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(54) **PROTECTION OF SUB-SURFACE ROPES**

(57) A guard and guard system for protecting a section of a sub-surface rope-like structure is disclosed. A plurality of sleeves are placed in a string on the rope-like structure for jointly covering the section, and each sleeve is configured to be placed around a portion of the rope-like structure and to freely rotate around to the rope-like structure.

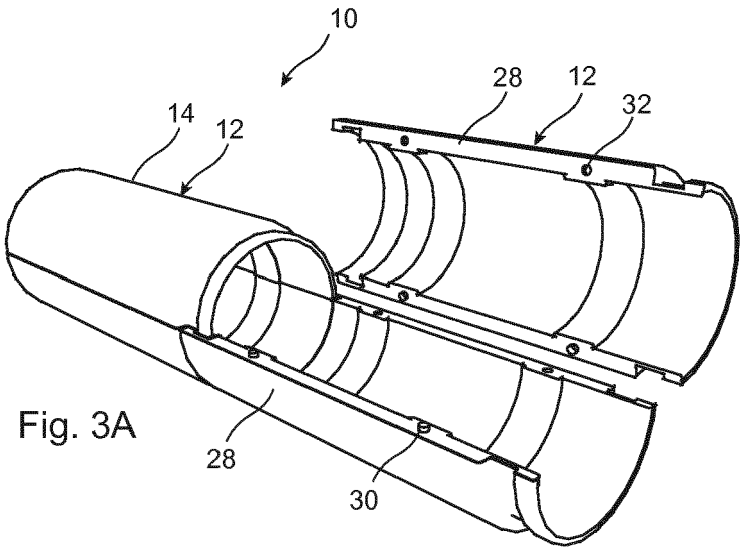


Fig. 3A

EP 3 073 170 A1

Description

TECHNICAL FIELD

[0001] The present invention relates to the protection of sub-surface ropes, and in particular to the protection of sub-surface fiber ropes from trawling wires.

BACKGROUND

[0002] Traditionally, permanently moored offshore floating units, such as oil rigs, tank ships, or Floating Production Storage Offloadings (FPSOs), use all-chain catenary moorings systems. The mooring lines of these systems are steel chains, which are seen as a reliable and robust solution. However, the all-chain systems have the drawback that they are heavy.

[0003] The weight of the all-chain systems limits the payload capacity of a floating unit. Further, the buoyancy of the floating unit and the weight of the all-chain systems also put a limit to the depth at which the floating unit can be moored. Additionally, the heavy all-chain systems require heavy auxiliary systems, such as the attachments to the floating unit, which adds to the overall weight of the all-chain system. Also, steel chains have a very limited elasticity, which contributes to the heavy load on the auxiliary systems in rough weather conditions. The weight of chains has the effect that they trace a curve close to the vertical, which has the drawback that it limits the horizontal stabilization of the all-chain system.

[0004] The above problems have, to some extent, been solved by introducing polymer fiber rope inserts in the mooring lines. A typical mooring line, for a mobile, semi-submersible drilling rig in the North Sea, consists of a chain on the seabed, 1000 m fiber rope in the water column and approximately 200 m chain connecting the fiber rope to the offshore unit.

[0005] Polymer fiber ropes contribute to solving the above described problems. They are typically 20 times lighter than a steel chain per meter. For example fiber ropes may have a submerged weight of 4 kg/m, and a steel chain with a corresponding minimum breaking load may have a submerged weight of 127 kg/m. Thus the overall weight of the mooring system is reduced by fiber ropes. As an example for a permanent offshore unit, if 16 chains 310 m in length are removed from 16 mooring lines, each having a diameter of 142mm and weighing 350 kg/m submerged, a weight reduction of approximately 1700 000 kg is achieved. If each of the chains is replaced by a fiber rope 1000 m in length and weighing of 8 kg/m, the effective weight reduction is approximately 1600 000 kg.

[0006] The much lower weight of the fiber ropes makes the mooring line close to horizontal in the water column, with the shorter chain connecting the fiber rope to the floating unit being close to vertical. Thus, the horizontal fiber ropes will hold the floating unit still in the horizontal plane much more effectively than a vertical all-chain system. Further, the fiber ropes are more elastic than steel chains and will act as springs, thus damping the loads on the floating unit and auxiliary systems and allowing for operation in worse weather conditions.

[0007] For permanent offshore units, the use of fiber ropes will increase payload capacity, reduce loads on units and maintain the position during worse weather conditions. This means that new projects may open up in areas previously seen as impossible to moor in. Increased payload on old units may also be achieved by replacing parts of the chain mooring with fiber ropes.

[0008] However, there is a disadvantage with fiber ropes in that they are less resistant to external wear or damage, especially from trawl wires, but also from ROV-tether lines, umbilicals and other submerged objects.

