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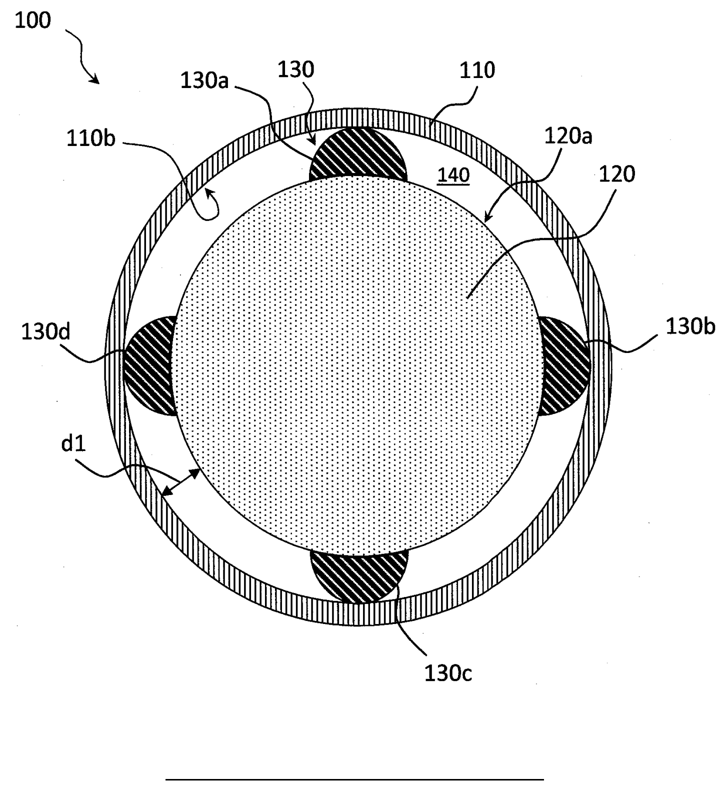
(54) **Cable and method of manufacturing a cable**

(57) The invention relates to a cable (100) comprising at least one radially outer section (110) and at least one radially inner section (120) arranged radially inwards of said radially outer section (110), wherein said cable (100) comprises at least one locking element (130, 130a, 130b, 130c, 130d; 170) which is configured to reduce and/or prevent an axial relative movement between said radially outer section (110) and said radially inner section (120).

Fig. 1



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Description

Field of the invention

[0001] The invention relates to a cable comprising at least one radially outer section and at least one radially inner section arranged radially inwards of said radially outer section. The invention further relates to a method of manufacturing such cable.

Background

[0002] Especially during vertical installation of a cable of the aforementioned type on site, e.g. at an antenna tower or the like, the force for hoisting the cable is applied to an outer section of the cable, e.g. to a component of the radially outer section. In view of the substantial mass of the components of the cable such as e.g. metallic conductors, filling material, isolating material, and the like, during especially vertical installation, there is a risk of "decomposition" of the cable, i.e. an axial displacement of various cable components relative to each other, which is highly undesired since it could result in damage to the cable. In order to avoid decomposition, conventional cables and corresponding manufacturing methods comprise/propose a "zero"-tolerance approach for the usually concentric cable elements to ensure the proper retention force. I.e., cable components which are radially adjacent to each other are provided with rather small manufacturing tolerances so that e.g. an inner diameter of a first component is identical to an outer diameter of a second component which is radially outward surrounded by the first cable component. While this effects friction forces that retain neighboring cable components in place, the "zero"-tolerance approach requires complex manufacturing steps and leads to increased costs.

Summary

[0003] Thus, it is an object of the present invention to provide an improved cable which can efficiently be mounted even in a vertical orientation, i.e. with its longitudinal axis in parallel to a gravitational vector, without the risk of decomposition, and wherein the manufacturing process is less complex and costly than the conventional zero-tolerance approach.

[0004] Regarding the aforementioned cable, according to the embodiments, this object is achieved by said cable comprising at least one locking element which is configured to reduce and/or prevent an axial relative movement between said radially outer section and said radially inner section.

[0005] Thus, advantageously, the further components of the cable such as the radially inner section and the radially outer section or their components, respectively, are not required to be manufactured by employing the zero-tolerance approach known from conventional systems and methods. Rather, comparatively large manufacturing tolerances and process variations can advantageously be tolerated, because the locking element according to the principle of the embodiment advantageously prevents or at least reduces an axial relative movement between the radially inner section and the radially outer section of the cable.

[0006] According to an embodiment, said cable comprises at least one locking element which is configured to reduce and/or prevent a rotational relative movement between said radially outer section and said radially inner section, whereby structural decomposition with regard to torsional forces is prevented.

[0007] According to a further embodiment, at least one of said locking elements is configured to establish a) form closure and/or b) force closure with at least one component of said radially outer section and/or said radially inner section. According to an embodiment, force closure can e.g. be achieved by dimensioning the locking element such that it only fits between the radial inner and outer sections while being compressed to some degree between these sections, whereby friction forces come into effect between the components. Alternatively or in addition, form closure may e.g. be attained by providing a certain geometry for the locking element which can form a positive lock with a further component such as e.g. a portion of a surface of the radially inner or outer section of the cable. Advantageously, the inner and outer sections are not required to be manufactured with small tolerances in this case. Rather, it is sufficient if the locking element is designed and arranged such that form closure and/or force closure is attained.

