem genannten aufblähbaren Element aufweist.

6. Vorrichtung nach Anspruch 5, wobei das Beschränkungsmittel wenigstens ein flexibles Element aufweist, das ausgeführt ist, um durch Aufblähen von wenigstens einem genannten aufblähbaren Element mit einem genannten Stützpfehl in Eingriff gebracht zu werden. 5
7. Vorrichtung nach einem der vorhergehenden Ansprüche, die ferner einen Fluidflussregler zum Regeln des Fluidflusses in das und/oder aus dem Innere(n) des genannten Stützpfehls aufweist. 10
8. Vorrichtung nach Anspruch 7, wobei der Fluidflussregler wenigstens ein Ventil aufweist. 15
9. Vorrichtung nach einem der vorhergehenden Ansprüche, wobei wenigstens ein genanntes erstes Vibrationsdämpfungselement ausgeführt ist, um Luft daraus entweichen zu lassen. 20
10. Vorrichtung nach Anspruch 9, wobei wenigstens ein genanntes erstes Vibrationsdämpfungselement wenigstens einen Luftauslass hat, um einstellbare Luftmengen daraus entweichen zu lassen. 25
11. Vorrichtung nach einem der vorhergehenden Ansprüche, wobei wenigstens ein genanntes erstes Vibrationsdämpfungselement ausgeführt ist, um mit einer Außenfläche von wenigstens einem genannten Stützpfehl in Eingriff zu sein. 30
12. Vorrichtung nach einem der vorhergehenden Ansprüche, wobei wenigstens ein genanntes erstes Vibrationsdämpfungselement ausgeführt ist, um mit einer Innenfläche von wenigstens einem genannten Stützpfehl in Eingriff zu sein. 35
13. Vorrichtung nach einem der vorhergehenden Ansprüche, die ferner mehrere genannte erste Vibrationsdämpfungselemente und wenigstens ein zweites Vibrationsdämpfungselement, das ausgeführt ist, um an einem Paar der genannten ersten Vibrationsdämpfungselemente montiert zu sein, aufweist. 40
14. Vorrichtung nach Anspruch 13, wobei wenigstens ein genanntes zweites Vibrationsdämpfungselement wenigstens ein Materialflächengebilde aufweist. 45
15. Vorrichtung nach Anspruch 14, wobei wenigstens ein genanntes zweites Schwingungsdämpfungselement wenigstens ein Paar Materialflächengebilde zur Aufnahme von Luft zwischen ihnen aufweist. 50

Revendications

1. Appareil de suppression du bruit (2) destiné à sup-

primer le bruit pendant l'enfoncement d'au moins une colonne de support (6) d'installation au large des côtes dans le fond marin, l'appareil de suppression du bruit (2) comprenant au moins un premier élément d'amortissement des vibrations (12) conçu pour être monté sur au moins une colonne de support (6) d'installation au large des côtes et pour atténuer au moins partiellement la transmission de vibrations engendrées dans ladite colonne de support (6) du fait du battage de ladite colonne de support (6) dans le fond marin, à travers l'eau voisine de ladite colonne de support.

2. Appareil selon la revendication 1, dans lequel ledit au moins un premier élément d'amortissement des vibrations est conçu pour atténuer au moins partiellement la transmission de vibrations lorsqu'il est en contact avec une surface de ladite au moins une colonne de support.
3. Appareil selon la revendication 1 ou 2, dans lequel ledit au moins un premier élément d'amortissement des vibrations comprend au moins un élément gonflable respectif.
4. Appareil selon la revendication 3, dans lequel ledit au moins un premier élément d'amortissement des vibrations est conçu pour être mis au contact d'une surface de ladite au moins une colonne, au moyen du gonflage dudit au moins un élément gonflable.
5. Appareil selon la revendication 3 ou 4, comprenant en outre un moyen de retenue destiné à limiter la dilatation dudit au moins un élément gonflable.
6. Appareil selon la revendication 5, dans lequel le moyen de retenue comprend au moins un élément flexible, conçu pour être mis en prise avec ladite colonne de support au moyen du gonflage dudit au moins un élément gonflable.
7. Appareil selon l'une quelconque des revendications précédentes, comprenant en outre un moyen de régulation de débit de fluide, destiné à réguler le débit de fluide dans et/ou hors de l'intérieur de ladite colonne de support.
8. Appareil selon la revendication 7, dans lequel le moyen de régulation de débit de fluide comprend au moins une soupape.
9. Appareil selon l'une quelconque des revendications précédentes, dans lequel ledit au moins un premier élément d'amortissement des vibrations est conçu pour laisser l'air s'en échapper.
10. Appareil selon la revendication 9, dans lequel ledit au moins un premier élément d'amortissement des

vibrations comporte au moins une sortie d'air destinée à laisser des quantités réglables d'air s'en échapper.

11. Appareil selon l'une quelconque des revendications précédentes, dans lequel ledit au moins un premier élément d'amortissement des vibrations est conçu pour entrer en prise avec une surface extérieure de ladite au moins une colonne de support. 5
- 10
12. Appareil selon l'une quelconque des revendications précédentes, dans lequel ledit au moins un premier élément d'amortissement des vibrations est conçu pour entrer en prise avec une surface intérieure de ladite au moins une colonne de support. 15
13. Appareil selon l'une quelconque des revendications précédentes, comprenant en outre une pluralité desdits premiers éléments d'amortissement des vibrations et au moins un second élément d'amortissement des vibrations conçu pour être monté sur une paire desdits premiers éléments d'amortissement des vibrations. 20
14. Appareil selon la revendication 13, dans lequel ledit au moins un second élément d'amortissement des vibrations comprend au moins une feuille de matériau. 25
15. Appareil selon la revendication 14, dans lequel ledit au moins un second élément d'amortissement des vibrations comprend au moins une paire de feuilles de matériau destinées à recevoir de l'air entre elles. 30

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