[0009] In deep sea trawling, fishing vessels regularly cross the area around floating offshore units, either intentionally or by accident. If passing over a fiber rope forming part of a mooring line, the steel wire connecting the trawl to the fishing vessel may be dragged over the mooring line. The abrasive forces in such an encounter are large enough for the trawl wire to potentially saw through the fiber rope, or at least make a cut in the fiber rope. Therefore, the use of unprotected polymer fiber ropes is prohibited for permanents offshore units and restricted for mobile units. Further, the present fiber ropes are not as reliable or robust as chains.

[0010] Today, protection of fiber ropes is achieved be adding some sort of abrasive resistant protective layer, such as a jacket or coating. However, a trawl wire, or another abrasive body, may be of a sufficient length for cutting through the protective layer, and further cut the fiber rope, when being dragged transversely to the fiber rope.

[0011] It is therefore an object to address some of the problems and technical challenges outlined above.

SUMMARY

[0012] According to a first aspect, the above object is achieved by a guard for protecting a sub-surface rope-like structure, wherein the guard comprising a sleeve configured to be placed around a portion of the rope-like structure and to freely rotate around to the rope-like structure. The working principle of the protection is the ability to transform a transverse abrasive force to a rotation of the sleeve, thus causing less friction or abrasive force on the rope-like structure. When functioning in an optimal manner, the sleeve is rotating at the same speed an abrasive body and with a with a minimum friction between the sleeve and the rope-like structure, thus reducing wear on both the sleeve and the rope-like structure.

[0013] The guard allows for a full or partial protection of a rope like structure of a mooring line against unforeseen abrasion by sub-surface object engaging the rope-like structure at an unforeseen location. The ability to protect fiber ropes, or rope-like structures, from external damage will open up new markets. For example, it may

make it possible to moor an offshore unit in close vicinity to one another. A close vicinity mooring is a high risk operation and thus requires higher safety factors, which may be achieved by the above described guard.

[0014] Throughout these specifications, that an object can freely rotate around a rope-like structure means that it is configured to perform any number of rotations in any given rotational direction around the rope-like structure.

[0015] A sleeve is here understood to encompass an object that fits around a portion of the rope-like structure to protect it. The rope-like structure may be fiber rope, and the fiber rope may be composed of polymer fibers, or mainly composed of polymer fibers. The rope-like structure may form part of a mooring line for offshore floating units, such as oil rigs or FPSOs. A rope-like structure is here understood to not encompass wires manufactured mainly or fully of metal.

[0016] The sleeve may comprise a first spacer positioned on its inside for forming a space between the sleeve and the rope-like structure and for engaging the rope-like structure. This has the effect that material present between sleeve and the rope-like structure, such as shells, is collected in the space, which leads to less fiction between the sleeve and the rope-like structure, thus reducing the wear on the rope-like structure. The lower friction also has the effect that the sleeve rotates more easily, which reduces the wear on the sleeve as such in the contact with a trawl wire.

[0017] The guard according to the first aspect may further comprise an inner support configured to be attached, or fixed, to the rope-like structure and to prevent the sleeve from contacting the rope-like structure, and the sleeve may further be configured to engage the inner support when freely rotating with respect to the rope-like structure. This has the effect of a reduced wear on the rope-like structure and allows for an optimization with respect to friction and rotation of the sleeve that is independent of the rope-like structure. The inner support may be positioned between the sleeve and the rope-like structure, or at least in part between the sleeve and the rope-like structure. The inner support may further be fixed to and/or static with respect to the rope-like structure. Thus, the inner sleeve may serve as a low friction base for the sleeve to rotate around.

[0018] The sleeve and the inner support may further be configured for cooperatively restricting the movement of the sleeve along the rope like structure. Additionally or alternatively, the sleeve may have a first circumferential ridge on its inside, and the inner support may have a second circumferential ridge on its outside, wherein the inner diameter of the first circumferential ridge is smaller than the outer diameter of the second circumferential ridge for restricting a movement of the sleeve along the rope like structure. Restricting a movement is here, and through these specifications, understood to encompass both a preventing of a movement, and a limiting of a movement, to a predetermined distance.

[0019] The guard according the first aspect may further comprise a second spacer positioned between the sleeve and the inner support for forming a space between the sleeve and the inner support. This has the effect that material present between sleeve and the inner support, such as marine growth, are collected in the space, which leads to less fiction between the sleeve and the inner support, thus allowing for an easier rotation of the sleeve and reduced wear on the components.

[0020] According to a second aspect, the above object is achieved by a guard system for protecting a section of a sub-surface rope-like structure. The guard system comprises a first plurality of sleeves configured to be placed in a string on the rope-like structure for jointly covering the section, wherein each sleeve is configured to be placed around a portion of the rope-like structure and to freely rotate around to the rope-like structure. Here placed in a string on the rope-like structure is understood to encompass the sleeves being stacked or placed in a sequence on the rope-like structure.

[0021] The section of the rope-like structure may correspond to a substantial portion of a mooring line. Each sleeve of the first plurality may be configured to rotate freely with respect neighboring sleeves of the first plurality.