[0008] According to a further embodiment at least one of said locking elements is arranged on a radially outer surface of said radially inner section and/or on a radially inner surface of said radially outer section.

[0009] According to a further embodiment, at least one of said locking elements forms an integral part of said radially inner section and/or said radially outer section, whereby manufacturing of the cable is simplified.

[0010] According to a further embodiment, at least one of said locking elements comprises a cross-section with about one of the following shapes: circular, half-circular, rectangular, trapezoidal, triangular.

[0011] According to a further embodiment, at least one of said locking elements is arranged with an angular distance to each other (i.e., neighbouring locking elements) of about 20 degrees to about 180 degrees, preferably about 45 degrees to 130 degrees.

[0012] According to a further embodiment, a plurality of said locking elements is arranged at a same length coordinate of said cable.

[0013] According to a further embodiment, at least one locking element comprises a basically cylindrical or hollow-cylindrical shape with a longitudinal axis arranged substantially parallel to a longitudinal axis of said cable.

[0014] According to a further embodiment, at least one locking element comprises a basically cylindrical or hollow-cylindrical shape and is helically arranged around said radially inner section.

[0015] According to a further embodiment, said radially outer section comprises at least one electrical conductor, wherein said radially inner section comprises at least one isolating layer arranged radially inward of said at least one electrical conductor, and wherein at least one of said locking elements is arranged radially between said isolating layer and said electrical conductor, preferably on a radially outer surface of said isolating layer or integrated, preferably integrally integrated, therein.

[0016] According to a further embodiment, said cable comprises at least one rip cord, which is preferably arranged in a radially inner section of said primary electrical conductor.

[0017] According to a further embodiment, at least one locking element comprises or is made of elastically and/or plastically deformable material, wherein a coefficient of elasticity preferably ranges from about 0.05 to about 0.60. I.e., according to an embodiment, a length dimension of said locking element may be compressed by application of external forces by at least about five per cent to at least about sixty per cent without suffering plastic deformation. Rather, if said external forces are removed, the so compressed locking element will assume its original shape again. This range of elasticity contributes to a superior axial retention effect between the components contacted by said locking element.

[0018] A further solution to the object of the present invention is given by a method of manufacturing a cable, comprising the steps of providing at least one radially outer section and at least one radially inner section arranged radially inwards of said radially outer section, wherein at least one locking element which is configured to reduce and/or prevent an axial relative movement between said radially outer section and said radially inner section is provided between said radially outer section and said radially inner section.

[0019] According to an embodiment, at least one locking element is provided on a radially outer surface of said radially inner section and/or on a radially inner surface of said radially outer section, preferably as integral part of the respective section.

Brief description of the figures

[0020] Further features, aspects and advantages of the present invention are given in the following detailed description with reference to the drawings in which:

Figure 1	schematically depicts a cross-sectional view of a first embodiment of a cable,
Figure 2a, 2b	schematically depict cross-sectional views of further embodiments of the cable with locking elements provided on a radially outer surface of an inner section of the cable,
Figure 3a, 3b	schematically depict cross-sectional views of a cable according to further embodiments,
Figure 4a to 4e	schematically depict side views of locking elements according to further embodiments,
Figure 5a, 5b	schematically depict side views of a radially inner section of a cable with locking elements arranged thereon,
Figure 6	schematically depicts a side view of a corrugated component of a radially outer section of a cable in locking position with locking elements according to an embodiment,
Figure 7	schematically depicts a side view of a locking element according to a further embodiment,
Figure 8, 9	schematically depict cross-sectional views of hybrid cables according to the embodiments, and
Figure 10A, 10B	schematically depict further embodiments.

Description of the embodiments

[0021] Figure 1 schematically depicts a cross-sectional view of a cable 100. The cable comprises a radially outer section 110 and a radially inner section 120, which is arranged radially inwards with respect to said radially outer section 110. For the sake of clarity, no details regarding the sections 110 or 120 are depicted in figure 1, while these sections may well comprise different components or layers at such as electrically insulating material, electrical and/or optical conductors, and the like.

[0022] According to the principle of the embodiments, at least one locking element 130 is provided which is configured to reduce and / or prevent an axial relative movement between said radially outer section 110 and said radially inner section 120. For example, with respect to figure 1, an axial movement would occur in a direction perpendicular to the drawing plane of figure 1.

[0023] As can be seen from figure 1, four locking elements 130a, 130b, 130c, 130d are provided between the sections 110, 120 of the cable 100. Presently, the locking elements 130 comprise a bulge-shape and are arranged on a radially outer surface 120a of the radially inner section 120 of the cable 100. However, according to further embodiments, the locking elements could also be arranged on a radially inner surface 110b of the radially outer section 110 of the cable. Combinations thereof are also possible.

