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(71) Applicant: **Pori Offshore Constructions Oy**
28880 Pori (FI)

(72) Inventors:
- **KAILA, Jarl**
  28880 Pori (FI)
- **LOULA, Jyrki**
  28880 Pori (FI)
- **NORDBERG, Jarmo**
  28880 Pori (FI)
- **LEPPÄNEN, Toni**
  28880 Pori (FI)
- **LINDROOS, Miikka**
  28880 Pori (FI)
- **PELTOMAA, Jouni**
  28880 Pori (FI)
- **REPOLAHTI, Matti**
  28880 Pori (FI)
- **TÄHKÄNEN, Petri**
  28880 Pori (FI)

(74) Representative: **Laine IP Oy**
Porkkalankatu 24
00180 Helsinki (FI)

(54) MARINE FOUNDATION, ARRANGEMENT, USE OF A MARINE FOUNDATION AND METHOD OF INSTALLING AND DE-INSTALLING A MARINE FOUNDATION

(57) According to an example aspect of the present invention, there is provided a marine foundation (1) comprising a polygonal base (2), a perimeter wall (3) having a plurality of sides (11) protruding from the base (2) to a polygonal cover (4), thus forming a shell structure having a cavity (5), a hollow structure (6) extending through an opening (7) in the cover (4) to the base (2), and wherein within the cavity (5) a plurality of compartments (8) is formed by inner walls (9) extending from at least two edges (10) to the hollow structure (6), wherein each edge (10) is formed between two adjacent sides (11) of the perimeter wall (3) to the hollow structure (6).

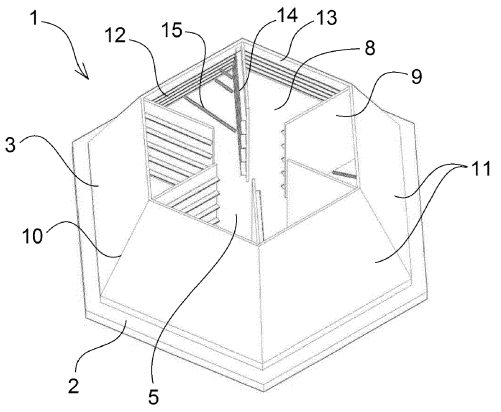

FIG. 1

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Description

FIELD

[0001] The present invention relates to a marine foundation.

[0002] Further, the present invention relates to an arrangement comprising a marine foundation and an object.

[0003] Furthermore, the present invention relates to a use of a marine foundation.

[0004] Even further, the present invention relates to a method of installing a marine foundation.

[0005] Additionally, the present invention relates to a method of de-installing a marine foundation.

BACKGROUND

[0006] Different kinds of marine foundations are known, in which the marine foundation structure is made by pile-driving the framework structure submerged in water to the bottom. The use of one large pile anchored or submerged to the bottom is known as a different alternative. A third alternative is to transport to the installation site or to manufacture on site a massive foundation structure of steel and/or concrete, onto which a construction or object can be joined above the water surface.

[0007] The problem with the previously used solutions has been the heavy special equipment needed in the transport and installation of the foundation structures, which is available to a very limited extent. In addition, the use of special equipment is very expensive, especially when preparing the foundation structures in offshore circumstances, in which the weather windows suitable for working are short. The time needed for installation is long in relation to the weather window that can be predicted, even in ideal conditions. Fast and hard changes in weather may interrupt the foundation project, and may even force to demobilize and remobilize expensive equipment. If several foundation structures are to be installed in the same area, for example when building a wind park, it is extremely difficult to work out a fixed schedule, and advantages of serial production are lost. Document

[0008] EP 1402119 B1, for example, discloses a marine foundation structure comprising a shell structure which is thin in relation to the diameter of the structure. The shell structure is filled with soil.

[0009] Another type of marine foundation is disclosed in document EP 2236676 B1.

[0010] Document EP 2930273 B1 further discloses a gravity based marine foundation.

[0011] In view of the foregoing, it would be beneficial to provide a marine foundation capable of being easily transported, installed and de-installed without use of special heavy equipment such as jack-up vessels and the like. The equipment required for transportation, installation and de-installation of the marine foundation should be moderately priced standard equipment. Certain embodiments of the marine foundation should be capable of being used in arctic weather conditions. The marine foundation should be further capable of being manufactured in industrial scale. Additionally, certain embodiments of the marine foundation should be capable of being used as a foundation for an offshore wind energy power plant.

SUMMARY OF THE INVENTION

[0012] The invention is defined by the features of the independent claims. Some specific embodiments are defined in the dependent claims.

[0013] According to a first aspect of the present invention, there is provided a marine foundation comprising a polygonal base, a perimeter wall having a plurality of sides protruding from the base to a polygonal cover, thus forming a shell structure having a cavity, a hollow structure extending through an opening in the cover to the base, and wherein within the cavity a plurality of compartments is formed by inner walls extending from at least two edges to the hollow structure, wherein each edge is formed between two adjacent sides of the perimeter wall.

[0014] Various embodiments of the first aspect may comprise at least one feature from the following bulleted list:

- the marine foundation is configured to change from a floating state to a semi-submerged state and reverse, wherein in the floating state at least the cover and a part of the hollow structure are located above a water surface, and wherein in the semi-submerged state the base is positioned on a seabed
- the shell structure is located below the water surface in the semi-submerged state and only a part of the hollow structure is located above the water surface
- the marine foundation is configured to be filled with pressurized air in the floating state
- the marine foundation is configured to be filled with water or with water and pressurized air in the semi-submerged state
- the marine foundation is configured to be filled with material capable of being pumped
- the marine foundation is configured to be filled with sand or gravel in the semi-submerged state
- the base is quadrangular, the cover is quadrangular and four compartments are formed within the cavity by four inner walls
- the base is hexagonal, the cover is hexagonal and six compartments are formed within the cavity by six inner walls

