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(54) **Light weight dynamic subsea power cable**

(57) Light weight dynamic subsea power cable comprising at least one conductor element (101), and at least one buoyancy element (2, 3) having a density lower than water, wherein the at least one conductor element (101) and the at least one buoyancy element (2, 3) are stranded together and a method for producing said cable is disclosed.

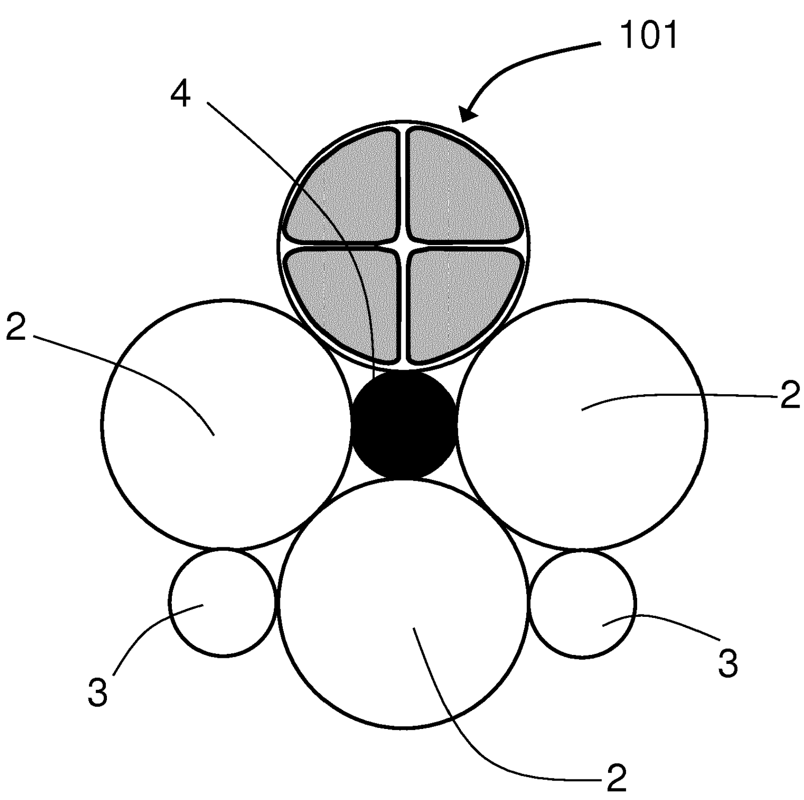

Fig. 2

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Description

[0001] The present invention relates to a light weight dynamic subsea power cable and a method for producing such a cable. More particularly, the invention relates to a light weight dynamic subsea power cable with buoyancy elements.

Background

[0002] The operation of a dynamic power cable requires that the cable is constructed to sufficiently dissipate heat generated by the conductor elements. Further, the dynamic subsea power cable should be designed for the intended depth. To reduce cable weight in water, pressure resistant buoyancy elements are required. The buoyancy must be provided without inducing local cable stress.

Prior art

[0003] For power cables the extruding of a sheath of high buoyancy material has been considered. However this solution is not able to effectively dissipate the large amounts of heat, generated by the electrical conductor element(s), to the surroundings due to the buoyant sheath encapsulating the cable. The excessive temperatures present due to insufficient heat transfer will lead to insulation degradation and subsequently reduction of the lifetime expectancy. Accordingly, extrusion of a sheath of high buoyancy material is not an applicable solution for power cables with electrical conductor element(s) which generate high temperatures.

[0004] US4132084 discloses a submarine conductor for transmission of high voltage adapted to accommodate flotation elements. The floating elements are disclosed as independent elements optionally as interconnectable modular elements. The structure requires a number of elements to interconnect all the elements thereof. The disclosed solution is intended for a substantially permanent and/or static connection between two systems separated by a body of water.

[0005] The use of independent elements in intervals will introduce local stress on the cable both during the assembly to secure the independent elements and during operation due to cable bending between the independent elements. This structure also makes the cable difficult to handle and install due to the variation in size over the length of the cable. The handling issue is especially evident for dynamic cables used in towed operations. Further, the prior art solution requires elements to interconnect all the parts of the subsea cable making this structure demanding to manufacture, install and operate.

Objectives of the invention

[0006] The aim of the present invention is to provide a dynamic subsea power cable with adapted buoyancy, which alleviates or avoids at least some of the disadvantages of the prior art cables. Particularly, the invention provides a subsea cable with adapted buoyancy, which is easy to manufacture, install and operate, and which has a high tolerance for dynamic loads. In addition, by allowing for sufficient heat transfer from the conductor element(s) to the surroundings of the cable, the subsea cable according to the invention is also suitable for conductor element(s) which in a prior art solution would generate temperatures exceeding the temperature rating of the insulation material of said conductor element(s).