[0024] The geometry of the locking elements 130 is preferably chosen such that they extend radially from the outer surface 120a to the inner surface 110b such that non-vanishing contact surfaces are defined between the radially outer surface portions of the locking elements 130 and the opposing portions of the radially inner surface 110b, whereby frictional forces come into effect which reduce or prevent an axial relative movement between components 110, 120, e.g. in such cases where the cable 100 is mounted in a vertical orientation, wherein a hoisting force is usually applied only to the outer section 110, but not to the inner section 120.

[0025] Generally, according to embodiments, where the locking elements effect force closure, the geometry and the arrangement of the locking elements 130 is chosen such that the distance d1 between the surfaces 120a, 110b is bridged for effecting the above-explained frictional forces.

[0026] It is to be noted that figure 1 as well as the further figures are not drawn to scale for the sake of intelligibility of details especially related to the locking elements. Particularly, for a real implementation of the cable 100, the distance d1 could be chosen much smaller with respect to a diameter of the cable 100, whereby the inter-section volume 140 would be reduced.

[0027] Figure 2a depicts a cross-sectional view of a further embodiment 100a of the cable. In contrast to the configuration of figure 1, the cable 100a of figure 2a comprises three locking elements 130a, 130b, 130c arranged with a respective angular distance of about 120 degrees. As can be seen from figure 2a, the radially inner section 120 of the cable 100a comprises a radially inner portion 122 and a radially outer portion 124 which defines the radially outer surface 120a the locking elements 130a, 130b, 130c are arranged on. According to the present embodiment, the locking elements 130a, 130b, 130c are configured such that they form integral parts of the outer layer 124 of the radial inner section 120 (cf. figure 1) of the cable. For example, the locking elements 130a, 130b, 130c could be formed as bulges or the like during a manufacturing process of the component 124.

[0028] Figure 2b depicts a further embodiment 100b of the cable. In contrast to figure 2a, the locking elements 130a, 130b, 130c - while again being arranged at an angular distance of about 120 degrees - are not positioned at the same longitudinal coordinate of the cable 100b with respect to each other. Instead, they are distributed along a longitudinal axis of the cable 100b which extends perpendicular to the drawing plane of figure 2b.

[0029] Figure 3a depicts a further embodiment 100c. In contrast to the embodiments explained above, with the cable 100c of figure 3a, locking elements 130a, 130b, 130c are arranged on a radially inner surface 110b (figure 1) instead of the radially outer surface 120a of the component 124. According to a further embodiment, it is also possible to provide a first number of locking elements on surface 120a of the inner section 120, and a second number of locking elements on the radially inner surface 110b of the radially outer section 110 (figure 1) of the cable.

[0030] Figure 3b depicts a further embodiment 100d of the cable, wherein the locking elements 130a, 130b, 130c are arranged on the radially inner surface 110a (figure 1) of the outer section 110, and wherein they are distributed along a longitudinal axis, i.e., the locking elements 130b, 130c do not lie in the drawing plane as is the situation with the locking element 130a.

[0031] Figure 4a to 4e schematically depict side views of locking elements according to the embodiments.

[0032] Figure 4a depicts a locking element 130e which comprises a roughly semi-circular cross-section and which is arranged on a radially outer surface 120a, also c.f. figure 1. A surface of the locking element 130e of figure 4a is denoted with reference sign 130e'. At least partially, this surface 130e' may come into contact with an opposing radially inner surface 110b (figure 1) to effect friction forces and thus to prevent an undesired axial movement between the components 110, 120 of the cable 100.

[0033] Figure 4b depicts a further configuration, wherein the locking element 130f comprises a rectangular cross-section.

[0034] A trapezoidal cross-section is depicted by the locking element 130g of figure 4c.

[0035] Figure 4d depicts a locking element 130h which comprises a triangular cross-section.

[0036] Figure 4e depicts a group of smaller, trapezoidal locking elements forming a locking element group 130i that operates similar to the single locking elements explained above.

[0037] Figure 5a depicts a side view of a radially inner section 120 of a cable according to the embodiments with a plurality of locking elements 130a, 130b, 130c arranged thereon. As can be seen from figure 5a, the locking elements are arranged in groups of e.g. four locking elements (cf. the cross-sectional view of figure 1) wherein the different groups are spaced apart in an axial coordinate direction 1 by constant distance d2. This ensures a reliable establishment of friction forces between the locking elements and a radially outer section 110 (not depicted in figure 5a) of the cable.

[0038] Figure 5b depicts an alternative approach, where only one single locking element 130a is arranged at a specific length coordinate position along the longitudinal axis 1 of the cable. An axial spacing between neighbouring locking elements is denoted by double arrow d3. An angular spacing of neighbouring locking elements is again about 90 degrees but may generally, i.e., with other embodiments, vary between about 20 degrees to about 180 degrees.

[0039] Figure 6 depicts a side view of a further embodiment, where semi-spherically shaped locking elements 130a are provided on a surface 120a of a radially inner section 120 of a cable. A radially outer section 110 (figure 1) of the cable comprises a corrugated metallic conductor 112, the corrugations of which are adapted to the locking elements 130a and vice versa so that a positive lock, i.e.

form closure, is attained between components 120, 112, which again prevents axial relative movement of these components along the direction depicted by the double-arrow DA in figure 6.