- the base is octagonal, the cover is octagonal and eight compartments are formed within the cavity by eight inner walls
- a plurality of compartments is formed by inner walls extending from each edge formed between two adjacent sides of the perimeter wall to the hollow structure
- the number of inner walls differs from the number of sides of the perimeter wall
- each side of the perimeter wall comprises a plurality of first profiles arranged parallel or substantially parallel to each other
- the first profiles are orientated in a direction perpendicular or substantially perpendicular to the Earth's normal, i.e. in horizontal direction
- the first profiles are comprised by or attached to each inner side of the perimeter wall
- the first profiles comprise T-profiles, I-profiles, U-profiles, or bulb flat profiles
- the first profiles are made of metal or a metal alloy, for example steel
- each inner wall comprises a plurality of second profiles arranged parallel or substantially parallel to each other
- the second profiles are orientated in a direction perpendicular or substantially perpendicular to the Earth's normal, i.e. in horizontal direction
- the second profiles are comprised by or attached to at least one side of each inner wall
- the marine foundation comprises within each compartment at least one stiffening element extending from a side of the perimeter wall to at least one inner wall
- a footprint of the base is greater than a footprint of the cover
- each side of the perimeter wall is inclined at an angle to a horizontal plane in a range between 45° and 90°, in a range between 45° and 80°, in a range between 45° and 70°, or in a range between 60° and 70°
- a footprint of the base and a footprint of the cover is identical
- the marine foundation comprises at least one connector or valve configured to guide (sea)water into at least a part of the cavity, preferably into each of the compartments
- the marine foundation comprises at least one connector or valve configured to guide (sea)water out of at least a part of the cavity, preferably out of each of the compartments
- the marine foundation comprises at least one connector or valve configured to guide pressurized air into at least a part of the cavity, preferably into each of the compartments
- the marine foundation comprises at least one connector or valve configured to guide pressurized air out of at least a part of the cavity, preferably out of each of the compartments
- the hollow structure comprises a coupling section for coupling an object to the marine foundation, for example for coupling a 8-16 MW wind energy power plant to the marine foundation
- the hollow structure comprises outside the cavity an ice shield extending radially from an outer surface of the hollow structure

[0015] According to a second aspect of the present invention, there is provided an arrangement comprising a marine foundation according to any one of claims 1-11 and an object coupled to a coupling section of the hollow structure of the marine foundation. According to a certain embodiment of the present invention, the object comprises a wind energy power plant, a light house, a seamark, a part of a bridge, or a marine structure.

[0016] According to a third aspect of the present invention, there is provided a use of a marine foundation according to any one of claims 1-11, wherein an object is coupled to a coupling section of the hollow structure of the marine foundation.

[0017] According to a fourth aspect of the present invention, there is provided a method of installing a marine foundation, the method comprising providing at an installation site a floating marine foundation comprising a polygonal base, a perimeter wall having a plurality of sides protruding from the base to a polygonal cover, thus forming a shell structure having a cavity, a hollow structure extending through an opening of the cover to the base, and wherein within the cavity a plurality of compartments is formed by inner walls extending from at least two edges to the hollow structure, wherein each edge is formed between two adjacent sides of the perimeter wall, and filling the cavity at least partially with ballast in order to lower the base of the marine foundation to a seabed.

[0018] Various embodiments of the fourth aspect may comprise at least one feature from the following bulleted list:

- the floating marine foundation is towed to the installation site prior to filling the cavity at least partially with ballast such as water, water and pressurized air or material capable of being pumped
- an object such as a wind energy power plant, lighthouse, seamark, or other marine structure is coupled to a coupling section comprised by the hollow structure of the marine foundation
- an object is coupled to a coupling section comprised by the hollow structure of the marine foundation prior to towing the combined unit comprising the marine foundation and the object to an installation site
- the marine foundation comprises at least one feature laid out in above bulleted list in connection with the first aspect

[0019] According to a fifth aspect of the present invention, there is provided a method of de-installing a marine foundation, the method comprising providing at a de-installation site a semi-submerged marine foundation comprising a polygonal base, a perimeter wall having a plurality of sides protruding from the base to a polygonal cover, thus forming a shell structure having a cavity, a hollow structure extending through an opening of the cover to the base, and wherein within the cavity a plurality of compartments is formed by inner walls extending from at least two edges to the hollow structure, wherein each edge is formed between two adjacent sides of the perimeter wall, and removing ballast from the cavity in order to change the state of the marine foundation to a floating state.

[0020] Various embodiments of the fifth aspect may comprise at least one feature from the following bulleted list:

- the floating marine foundation is towed from the de-installation site after removing water from the cavity
- an object is de-coupled from a coupling section comprised by the hollow structure of the marine foundation prior to removing water from the cavity
- water is removed from the cavity utilizing at least one pump and/or pressurized air
- material capable of being pumped is removed from the cavity
- the marine foundation comprises at least one feature laid out in above bulleted list in connection with the first aspect

[0021] Considerable advantages are obtained by means of certain embodiments of the present invention. A marine foundation and a method of installing a marine foundation are provided. The design of the marine foundation is such that land-based construction of the marine foundation can take place, for example at a harbour or shipyard, and then the floating marine foundation can be towed to a sea-based installation site prior to installing it at the installation site by ballasting the marine foundation. Thus, a jack-up vessel comprising a crane or similar other heavy equipment is not required at the installation site for installation of the marine foundation. The marine foundation is typically mainly built on land. The marine foundation may be finalized when being positioned at the bottom at a quay. In other words, the marine foundation is typically not built in a floating condition. The design of the marine foundation according to certain embodiments is further such that the marine foundation is able to float even in shallow waters prior to installation. This is of importance in case that the marine foundation has to be towed to the final installation site via shallow waters. Installation at the installation site by changing the state of the marine foundation from a floating state to a semi-submerged state can take place utilizing ballast water. In the semi-submerged state the cavity of the marine foundation may be completely filled with ballast water or with ballast water and pressurized air. In a similar way, de-installation of the marine foundation, for example 20 years after installation, is possible by removing ballast water or any other sort of ballast present in the shell structure. This may, for example, take place utilizing pressurized air and/or pumps. Also sand, gravel or material capable of being pumped may be present instead or in addition to water in the shell structure. Consequently, transportation, installation and de-installation of the marine foundation can take place quickly, safely, reliably, easily and cost-efficiently without that use of special heavy equipment is required. The equipment required for transportation, installation and de-installation of the marine foundation is moderately priced standard equipment such as tugs, pumps, means for providing pressurized air, etc. The structure of the marine foundation is further strong enough to allow towing.