[0007] To obtain these and other features the present invention provides a power cable comprising continuous buoyancy elements stranded together with the electrical conductor element(s). By stranding the buoyancy elements together with the conductor element(s), the heat from the conductor element(s) is allowed to dissipate while at the same time the desired buoyancy is achieved. Stranding of the buoyancy elements leads to a flexible cable with significantly improved bending properties. The improved bending properties are highly important for cables subjected to dynamic loads as it significantly improves the fatigue lifetime.

[0008] Accordingly, the present invention provides a light weight power cable defined by the attached claims, and in the following:

[0009] In one aspect, the present invention provides a subsea power cable comprising at least one conductor element, and at least one continuous buoyancy element having a density lower than water, wherein the at least one conductor element and the at least one buoyancy element are stranded together.

[0010] In a further aspect, the power cable according to the invention comprises at least one continuous buoyancy element having, or being made in a material having, a density less than 0.95 kg/dm^3, preferably less than 0.90 kg/dm^3, or even more preferred equal to, or less than, 0.85 kg/dm^3.

[0011] In a further aspect, the power cable according to the invention comprises at least one strain element assembled with the other elements, the strain element is preferably made of a synthetic yarn such as polyamide or a polyolefin, such as polyethylene, optionally with a mantle made in a polymer material.

[0012] In a further aspect, the power cable according to the invention comprises at least one strain element arranged at the center and/or the periphery of the power cable, and/or stranded together with the at least one conductor element and/or the at least one buoyancy element.

[0013] In a further aspect, the power cable according to the invention comprises at least one conductor element arranged at, or near, the outer surface of the power cable.

[0014] In a further aspect, the present invention provides a power cable, wherein less than 60%, or preferably less than 50%, of the circumference of the at least one conductor element is insulated from the outer surface of the power cable by the at least one buoyancy element.

[0015] In a further aspect, the power cable according to the invention comprises an outer sheath and/or optionally an outer layer of mechanical protection consisting of a layer of weaved or braided yarn, bands, ribbons or tape.

[0016] In a further aspect, the buoyancy element(s) of the power cable according to the invention is made in a material selected from the group of thermoplastic elastomers, such as styrenic block copolymers, polyolefin blends and thermoplastic polyurethanes.

[0017] In a further aspect, the conductor element(s) of the power cable according to the invention is designed to transfer electrical current with a current density above 0.8 A/mm^2.

[0018] In a further aspect, the power cable according to the invention comprises at least one signal carrying element, such as an optical fiber cable.

[0019] In a further aspect, the at least one conductor element of the power cable according to the invention is in fluid contact with water surrounding the cable when in use.

[0020] In yet a further aspect, the present invention provides a method of producing a subsea power cable, wherein the method comprises the steps of:

- preparing at least one conductor element;

- preparing at least one buoyancy element having, or being made in a material having, a density less than 0.95 kg/dm^3, preferably less than 0.90 kg/dm^3, or even more preferred equal to, or less than, 0.85 kg/dm^3, with a string like form, such that a required buoyancy of the power cable is achieved;

- stranding the at least one conductor element together with the at least one buoyancy element.

[0021] In one aspect of the method according to the invention, the method comprises the step of preparing at least one strain element with a string like form and assembling the at least one strain element together with the at least one conductor element and the at least one buoyancy element, preferably such that the strain element is arranged at the center, is stranded together with the at least one conductor element and/or the at least one buoyancy element, and/or is arranged at the periphery of the power cable.

[0022] In a further aspect of the method according to the invention, the method comprises the step of adding an outer sheath and/or an outer layer of mechanical protection consisting of a layer of weaved or braided yarn, bands, ribbons or tape.

[0023] The present invention further disclose the use of at least one continuous buoyancy element having, or being made in a material having, a density less than 0.95 kg/dm^3, preferably less than 0.90 kg/dm^3, or even more preferred equal to, or less than, 0.85 kg/dm^3, to provide a light weight dynamic power cable with a required buoyancy by stranding said at least one buoyancy element with at least one conductor element.

[0024] The power cable may comprise buoyancy elements which are pressure resistant at water depths of up to 6000 meters, or more. The pressure resistance depends on the properties of the material and/or the design of the buoyancy elements.