[0040] In other words, the concave ranges 112a and convex ranges 112b defined by the corrugated conductor 112 are adapted regarding their shape and their spacing and the like to the locking elements 130a and vice versa.

[0041] Figure 7 depicts a side view of a locking element 130a according to a further embodiment. Virtual surfaces 120a, 110b of the components 120, 110 as explained above with reference to figure 1 are also depicted for illustration purposes. In the present case, the locking element 130a comprises a trapezoidal cross-section, whereby a first contact area A1 with the contact surface 110b and a second contact area A2 with the second surface 120a is defined.

[0042] Preferred values for the contact areas A1, A2 range from about 0.5 mm^2 (square millimeter) to about 5 mm^2.

[0043] According to a further embodiment, a preferred height h of the locking element 130a ranges from about 0.3 to about 1.5 mm.

[0044] Figure 8 depicts a cross-section of a cable 100e according to a further embodiment. Presently, the cable 100e is configured as a so-called hybrid cable comprising electrical conductors and optical fibres. An outer section 110 (figure 1) of the cable 100e according to figure 8 is defined by an outer insulating layer 112, e.g., an insulating jacket, and a metallic conductor 114, which is arranged radially inwards of said insulating jacket 112. The metallic conductor 114 may be corrugated, but is not required to comprise corrugations.

[0045] An inner section 120 (figure 1) of the cable 100e according to figure 8 comprises an insulating jacket 124, and a further electric conductor 122, which is arranged radially inwards of said insulating jacket 124. Generally, the components 112, 114, 124, 122 comprise a substantially hollow-cylinder-like shape and define a coaxial arrangement. However, according to the embodiments, the aforementioned components may also comprise other shapes than depicted here.

[0046] Radially inwards of said second conductor 122, a filling layer 126 with filling material 126a such as a foam material or the like is provided. Within the filling material 126a, an optical cable 128 is arranged which comprises a jacket 128a and a further filling material 128b arranged radially inside of the jacket 128a. Embedded in the filling material 128b are optical fibres 128c which may be used for optical data transmission in a per se known manner.

[0047] Altogether, the electrical conductors 122, 114 of the hybrid cable 100e may e.g. be used to provide electrical energy from a source to a sink. Alternatively or in addition, signal transmission by means of electrical signals is also possible. Moreover, the optical cable 128 embedded in the filling material 126a of the hybrid cable 100e advantageously enables to also transmit optical signals via the optical fibres 128c.

[0048] The hybrid cable 100e may e.g. be used for connecting a remote radio head of a base station of a cellular communications system to a processing device, wherein the processing device may be located in a building on the ground, and wherein the radio head may be arranged on an antenna tower. This mounting situation requires a substantially vertical arrangement of the cable 100e, wherein an axial displacement which might result from gravitational force and the like is advantageously prevented by means of the locking elements 130a, 130b, 130c according to the embodiments.

[0049] Presently, the locking elements 130a, 130b, 130c are arranged within the insulating jacket layer 124 and provide friction to attain at least force closure, but optionally also form closure with the metallic conductor 114. Form closure with conductor 114 can e.g. be achieved if the conductor 114 is of the corrugated type, and if the locking elements are adapted to the form of the corrugations of the conductor 114, also cf. the principle depicted by figure 6.

[0050] Optionally, the optical cable 128 embedded in the filler material 126a may also comprise locking elements 150a, 150b to prevent axial displacement between the components 128, 126a.

[0051] Figure 9 depicts a further embodiment 100f of a hybrid cable, which in addition to the figure 8 configuration further comprises rip cords 160a, 160b arranged between the insulating jacket 124 and the metallic conductor 114. This advantageously enables an efficient mounting and confectioning of the cable 100f. For example, by applying a tensile force to an end portion of one of the rip cords 160a, 160b, the metallic conductor 114 and optionally also the insulating jacket 112 may be ruptured or severed, respectively, whereby a slit is defined in the layers 114, 112 which facilitates removal of said layers, e.g. to reach the radially inner layers of the cable 100f. If both rip cords 160a, 160b are used to slit the respective surrounding portions of the layers 114, 112, an easy removal of portions of the layers 114, 112 is enabled.

[0052] Figure 10a schematically depicts a further configuration according to the embodiments. Depicted is a radially inner section 120 of a cable, wherein a locking element 170a is arranged substantially in parallel to the cable or its radial inner section 120, i.e. in parallel to the longitudinal axis LA. I.e., in this embodiment, the locking element is not of the bulge-shaped type, but rather comprises a cylinder shape and as such resembles the rip cords 160a, 160b of the configuration according to figure 9.

[0053] In this configuration, manufacturing tolerances regarding the outer diameter of the component 120 and an inner diameter of a surrounding component 110 (figure 1) can be compensated by providing the locking element 170a therein between so as to effect friction forces between the components 120, 170a and the components 170a, 110, whereby an axial displacement may advantageously be prevented. Advantageously, said locking element 170a comprises an elastic material.