[0022] According to certain embodiments of the present invention, only minor preparation of the seabed has to be carried out prior to installation of the marine foundation. For example, only a gravel layer has to be provided on the seabed prior to installation of the marine foundation. The design of the marine foundation is such that a low accuracy in gravel layer tolerances is sufficient for installation of the marine foundation. Consequently, pre-treatment of the seabed can be carried out quickly, cost-efficiently and with standard equipment such as a dredger or an excavator positioned on a lighter or barge. According to certain other embodiments, there is no preparation of the seabed required at all prior to installation of the marine foundation. For example, it may not be required to drive a pile or to pre-treat moraine by exploding when installing a seamark.

[0023] The marine foundation in accordance with the present invention is further easily scalable depending on

its intended use. Certain embodiments of the present invention may be used in connection with installation of objects such as offshore wind energy power plants, lighthouses, seamarks, marine structures or as structures of a bridge.

[0024] According to certain embodiments of the present invention, a wind energy power plant can be coupled to the marine foundation e.g. in a harbour prior to towing the combined unit including the marine foundation and the wind energy power plant to the installation site. At the installation site, the state of the combined unit is then changed from a floating state to a semi-submerged state as described above. Thus, heavy installation equipment is not required at the sea-based installation site and the wind energy power plant can be installed quickly, safely, reliably, easily and cost-efficiently.

[0025] According to certain embodiments of the present invention, the marine foundation is capable of being used in arctic weather conditions due to arrangement of an ice protector or an ice shield.

[0026] According to certain embodiments of the present invention, each side of the perimeter wall is inclined at an angle to a horizontal plane in a range between 45° and 80° and even more preferably in a range between 45° and 70°. As a result, the marine foundation is able to float even in very shallow waters when the cavity is filled with air or pressurized air.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027] For a more complete understanding of particular embodiments of the present invention and their advantages, reference is now made to the following descriptions, taken in conjunction with the accompanying drawings. In the drawings:

FIGURE 1 illustrates a schematic perspective view of a part of a marine foundation in accordance with at least some embodiments of the present invention,

FIGURE 2 illustrates a schematic cross-sectional view of a detail of a marine foundation in accordance with at least some embodiments of the present invention,

FIGURE 3 illustrates a schematic view of another detail of a marine foundation in accordance with at least some embodiments of the present invention,

FIGURE 4 illustrates a schematic perspective view of a detail of a marine foundation in accordance with at least some embodiments of the present invention, and

FIGURE 5 illustrates a schematic perspective view of an arrangement comprising an object and a marine foundation in accordance with at least some embodiments of the present invention.

EMBODIMENTS

[0028] In this document, the term "marine foundation" is used. The term "marine foundation" includes an offshore foundation, an inshore foundation to be installed near the coastline as well as a foundation structure to be installed in rivers and lakes.

[0029] In this document, the word "polygonal" is used. The word "polygonal" means a geometric form having a number of corners, for example a triangular form, a quadrangular form, a hexagonal form, or an octagonal form. The number of corners can be three or more. Preferably, the polygonal form is symmetrical.

[0030] In this document, the expression "material capable of being pumped" is used. Of course, said material includes water. However, said expression also includes other material that can be transported from one position to another position utilizing pumps. The expression further includes material that cannot be transported from one position to another position utilizing only pumps, but also material that can be transported from one position to another position utilizing pumps and an additive which creates the pumping capability of the material during the pumping process. Such an additive may be, for example, water.

[0031] In FIGURE 1 a schematic perspective view of a part of a marine foundation 1 in accordance with at least some embodiments of the present invention is illustrated. The shown marine foundation 1 comprises a hexagonal base 2, a perimeter wall 3 having six sides 11, i.e. outer walls, protruding from the base 2 to a hexagonal cover (not shown), thus forming a shell structure. The hexagonal base 2 and the hexagonal cover are symmetrical to provide a shell structure that can be uniformly loaded with ballast. The sides 11 are typically, but not necessarily, planar. The base 2 and the cover 4 are typically planar. Between two adjacent sides 11 an edge 10 is formed. The shell structure is typically made of concrete. Within the shell structure formed by the base 2, the perimeter wall 3 and the cover a cavity 5 is formed. Further, a hollow structure (not shown) extends through an opening (not shown) of the cover to the base 2. Within the cavity 5 a plurality of compartments 8 is formed by inner walls 9 extending from each edge 10 formed between two adjacent sides 11 of the perimeter wall 3 to the hollow structure 6. The inner walls 9 are typically also made of concrete. According to certain embodiments, the number of sides 11 is different than the number of inner walls 9, i.e. the number of compartments 8 is not necessarily linked to the shape of the perimeter wall 3 or the base plate 2. For example, the base 2 may be quadrangular, the cover 4 may be quadrangular and two compartments 8 are formed within the cavity 5 by two inner walls 9.

[0032] Each side 11 of the perimeter wall 3 comprises a plurality of first profiles 12 arranged parallel or substantially parallel to each other. In other words, each side 11 of the perimeter wall 3 is reinforced by the first profiles

12. The first profiles 12 are orientated in a direction perpendicular or substantially perpendicular to the Earth's normal, i.e. in a horizontal direction. The first profiles 12 are comprised by the sides 11 of the perimeter wall 3 or attached to each inner side 13 of the perimeter wall 3. The sides 11 may comprise a plurality of connector plates (not shown) to which the first profiles 12 are welded, for instance. The first profiles 12 typically extend along the entire width of each side 11 of the perimeter wall 3. The first profiles 12 may be T-shaped profiles, for instance. The first profiles 12 may be, for example, made of steel.

[0033] Further, each inner wall 9 comprises a plurality of second profiles 14 arranged parallel or substantially parallel to each other. In other words, each inner wall 9 of the perimeter wall 3 is reinforced by the second profiles 14. The second profiles 14 are orientated in a direction perpendicular or substantially perpendicular to the Earth's normal, i.e. in a horizontal direction. In FIGURE 1, the second profiles 14 are comprised by or attached to only one side of each inner wall 9. However, second profiles 14 may also be present on both sides of each inner wall 9. The inner walls 9 may comprise a plurality of connector plates (not shown) to which the second profiles 14 are welded, for instance. The second profiles 14 typically extend along the entire width of each inner wall 9. The second profiles 14 may be T-shaped profiles, for instance. The second profiles 14 may be, for example, made of steel.