[0025] The term "maximum conductor temperature rating" as used herein refers to the temperature rating specified for the respective insulation materials used for the conductor elements. For some of the prospective insulation materials, the maximum temperature ratings are specified in IEC 60502. For insulation materials not specified in IEC 60502, for instance PP (polypropylene), testing and/or analyses is required to determine the correct temperature rating. At temperatures above the maximum temperature rating of a specific insulation material, said material will degrade and as a consequence, the cable will have reduced lifetime expectancy.

[0026] Thus, a subsea power cable according to the invention will be able to carry a higher current, be of longer length and/or be in an environment with a higher ambient temperature, without the conductor element(s) reaching a temperature above the maximum conductor temperature rating, than a similar power cable wherein the difference is the arrangement/design of the buoyancy element(s) as an outer sheath of the cable.

[0027] The maximum current which the conductor(s) of the light weight power cable is able to transfer may vary significantly depending on variables such as the cross-sectional area of the conductor(s), the conductor material, the length of the power cable, the ambient temperature and convection. However, the conductor(s) will generally be designed for electrical currents with a current density above 0.8 A/mm^2.

[0028] The term "continuous buoyancy element" as used herein refers to a string formed, or longitudinal, element with a density that provides buoyancy when the cable is submerged in water. The buoyancy element is preferably made of a polymer material such as a thermoplastic elastomer, for instance a polyolefin, or other suitable light weight materials, having a suitable density. Said density may in theory only be less than the density of water, but is preferably less than 0.95 kg/dm^3, less than 0.90 kg/dm^3, or even more preferred equal to, or less than, 0.85 kg/dm^3. Materials having a density higher than water may also be used, provided that the buoyancy elements are formed such that the average density of the element is lower than water. The string formed buoyancy elements are preferably continuous along substantially the whole length of the conductor element(s).

[0029] The term "stranded" as used herein refers to a twisted, twined or braided structure, wherein at least two longitudinal, or string formed, elements are twisted, braided or twined together to form a common structure.

[0030] A person skilled in the art will understand that the number and dimensions of the conducting elements, in the form of individual power conductors, within the power cable with buoyancy elements can be varied. Thus, the power cable with buoyancy elements according to the present invention may comprise 1, 2, 3, 4, 5, 6, 7, 8, 9 or even more conductor elements.

[0031] A person skilled in the art will understand that the number and dimension of buoyancy elements in the form of string like elements forming part of the power cable with buoyancy elements can be varied. Thus, the power cable with buoyancy elements according to the present invention may comprise 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16 or even more buoyancy elements.

[0032] A person skilled in the art will understand that the number of strain elements can be varied; accordingly the power cable with buoyancy elements according to the present invention may comprise 1, 2, 3, 4, 5, 6 or even more strain elements.

[0033] According to one aspect of the present invention the power cable with buoyancy elements comprises between 1-4 conductor elements, 2-10 buoyancy elements and 0-3 strain elements. In another aspect the power cable with buoyancy elements comprises between 1-3 conductor elements, 2-6 buoyancy elements and 0-1 strain element.

[0034] In one embodiment of the present invention the power cable with buoyancy elements comprises 1 conductor element and 2 buoyancy elements. In another embodiment the power cable with buoyancy elements comprises 1 conductor element, 1 strain element and 5 buoyancy elements. In yet another embodiment, the subsea power cable with buoyancy elements comprises 3 conductor elements, and 4 buoyancy elements. In yet another embodiment the subsea power cable with buoyancy elements comprises 2 conductor elements, 1 strain element and 6 buoyancy elements.

[0035] The present invention allows light weight dynamic subsea power cables to dissipate heat to the surroundings and at the same time achieve desired buoyancy. When stranded, there are no local stresses and the cable is significantly easier to handle and install compared to buoyancy modules which are clamped on the cable at fixed intervals. The stranding also provides the cable with significantly improved bending properties and subsequently, significantly increase the fatigue lifetime. These features are especially important for dynamic cables.

Brief description of the drawings

[0036] The present invention will be discussed in further detail referring to the enclosed drawings illustrating possible embodiments thereof. The figures outline possible cross-sectional configurations of the stranded cable elements.

Figure 1 is a cross-sectional sketch of a first embodiment of the present invention.

Figure 2 is a cross-sectional sketch of a second embodiment of the present invention.

Figure 3 is a cross-sectional sketch of a third embodiment of the present invention.

Figure 4 is a cross-sectional sketch of a fourth embodiment of the present invention.

Figure 5 is a cross-sectional sketch of a fifth embodiment of the present invention.

[0037] The figures illustrate different embodiments of the invention, where a combination of one or more conductive elements is stranded together with one or more buoyancy elements and optionally one or more strain elements. The number of the different elements and the diameter of each element can be varied considerably to obtain the desired properties.