[0054] According to a further embodiment, the functionality of the locking element 170a (Fig. 10a) and of the rip cord 160a may also be combined. I.e., at least one rip cord may be configured such that it enables the force closure and/or form closure explained above for the locking element according to the embodiments. In this case, one combine rip cord / locking element may be sufficient to prevent/reduce an axial movement between inner and outer sections 110, 120, and at the same time severing the outer section 110 for easy installation of the cable is enabled.

[0055] Figure 10b depicts a further configuration, wherein the locking element 170b is arranged helically around the outer surface of the radially inner section 120 of a cable.

[0056] According to a particularly preferred embodiment, when employing the bulge-shaped locking elements as e.g. depicted by figure 1, a minimum of three locking elements is recommended for proper radial alignment of the components 110, 120.

[0057] The locking elements according to the embodiments advantageously enable to compensate for typical manufacturing tolerances of components 110, 120 of a cable.

[0058] The description and drawings merely illustrate the principles of the invention. It will thus be appreciated that those skilled in the art will be able to devise various arrangements that, although not explicitly described or shown herein, embody the principles of the invention and are included within its spirit and scope. Furthermore, all examples recited herein are principally intended expressly to be only for pedagogical purposes to aid the reader in understanding the principles of the invention and the concepts contributed by the inventor(s) to furthering the art, and are to be construed as being without limitation to such specifically recited examples and conditions. Moreover, all statements herein reciting principles, aspects, and embodiments of the invention, as well as specific examples thereof, are intended to encompass equivalents thereof.

Claims

1. Cable (100) comprising at least one radially outer section (110) and at least one radially inner section (120) arranged radially inwards of said radially outer section (110), wherein said cable (100) comprises at least one locking element (130, 130a, 130b, 130c, 130d; 170) which is configured to reduce and/or prevent an axial relative movement between said radially outer section (110) and said radially inner section (120).

2. Cable (100) according to claim 1, wherein said cable (100) comprises at least one locking element (130) which is configured to reduce and/or prevent a rotational relative movement between said radially outer section (110) and said radially inner section (120).

3. Cable (100) according to one of the preceding claims, wherein at least one of said locking elements (130) is configured to establish a) form closure and/or b) force closure with at least one component of said radially outer section (110) and/or said radially inner section (120).

4. Cable (100) according to one of the preceding claims, wherein at least one of said locking elements (130a, 130b, 130c) is arranged on a radially outer surface (120a) of said radially inner section (120) and/or on a radially inner surface (110b) of said radially outer section (110).

5. Cable (100) according to one of the preceding claims, wherein at least one of said locking elements (130a, 130b, 130c) forms an integral part of said radially inner section (120) and/or said radially outer section (110).

6. Cable (100) according to one of the preceding claims, wherein at least one of said locking elements (130a, 130b, 130c) comprises a cross-section with about one of the following shapes: circular, half-circular, rectangular, trapezoidal, triangular.

7. Cable (100) according to one of the preceding claims, wherein at least one of said locking elements (130a, 130b, 130c) is arranged with an angular distance to each other of about 20 degrees to about 180 degrees.

8. Cable (100) according to one of the preceding claims, wherein a plurality of said locking elements (130a, 130b, 130c) is arranged at a same length coordinate (1) of said cable.

9. Cable (100) according to one of the preceding claims, wherein at least one locking element (170a) comprises a basically cylindrical or hollow-cylindrical shape with a longitudinal axis arranged substantially parallel to a longitudinal axis of said cable (100).

10. Cable (100) according to one of the preceding claims, wherein at least one locking element (170b) comprises a basically cylindrical or hollow-cylindrical shape and is helically arranged around said radially inner section (120).

11. Cable (100) according to one of the preceding claims, wherein said radially outer section (110) comprises at least one electrical conductor (114), wherein said radially inner section (120) comprises at least one isolating layer (124) arranged radially inward of said at least one electrical conductor (114),

and wherein at least one of said locking elements (130) is arranged radially between said isolating layer (124) and said electrical conductor (114).

12. Cable (100) according to one of the preceding claims, wherein said cable (100) comprises at least one rip cord (160a, 160b).

13. Cable (100) according to one of the preceding claims, wherein at least one locking element (130; 130a, 130b, 130c, 130d; 150a, 150b; 170a, 170b) comprises or is made of elastically and/or plastically deformable material.

14. Method of manufacturing a cable (100), comprising the steps of providing at least one radially outer section (110) and at least one radially inner section (120) arranged radially inwards of said radially outer section (110), wherein at least one locking element (130, 130a, 130b, 130c, 130d) which is configured to reduce and/or prevent an axial relative movement between said radially outer section (110) and said radially inner section (120) is provided between said radially outer section (110) and said radially inner section (120).

15. Method according to claim 14, wherein at least one locking element (130, 130a, 130b, 130c, 130d) is provided on a radially outer surface (120a) of said radially inner section (120) and/or on a radially inner surface (110b) of said radially outer section (110), preferably as integral part of the respective section (110, 120).