[0034] Typically, the marine foundation 1 comprises within each compartment 8 at least one stiffening element 15 extending from an inner side 13 of the perimeter wall to at least one inner wall 9. In FIGURE 1, a plurality of stiffening elements 15 extend within each compartment 8 from a side 11 of the perimeter wall 3 to one inner wall 9. The stiffening elements 15 provide stability to the shell structure and the inner walls 9 of the marine foundation 1. The stiffening elements 15 may be, for example, in the form of pipes or hollow cylinders. The stiffening elements 15 may be, for example, made of steel. Typically, each stiffening element 15 is welded to a first profile 12 and a second profile 14.

[0035] In FIGURE 1, a footprint of the base 2 is greater than a footprint of the cover 4, i.e. a surface area of the base 2 is greater than a surface area of the cover 4. Consequently, each side 11 of the perimeter wall 3 is inclined at an angle relative to the horizontal plane. Each side 11 of the perimeter wall 3 may be inclined at an angle to a horizontal plane in the range between 45° and 90°, for example 75°. As a result, the marine foundation 1 is able to float even in very shallow waters when the cavity is filled with air or pressurized air.

[0036] The marine foundation 1 typically comprises at least one connector or valve (not shown) for filling at least a part of the cavity 5 with ballast such as (sea-) water or material capable of being pumped in order to install the floating marine foundation 1 at a desired installation site. Typically, ballast is then simultaneously guided into each of the compartments 8 of the marine foundation 1 for reaching final installation depth, i.e. the marine foundation 1 is gravity based. The marine foundation 1 further comprises at least one connector or valve configured to guide pressurized air into at least a part of the cavity 5, preferably into each of the compartments 8. In the semi-submerged state the cavity 5 of the marine foundation 1 may be completely filled with ballast such as water, water and pressurized air, or material capable of being pumped. Thus, forces are exerted against the forces created by the environment, in particular the water pressure, against the sides 11 of the perimeter wall 3. Additionally, the marine foundation 1 typically comprises at least one connector or valve for emptying at least a part of the cavity 5 from ballast such as (sea-) water or material capable of being pumped. Water can also be removed using a pump and/or pressurized air in order to de-install the floating marine foundation 1. Typically, ballast is then simultaneously guided out of each of the compartments 8 of the marine foundation 1 until the marine foundation 1 is floating again.

[0037] The form of the base 2 and/or the cover 4 may also be circular according to certain embodiments. In such a case, the shell structure typically has a circular cross-section. However, manufacturing a shell structure having a circular-cross section is more complex than providing a polygonal base 2 and a polygonal cover 4 separated by a plurality of planar sides 11 of the perimeter wall 3.

[0038] In FIGURE 2 a schematic cross-sectional view of a detail of a marine foundation in accordance with at least some embodiments of the present invention is illustrated. Six inner walls 9 are connected to a hollow structure 6. The hollow structure 6 may comprise at least one ring 20 for stiffening the hollow structure 6. The at least one stiffening ring 6 is typically arranged within the hollow structure 6. The hollow structure 6 is typically arranged in the center of the polygonal base (not shown). The inner walls 6 are connected within the cavity to an outer surface 17 of the hollow structure 6, thus forming a plurality of compartments 8.

[0039] In FIGURE 3 a schematic view of another detail of a marine foundation in accordance with at least some embodiments of the present invention is illustrated. A plate 21 or ring is arranged outside of the hollow structure 6. The plate 21 is typically made of steel and welded to the hollow structure 6. A concrete layer 22 is then made in such a way, that the plate 21 is embedded in or covered by the concrete layer 22, i.e. a concrete layer surrounding the hollow structure 6 is made above the cover 4. The cover 4 is further reinforced by several first beams 23. The first beams 23 are typically arranged within the cavity 4 in horizontal direction. The first beams 23 are typically made of steel. Between the cover 4 and the first beams 23 an additional steel cover 25 may be arranged. Further, second beams 24 are integrated at an end of each inner wall. The second beams 24 extend from the base to the plate 21 in vertical direction. The second beams 24 are typically made of steel. The second beams 24 are welded

to the hollow structure 6, to the first beams 23, to the steel cover 25 and to the plate 21, i.e. the second beams 24 extend into the concrete layer 22. Manufacturing takes place by welding the parts made of steel prior to forming the concrete cover 4 and the concrete layer 22. The described construction avoids or at least reduces the risk of fatigue failure in the area of the opening in the cover 4.

[0040] In FIGURE 4 a schematic perspective view of a detail of a marine foundation 1 in accordance with at least some embodiments of the present invention is illustrated. The hollow structure 6 extends through an opening 7 in the cover 4. The hollow structure is typically in the form of a hollow cylinder made of metal or a metal alloy, for example steel. The dimensions of the hollow structure 6 depend on various parameters such as water depth, height of the tide, intended use of the marine foundation 1 and size of the marine foundation 1 as such. An ice protector or ice shield 17 is connected to the hollow structure 16 outside of the cavity. The ice shield 17 may be, for example, in the form of a conical ring. The ice shield 17 is typically made of steel and welded to the hollow structure 6. The position and the dimensions of the ice shield 17 depend on various parameters such as water depth, height of the tide, and size of the marine foundation 1 as such.

[0041] In FIGURE 5 a schematic perspective view of an arrangement comprising an object 18 and a marine foundation 1 in accordance with at least some embodiments of the present invention is illustrated. The shown object 18 is a wind energy power plant. The object 18 is coupled to the marine foundation 1 at the upper end of the hollow structure 6 comprising a coupling section 19. The coupling section 19 may, for example, comprise a flange for attachment of the object 18.

[0042] In the semi-submerged state, the shell structure of the marine foundation 1 may be covered with soil, gravel and/or stones in order to provide further stability.

[0043] According to certain embodiments of the present invention, a wind energy power plant can be coupled to the marine foundation floating e.g. in a harbour prior to towing the combined unit including the marine foundation and the wind energy power plant to the installation site. The marine foundation 1 is configured to change its state from a floating state to a semi-submerged state and reverse. In the floating state the cover 4 and a part of the hollow structure 6 are located above the water surface. At the installation site, the combined unit is partially submerged into a semi-submerged state. In the semi-submerged state only a part of the hollow structure 6 is located above the water surface, i.e. the base 2, the perimeter wall 3 and the cover 4 forming the shell structure are submerged completely below the water surface. After its lifespan, the combined unit can be de-installed by changing the state back into the floating state and towing the combined unit to a land-based de-installation site. Thus, heavy installation equipment is not required at the sea-based installation site and the wind energy power plant can be installed and de-installed cost-efficiently.