Detailed description of the invention

[0038] According to the present invention, continuous buoyancy elements, preferably of a light weight material, such as thermoplastic elastomers, for instance polyolefins, or other suitable light weight materials, are stranded together with the electrical conductor element(s). Figure 1 shows a cross-sectional view of a first embodiment of the present invention. Here one conductor element 1 is twined together with two buoyancy elements 2. In the illustrated embodiment the diameter of the different elements are similar but a person skilled in the art will recognise that the diameter of each element can be selected separately according to need. The details of the conductor elements are not included in the illustration as these are not limiting for the present invention. The conductor element may accordingly be any type of power cable including one or more conductors that in them self can be massive, a combination of massive conductors, or stranded conductive wires or any combination thereof. Further the conductor element may comprise any number of other layers/elements such as insulation, semiconducting layers, strain members, barriers etc. adapted to the special needs of the subsea equipment connected to the cable and the surrounding conditions. The conductors may consist of any type of suitable conductive material, such as copper, aluminium and alloys thereof.

[0039] Figure 2 illustrates the cross section of a second embodiment of the present invention. Here the power cable consists of a conductor element 101 comprising four conductor sections, three buoyancy elements 2 of similar size as the conductor element, two smaller buoyancy elements 3 and one strain element 4. The strain element 4 supplies the cable with additional strength.

[0040] The strain element may in this and other embodiments preferably be made of a light weight material, for instance a polyamide or a polyolefin, such as aramid or polyethylene, optionally with a mantle made in a polymer material, such as a polyester or a polyolefin. The main function of the strain element is to provide additional strength during manufacture, installation and operation. The strain element may advantageously be arranged along the centre or the periphery of the power cable of the invention. Use of a synthetic yarn as a strain element may provide the further advantage of contributing to the buoyancy of the cable, depending on the density of the synthetic yarn material.

[0041] Figure 3 illustrates the cross-section of a third embodiment where the cable comprises two conductor elements 101 each with internal conductor sections. Further the cable comprises two buoyancy elements 2 of similar diameter as the conductor elements and five smaller buoyancy elements 3.

[0042] Figure 4 illustrates the cross section of a fourth embodiment comprising a central strain element 4 surrounded in an inner circle by four buoyancy elements 2 and in an outer circle by four conductor elements 1, four buoyancy elements of similar diameter and eight smaller buoyancy elements 3.

[0043] Figure 5 illustrates a cross section of a fifth embodiment comprising one central buoyancy element 2' surrounded by three buoyancy elements 2 and three conductor elements 1.

[0044] The figures illustrate only a small number of possible arrangements of the at least one conductor element, the at least one buoyancy element and the optional strain element. In principle each of the elements illustrated by a circle can be either a conductor element, a buoyancy element or strain element as long as the cable comprises at least one conductor element and at least one buoyancy element.

[0045] In all the illustrated embodiments, the conductor element(s) are arranged at the periphery of the cable so that a large part of the surface of the conductor element(s) will be close to the surface of the cable. The cable will be in contact with the surrounding water when the cable is submerged, thus allowing for maximum heat transfer from the conductor element(s) to the surrounding water. The cable may also comprise an outer sheath, said sheath preferably perforated to allow water into contact with the conductor element(s). It should also be noted that the conductor element(s) may also be arranged at the centre, or middle, of the cable as long as the surrounding water may come into contact with said conductor element(s).

[0046] When producing a cable according to the present invention, the different elements are produced separately according to well known techniques. The conductor elements may accordingly be the same as used in existing subsea power cables. The buoyancy element(s) and optional strain element(s) are provided in the form of string or cable like elements. Initially prior to the termination of the light weight cable the ends of the different elements are arranged according to the intended cross sectional configuration and fixated in this configuration by applying a fixation means such as a fibre tape a clamp or similar. The configuration could for instance be one of the configurations according to figures 1-5. Thereafter the stranding of the different elements into one buoyant subsea cable takes place. A similar fixation means may be applied to the end after the stranding is completed. The fixation means keep the ends of the different elements in position until the cable is installed according to the intended use and a adequate termination is installed, thereafter the fixation means may be removed as the integrity of the light weight subsea power cable is provided by the stranded structure.

Claims

1. A subsea power cable comprising at least one conductor element (1), and at least one continuous buoyancy element (2) having a density lower than water, wherein the at least one conductor element and the at least one buoyancy element are stranded together.

2. A power cable according to claim 1, wherein the at least one continuous buoyancy element has, or is made in a material having, a density less than 0.95 kg/dm^3, preferably less than 0.90 kg/dm^3, or even more preferred equal to, or less than, 0.85 kg/dm^3.