Fig. 1

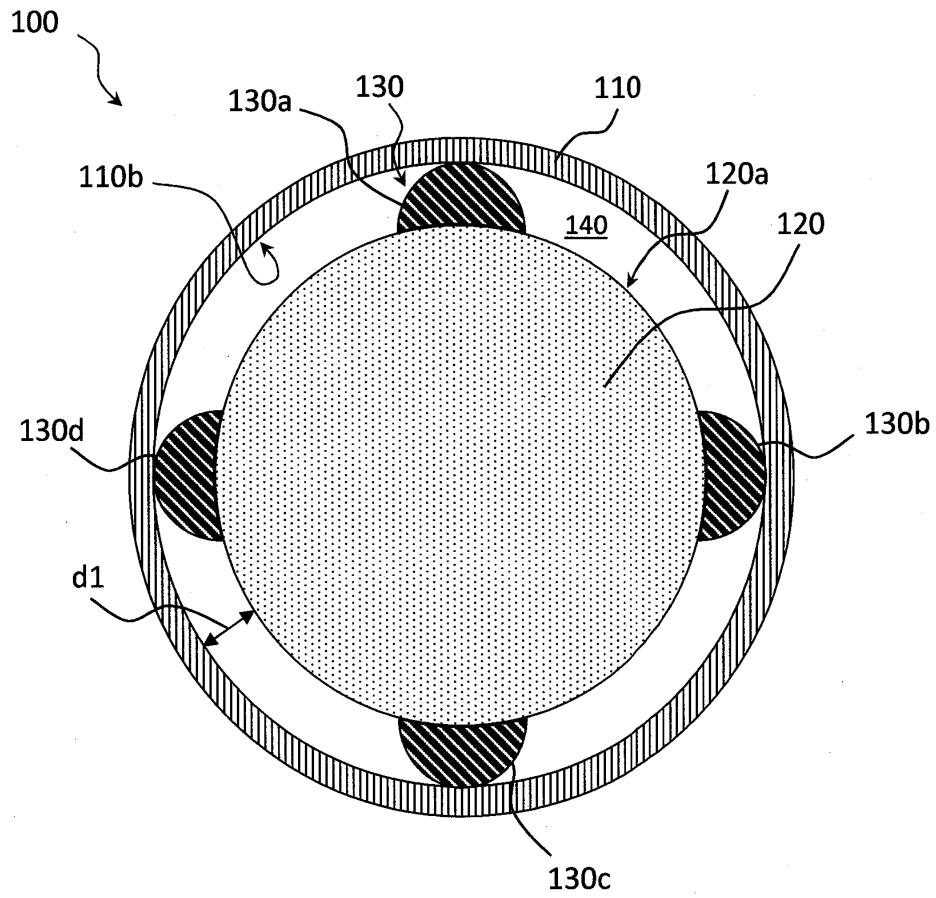


Fig. 2a

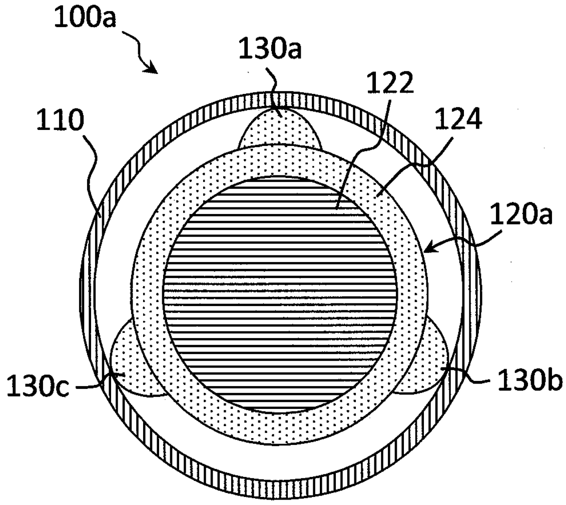


Fig. 2b

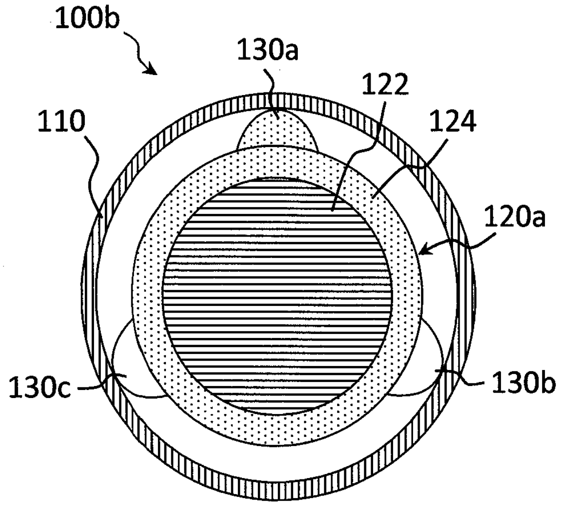


Fig. 3a

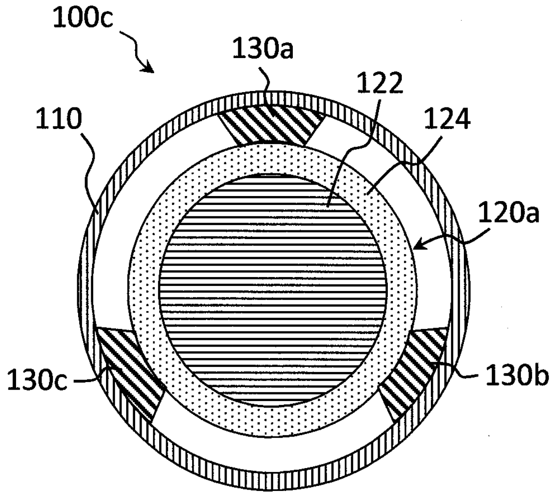


Fig. 3b

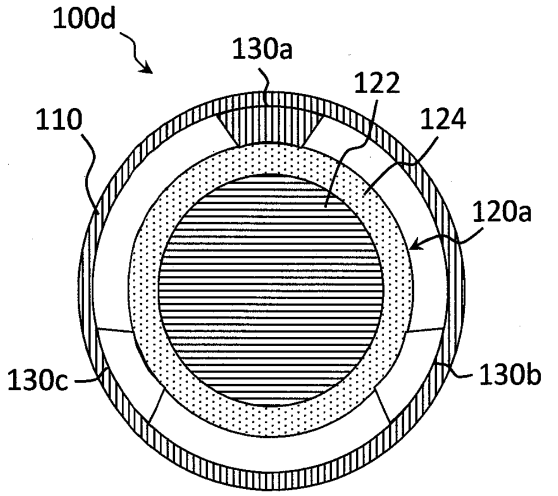


Fig. 4a

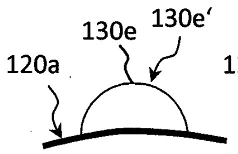


Fig. 4b

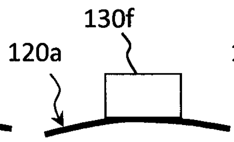


Fig. 4c