[0044] It is to be understood that the embodiments of the invention disclosed are not limited to the particular structures, process steps, or materials disclosed herein, but are extended to equivalents thereof as would be recognized by those ordinarily skilled in the relevant arts. It should also be understood that terminology employed herein is used for the purpose of describing particular embodiments only and is not intended to be limiting.

[0045] Reference throughout this specification to one embodiment or an embodiment means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the present invention. Thus, appearances of the phrases "in one embodiment" or "in an embodiment" in various places throughout this specification are not necessarily all referring to the same embodiment. Where reference is made to a numerical value using a term such as, for example, about or substantially, the exact numerical value is also disclosed.

[0046] As used herein, a plurality of items, structural elements, compositional elements, and/or materials may be presented in a common list for convenience. However, these lists should be construed as though each member of the list is individually identified as a separate and unique member. Thus, no individual member of such list should be construed as a de facto equivalent of any other member of the same list solely based on their presentation in a common group without indications to the contrary. In addition, various embodiments and example of the present invention may be referred to herein along with alternatives for the various components thereof. It is understood that such embodiments, examples, and alternatives are not to be construed as de facto equivalents of one another, but are to be considered as separate and autonomous representations of the present invention.

[0047] Furthermore, the described features, structures, or characteristics may be combined in any suitable manner in one or more embodiments. In the above description, numerous specific details are provided, such as examples of lengths, widths, shapes, etc., to provide a thorough understanding of embodiments of the invention. One skilled in the relevant art will recognize, however, that the invention can be practiced without one or more of the specific details, or with other methods, components, materials, etc. In other instances, well-known structures, materials, or operations are not shown or described in detail to avoid obscuring aspects of the invention.

[0048] While the forgoing examples are illustrative of the principles of the present invention in one or more particular applications, it will be apparent to those of ordinary skill in the art that numerous modifications in form, usage and details of implementation can be made without the exercise of inventive faculty, and without departing from the principles and concepts of the invention. Accordingly, it is not intended that the invention be limited,

except as by the claims set forth below.

[0049] The verbs "to comprise" and "to include" are used in this document as open limitations that neither exclude nor require the existence of also un-recited features. The features recited in depending claims are mutually freely combinable unless otherwise explicitly stated. Furthermore, it is to be understood that the use of "a" or "an", that is, a singular form, throughout this document does not exclude a plurality.

INDUSTRIAL APPLICABILITY

[0050] At least some embodiments of the present invention find industrial application in installation of marine foundations, for example installation of marine foundations for wind energy power plants.

REFERENCE SIGNS LIST

[0051]

1	marine foundation
2	base
3	perimeter wall
4	cover
5	cavity
6	hollow structure
7	opening
8	compartment
9	inner wall
10	edge
11	side of perimeter wall
12	first profile
13	inner side of perimeter wall
14	second profile
15	stiffening element
16	ice shield
17	outer surface of hollow structure
18	object
19	coupling section
20	stiffening ring
21	plate
22	concrete layer
23	first beam
24	second beam
25	steel cover

CITATION LIST

Patent Literature

[0052] EP 1402119 B1

Non-Patent Literature

Claims

1. A marine foundation (1) comprising:

- a polygonal base (2),
- a perimeter wall (3) having a plurality of sides (11) protruding from the base (2) to a polygonal cover (4), thus forming a shell structure having a cavity (5),
- a hollow structure (6) extending through an opening (7) in the cover (4) to the base (2),
- and wherein within the cavity (5) a plurality of compartments (8) is formed by inner walls (9) extending from at least two edges (10) to the hollow structure (6), wherein each edge (10) is formed between two adjacent sides (11) of the perimeter wall (3).

2. The marine foundation (1) according to claim 1, wherein the marine foundation (1) is configured to change from a floating state to a semi-submerged state and reverse, wherein in the floating state at least the cover (4) and a part of the hollow structure (6) are located above a water surface, and wherein in the semi-submerged state the base (2) is positioned on a seabed.

3. The marine foundation (1) according to claim 1 or 2, wherein

- the base (2) is quadrangular, the cover (4) is quadrangular and four compartments (8) are formed within the cavity (5) by four inner walls (9), or
- the base (2) is hexagonal, the cover (4) is hexagonal and six compartments (8) are formed within the cavity (5) by six inner walls (9), or
- the base (2) is octagonal, the cover (4) is octagonal and eight compartments (8) are formed within the cavity (5) by eight inner walls (9).

4. The marine foundation (1) according to any one of claims 1-3, wherein each side (11) of the perimeter wall (3) comprises a plurality of first profiles (12) arranged parallel or substantially parallel to each other, and wherein the first profiles (12) are orientated in a direction perpendicular or substantially perpendicular to the Earth's normal.

5. The marine foundation (1) according to claim 4, wherein the first profiles (12) are comprised by or attached to each inner side (13) of the perimeter wall (3).

6. The marine foundation (1) according to any one of claims 1-5, wherein each inner wall (9) comprises a plurality of second profiles (14) arranged parallel or substantially parallel to each other, and wherein the

second profiles (14) are orientated in a direction perpendicular or substantially perpendicular to the Earth's normal.

7. The marine foundation (1) according to claim 6, wherein the second profiles (14) are comprised by or attached to at least one side of each inner wall (9).

8. The marine foundation (1) according to claims 4 and 6, wherein the marine foundation (1) comprises within each compartment (8) at least one stiffening element (15) extending from a side (11) of the perimeter wall to at least one inner wall (9).

9. The marine foundation (1) according to any one of claims 1-8, wherein a footprint of the base (2) is greater than a footprint of the cover (4).

10. The marine foundation (1) according to claim 9, wherein each side (11) of the perimeter wall (3) is inclined at an angle to a horizontal plane in a range between 45° and 90°, in a range between 45° and 80°, in a range between 45° and 70°, or in a range between 60° and 70°.

11. The marine foundation (1) according to any one of claims 1-10, wherein the hollow structure (6) comprises outside the cavity (5) an ice shield (16) extending radially from an outer surface (17) of the hollow structure (6).