3. A power cable according to claim 1, wherein the power cable further comprises at least one strain element (4) assembled with the other elements, the strain element is preferably made of a synthetic yarn such as polyamide or a polyolefin, such as polyethylene, optionally with a mantle made in a polymer material.

4. A power cable according to claim 3, wherein the strain element (4) is arranged at the center and/or the periphery of the power cable, and/or is stranded together with the at least one conductor element (1) and/or the at least one buoyancy element (2).

5. A power cable according to any one of the preceding claims, wherein the at least one conductor element is arranged at, or near, the outer surface of the power cable.

6. A power cable according to any one of the preceding claims, wherein less than 60%, or preferably less than 50%, of the circumference of the at least one conductor element is insulated from the outer surface of the power cable by the at least one buoyancy element.

7. A power cable according to any one of the preceding claims, wherein the cable further comprises an outer sheath and/or optionally an outer layer of mechanical protection consisting of a layer of weaved or braided yarn, bands, ribbons or tape.

8. A power cable according to any one of the preceding claims, wherein the buoyancy element(s) is made in a material selected from the group of thermoplastic elastomers, such as styrenic block copolymers, polyolefin blends and thermoplastic polyurethanes.

9. A power cable according to any one of the preceding claims, wherein the conductor element is designed to transfer electrical current with a current density above 0.8 A/mm^2.

10. A power cable according to any one of the preceding claims, the cable further comprising at least one signal carrying element, such as an optical fiber cable.

11. A power cable according to any one of the preceding claims, wherein the at least one conductor element is in fluid contact with water surrounding the cable when in use.

12. Method of producing a subsea power cable wherein the method comprises the steps of:

- preparing at least one conductor element (1);
- preparing at least one buoyancy element (2) having, or being made in a material having, a density less than 0.95 kg/dm^3, preferably less than 0.90 kg/dm^3, or even more preferred equal to, or less than, 0.85 kg/dm^3, with a string like form, such that a required buoyancy of the power cable is achieved;
- stranding the at least one conductor element together with the at least one buoyancy element.

13. Method according to claim 12, wherein the method comprises the step of preparing at least one strain element (4) with a string like form and assembling the at least one strain element together with the at least one conductor element and the at least one buoyancy element, preferably such that the strain element is arranged at the center, is stranded together with the at least one conductor element and/or the at least one buoyancy element, and/or is arranged at the periphery of the power cable.

14. Method according to claim 12 or 13, wherein the method comprises the step of adding an outer sheath and/or an outer layer of mechanical protection consisting of a layer of weaved or braided yarn, bands, ribbons or tape.

15. Use of at least one continuous buoyancy element having, or being made in a material having, a density less than 0.95 kg/dm^3, preferably less than 0.90 kg/dm^3, or even more preferred equal to, or less than, 0.85 kg/dm^3, to provide a light weight dynamic power cable with a required buoyancy by stranding said at least one buoyancy element with at least one conductor element of said cable.