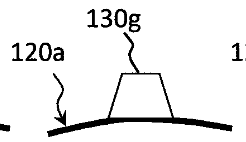


Fig. 4d

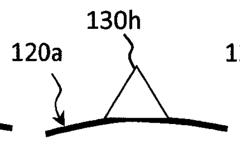


Fig. 4e

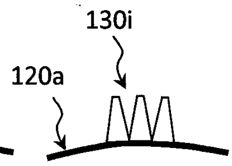


Fig. 5a

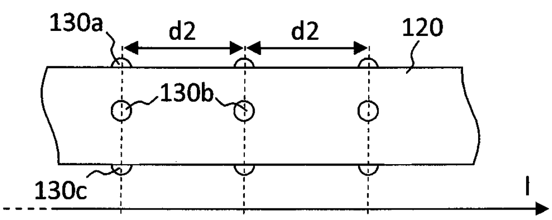


Fig. 5b

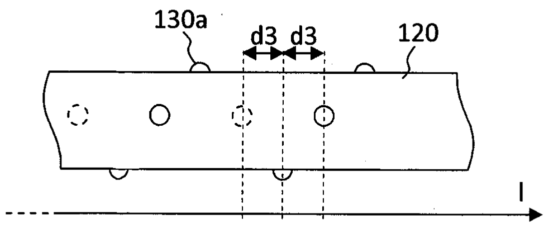


Fig. 6

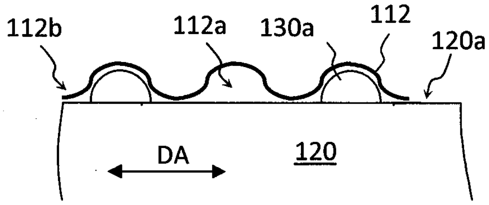


Fig. 7

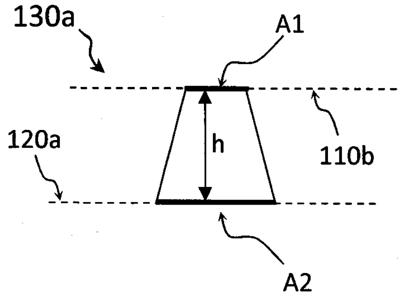
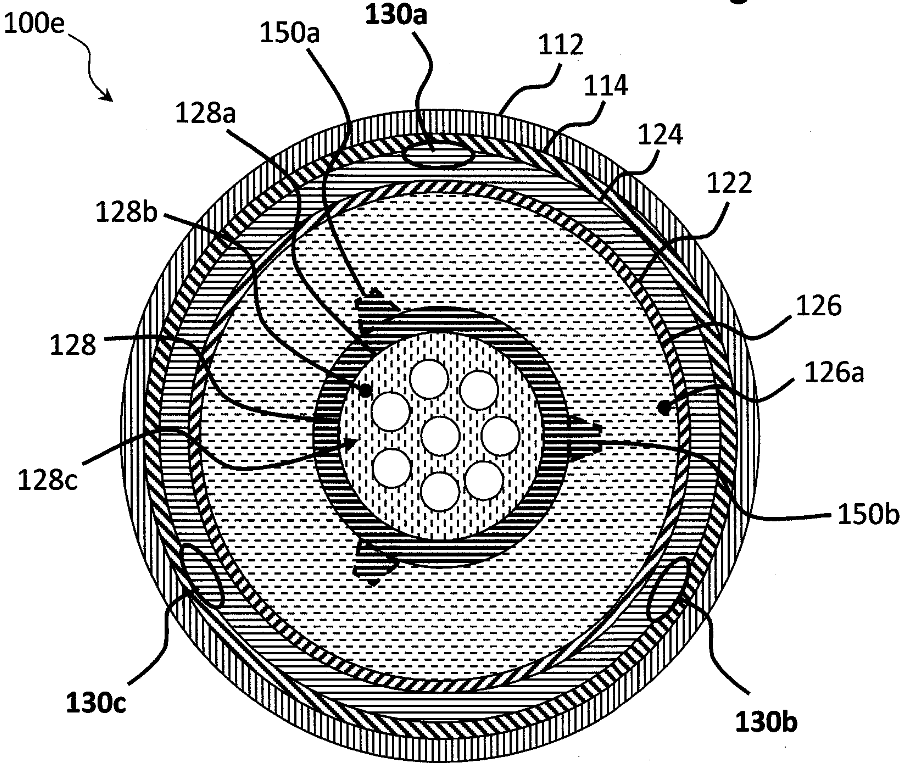