12. An arrangement comprising a marine foundation (1) according to any one of claims 1-11 and an object (18) coupled to a coupling section (19) of the hollow structure (6) of the marine foundation (1).

13. Use of the marine foundation according to any one of claims 1-11, wherein an object (18) is coupled to a coupling section (19) of the hollow structure (6) of the marine foundation (1).

14. A method of installing a marine foundation (1), the method comprising:

- providing at an installation site a floating marine foundation (1) comprising:

  ◦ a polygonal base (2),
  ◦ a perimeter wall (3) having a plurality of sides (11) protruding from the base (2) to a polygonal cover (4), thus forming a shell structure having a cavity (5),
  ◦ a hollow structure (6) extending through an opening (7) of the cover (4) to the base (2),
  ◦ and wherein within the cavity (5) a plurality of compartments (8) is formed by inner walls (9) extending from at least two edges (10) to the hollow structure (6), wherein each edge (10) is formed between two adjacent sides (11) of the perimeter wall (3), and

- filling the cavity (5) at least partially with ballast in order to lower the base (2) of the marine foundation (1) to a seabed.

15. A method of de-installing a marine foundation (1), the method comprising:

- providing at a de-installation site a semi-submerged marine foundation (1) comprising:

  ◦ a polygonal base (2),
  ◦ a perimeter wall (3) having a plurality of sides (11) protruding from the base (2) to a polygonal cover (4), thus forming a shell structure having a cavity (5),
  ◦ a hollow structure (6) extending through an opening (7) of the cover (4) to the base (2),
  ◦ and wherein within the cavity (5) a plurality of compartments (8) is formed by inner walls (9) extending from at least two edges (10) to the hollow structure (6), wherein each edge (10) is formed between two adjacent sides (11) of the perimeter wall (3), and

- removing ballast from the cavity (5) in order to change the state of the marine foundation to a floating state.