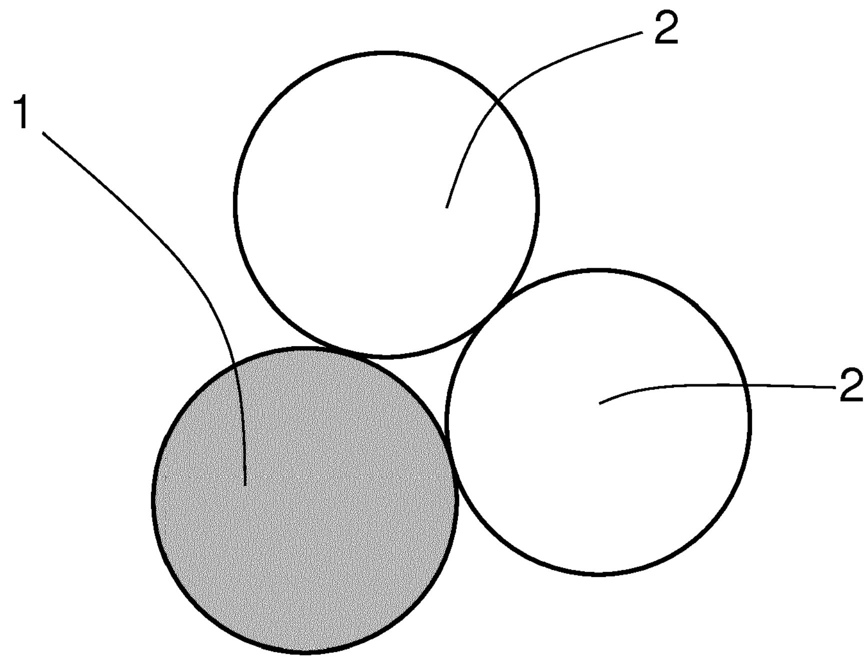

Fig. 1

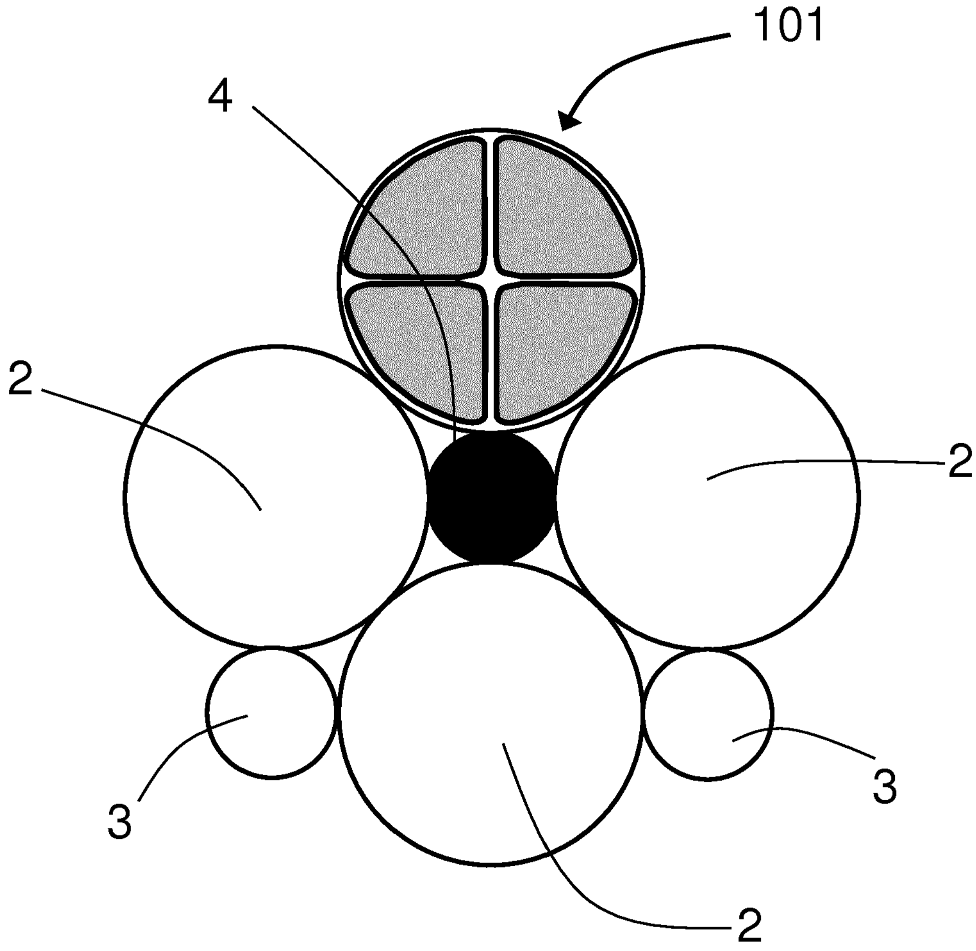

Fig. 2

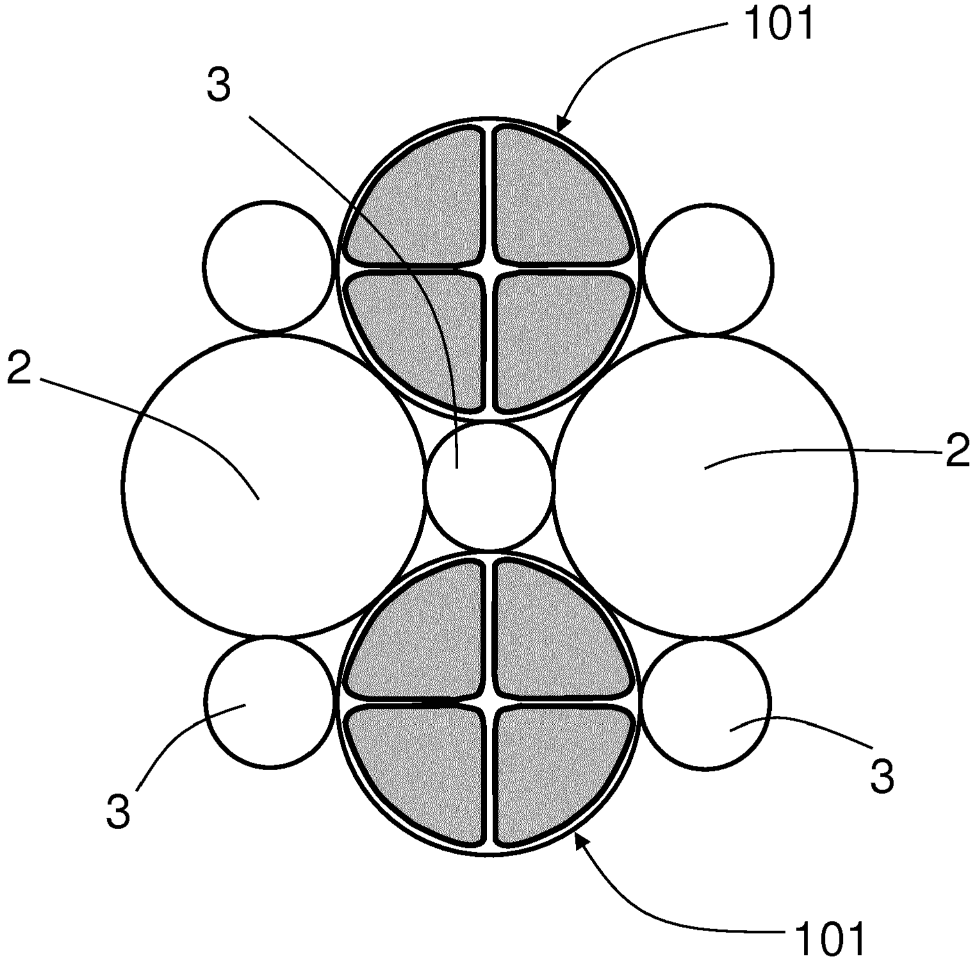

Fig. 3

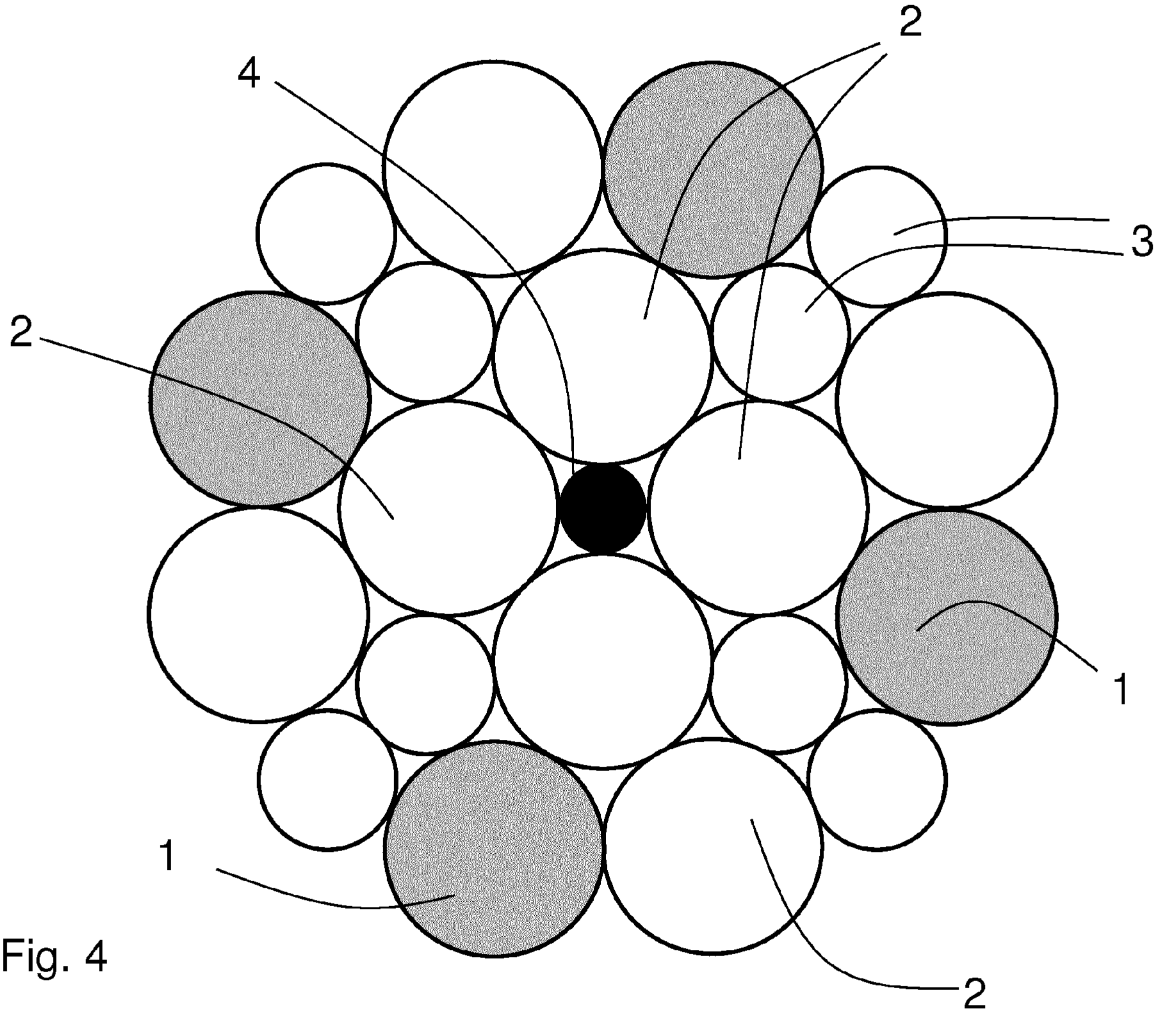