Fig. 8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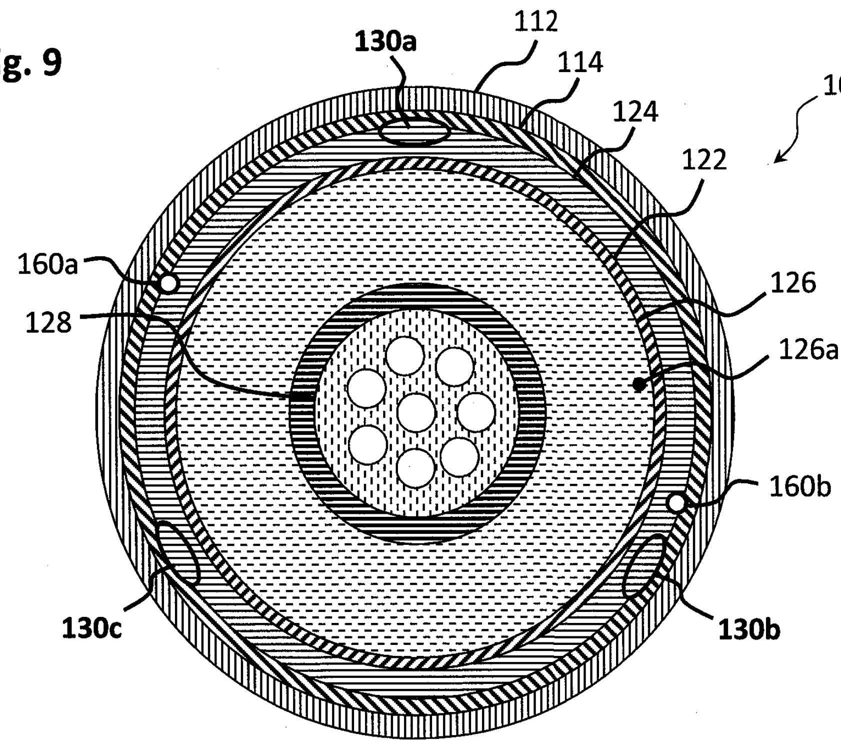
150a
112
114
128a
124
122
128b
126
128
126a
128c
150b
130c
130b

Fig. 9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112
114
100f
124
122
160a
126
128
126a
160b
130c
130b

Fig. 10a

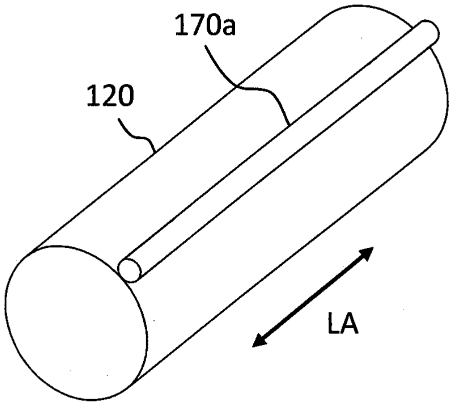
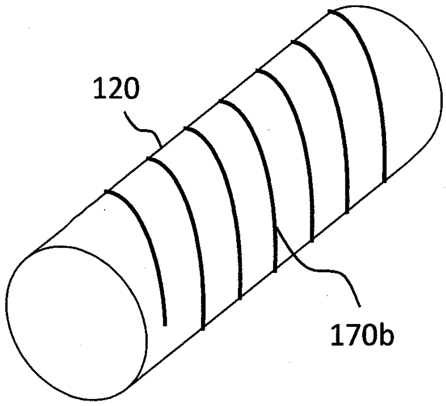


Fig. 10b



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Application Number
EP 13 16 1537

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Place of search	Date of completion of the search	Examiner
The Hague	29 July 2013	Hillmayr, Heinrich

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