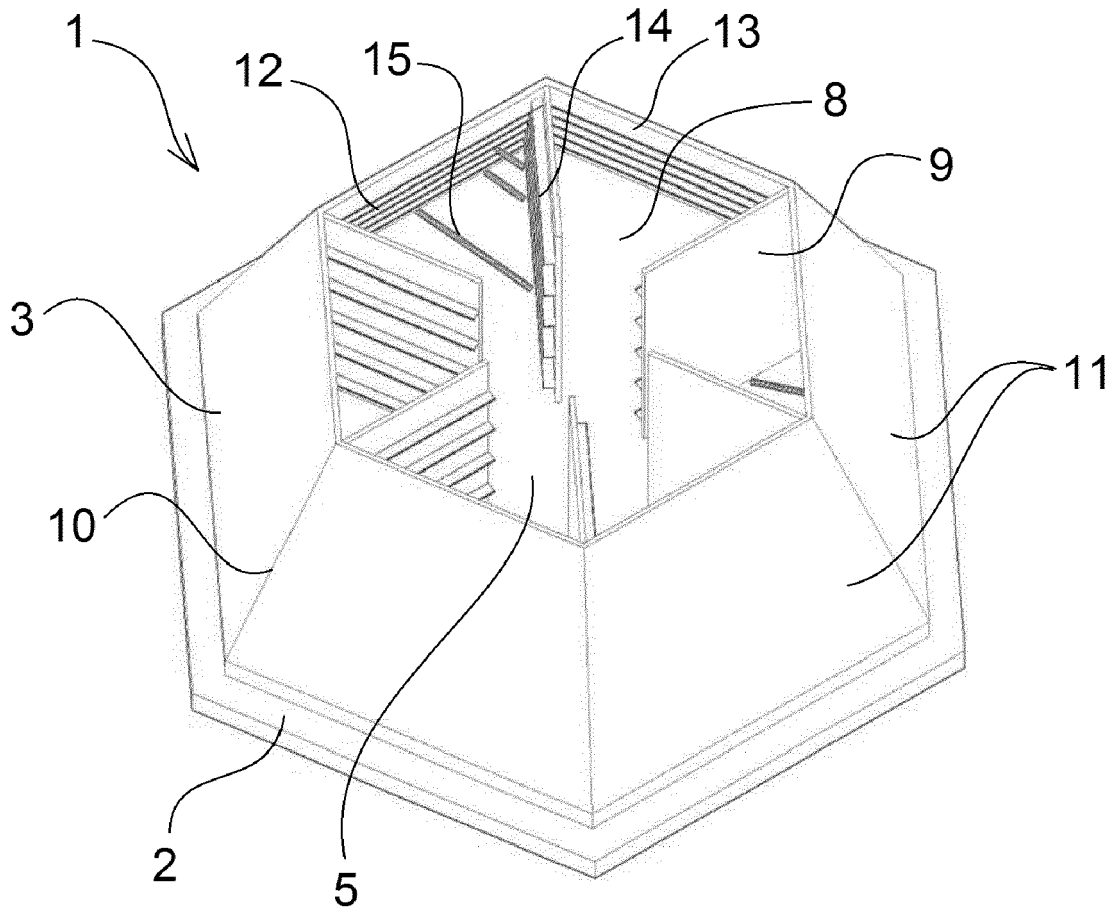

FIG. 1

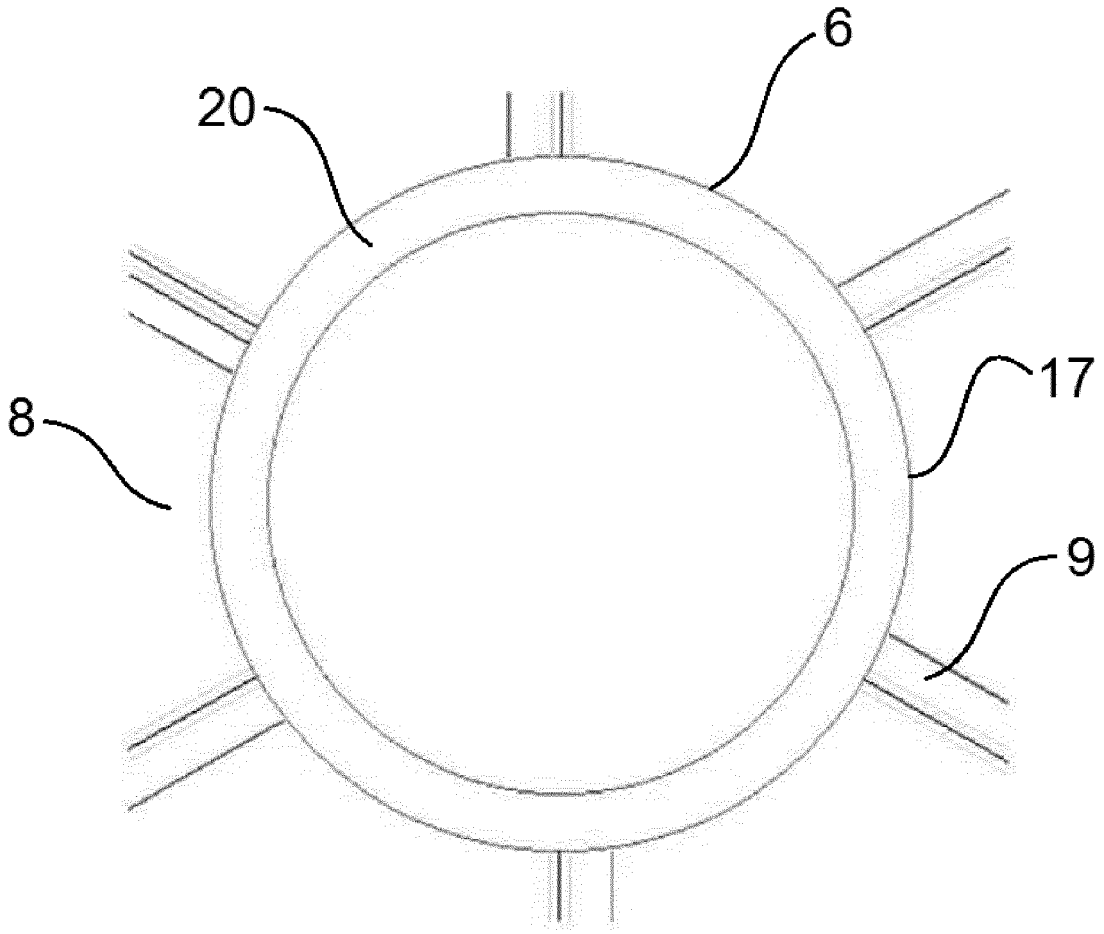

FIG. 2

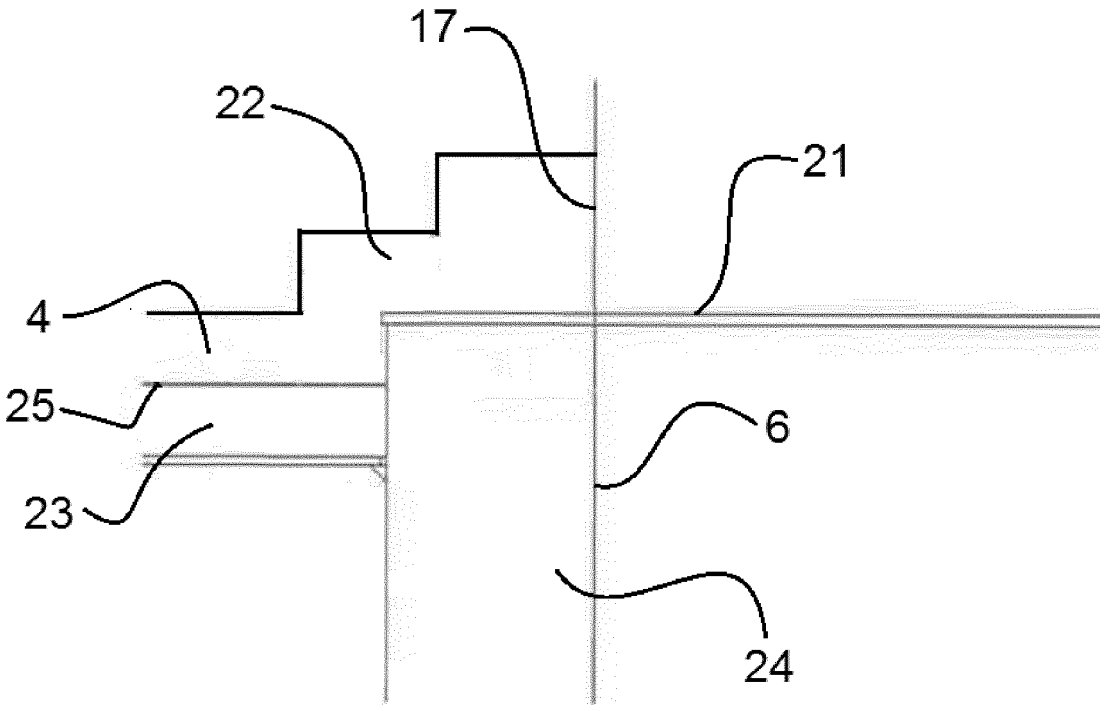

FIG. 3

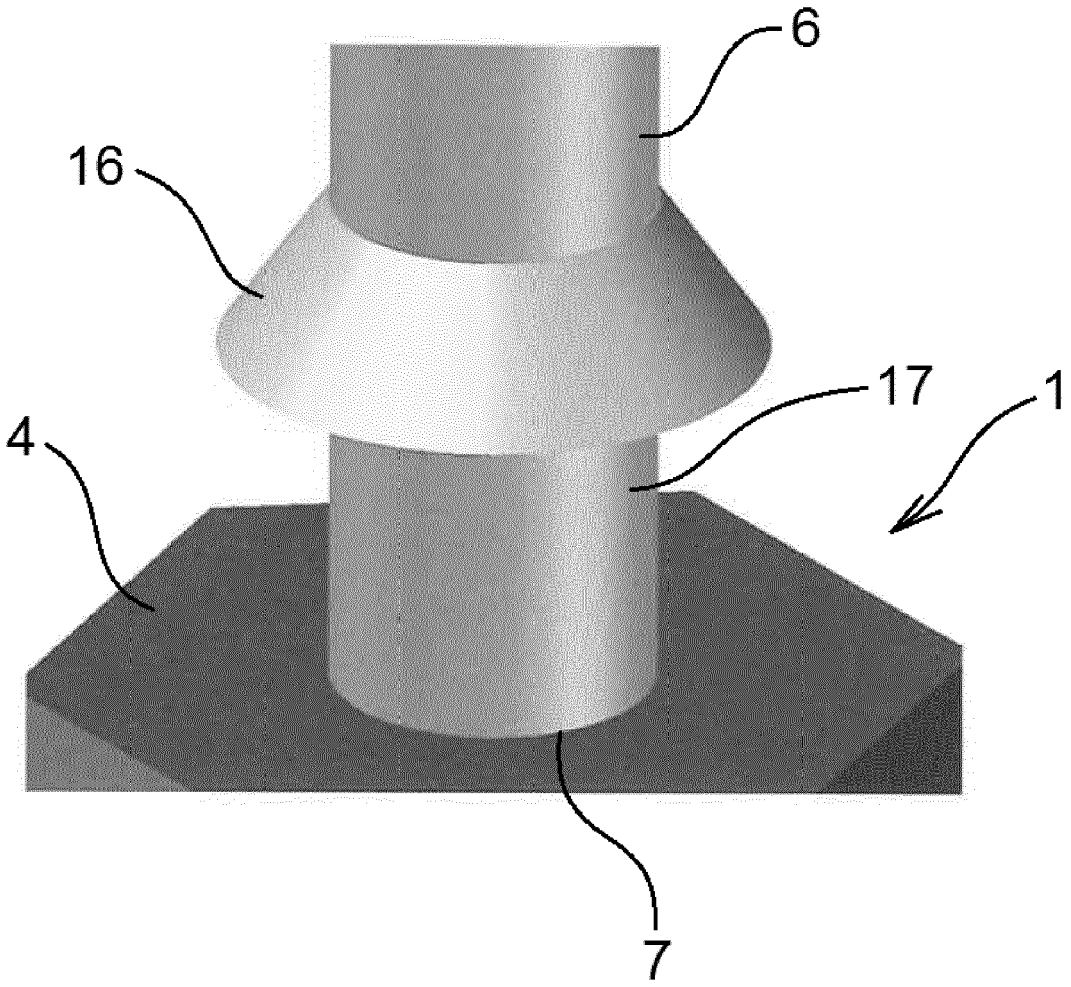

FIG. 4

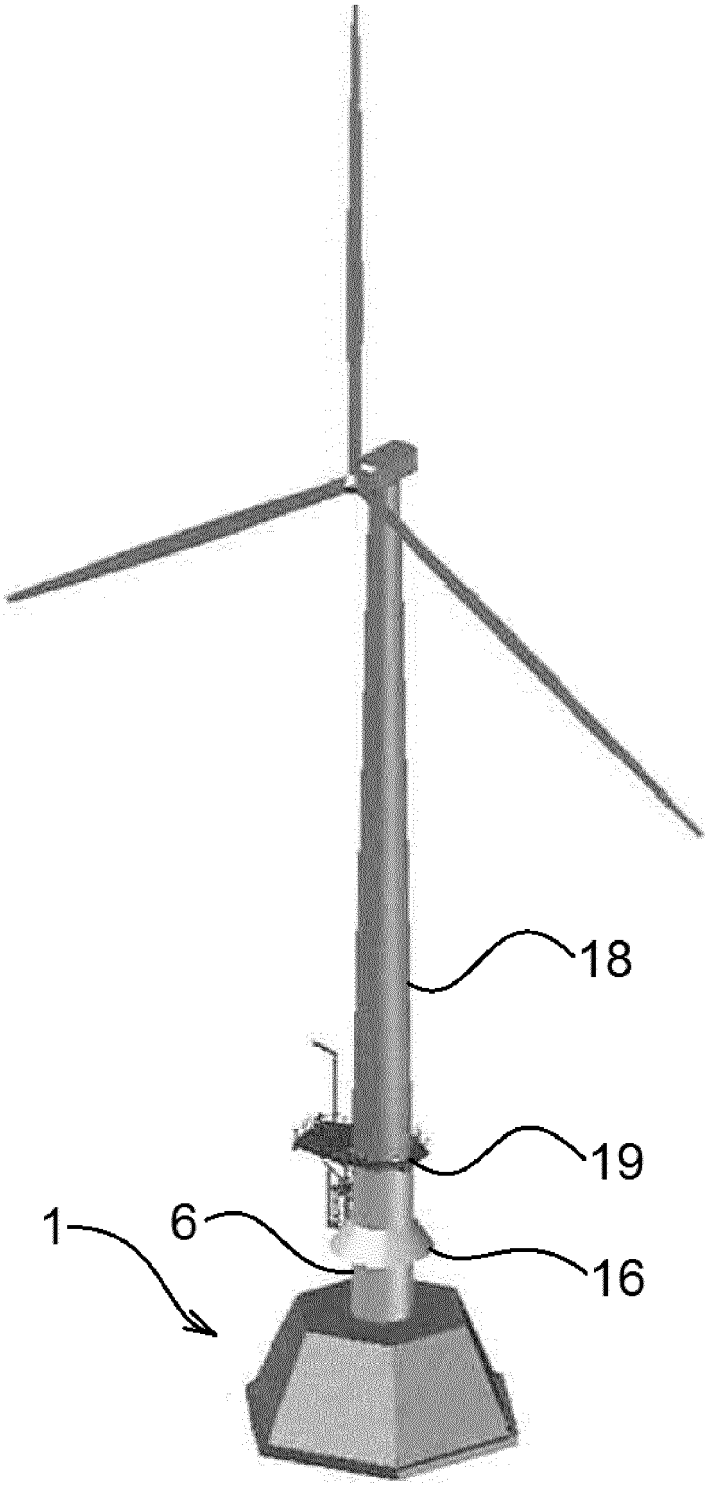

FIG. 5

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EUROPEAN SEARCH REPORT

Application Number
EP 20 16 2902

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	WO 2014/060650 A2 (STX FINLAND OY [FI]) 24 April 2014 (2014-04-24) * page 1, lines 5-11 * * page 2, lines 15-21 * * page 7, line 1 - page 17, line 22; figures 1-13 *	1-8, 11-15 9,10	INV. E02D27/42 E02D27/52 E02D23/02 E02B17/00
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E02D
E02B
F03D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	14 August 2020	Koulo, Anicet

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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