Fig. 4

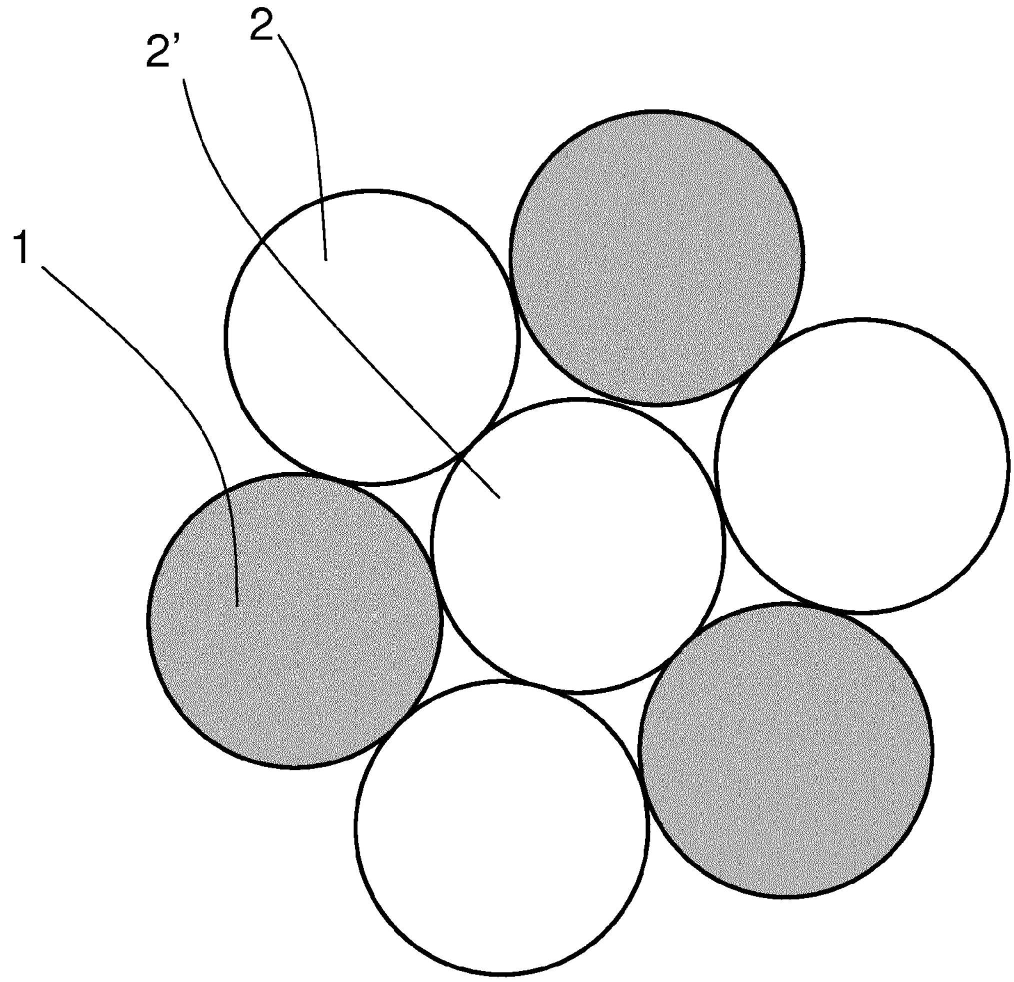

Fig. 5

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EUROPEAN SEARCH REPORT

Application Number
EP 13 30 6757

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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	16 April 2014	Hillmayr, Heinrich

CATEGORY OF CITED DOCUMENTS

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