[0022] One or more sleeves of the first plurality may comprise a first spacer positioned on its inside for forming a space between each of the one or more sleeves and the rope-like structure. This has the same effect as the first spacer described above in relation to the first aspect.

[0023] Neighboring sleeves in the string may be configured to overlap. This may allow for a relative movement of the neighboring sleeves along the rope-like structure with the covering of the rope-like structure maintained, which means that the protective properties may be maintained when the rope-like structure is stretched and elongated, for example under heavy loads in rough weather conditions, or by time and wear.

[0024] Neighboring sleeves in the string may be configured, or longitudinally locked to one another, for restricting a relative movement between the neighboring sleeves along the rope-like structure. Restricting a relative movement is here understood to encompass to limit a longitudinal shift between neighboring sleeves to a predetermined length. Neighboring sleeves is here understood to encompass two, or a pair of, neighboring sleeves. This has the effect that gaps forming between the sleeves is reduced or prevented, which contributes to an improved protection of the rope-like structure. Neighboring sleeves in the string may be configured to restrict the relative movement between them to a maximum longitudinal shift in the range 1-7 mm, or 3-5 mm. Additionally or alternatively, neighboring sleeves in the string may be configured to restrict the relative movement between them to a maximum span within 1-100 ‰, between 2-7 ‰, or between 3-5 ‰, of the combined length of neighboring sleeves. The above limitations typically haves the effect that trawling wires are prevented from entering or falling into gaps formed between neighboring

sleeves. For example, a 1000 m fiber rope is stretched 7 m at a load of 110 000 kg, which corresponds to a 7 ‰ stretching. If the sleeves have a length of 0.5 m and the gaps between the sleeves are uniform in length, the gaps would be 3.5 mm in length, which is approximately a tenth of the diameter of a typical trawling wire.

[0025] The guard system according to the second aspect may further comprise an inner support structure configured to be attached, or fixed, to the rope-like structure, and one or more sleeves of the first plurality may be configured to engage the inner support structure when freely rotating with respect to the rope-like structure. The inner support structure may be composed of a plurality of inner supports, wherein each inner support is inner support described in relation to the first aspect. The inner support structure described here has the same general function as the inner support of the first aspect in that a reduced wear is achieved on the rope-like structure, and in that an optimization of the friction between the sleeves and the inner support structure can be achieved independently of the rope-like structure.

[0026] One or more sleeves of the first plurality and the inner support structure may be configured for cooperatively restricting a movement of the one or more sleeves along the rope-like structure. Additionally or alternatively, a sleeve of the first plurality may have a first circumferential ridge on its inside, and the inner support structure may have a second circumferential ridge on its outside, wherein the inner diameter of the first circumferential ridge is smaller than the outer diameter of the second circumferential ridge for restricting a movement of the sleeve along the rope like structure. The above restrictions has the effect that the sleeves can be dedicated for protecting specific points of the rope-like structure, and they may also prevent gaps to form between sleeves.

[0027] One or more sleeves of the first plurality may comprise a second spacer positioned between each of the one or more sleeves and the inner support structure for forming a space between them. The second spacer described here has the same general effect as the second spacer described in relation to the first aspect.

[0028] According to a third aspect, the above object is achieved by a sub-surface rope system comprising a rope-like structure for sub-surface environments and guard system for protecting a section of the rope-like structure. The guard system comprises a first plurality of sleeves that are placed in a string on the rope-like structure for jointly covering the section, wherein each sleeve is placed around a portion of the rope-like structure and is freely rotatable around to the rope-like structure. The guard system in the sub-surface rope system further may comprise any of the features of the guard system of the second aspect. The inner support structure may further be fixed to and/or static with respect to the rope-like structure.

[0029] According to a fourth aspect, the above object is achieved by a method of in-situ refurbishing of a sub-surface rope system forming part of an established off-shore mooring, the sub-surface rope system comprising a rope-like structure and guard system for protecting a section of the rope-like structure, wherein the guard system comprises a first plurality of sleeves that are placed in a string on the rope-like structure for jointly covering the section, wherein each sleeve is placed around a portion of the rope-like structure and is freely rotatable around to the rope-like structure, the method comprising removing a sleeve of the first plurality from its place in the string, placing a new sleeve at the corresponding place in the string, wherein the new sleeve configured to function as a sleeve of the first plurality.

[0030] According to one aspect, the above object is achieved by the use of a guard according to the first aspect for protecting a portion of a sub-surface rope-like structure. According to another aspect, the above object is achieved by the use of a guard system according to the second embodiment for protecting a section of a sub-surface rope-like structure.

[0031] In the above embodiments, each sleeve may be configured to provide a frictional force between the sleeve and the rope-like structure that is sufficiently low for the sleeve to rotate when a trawl wire engages the sleeve and is dragged transversely to the rope-like structure. Additionally or alternatively, each sleeve may be configured to provide a frictional force between the sleeve and the rope-like structure that is smaller than the frictional force between the sleeve and a trawl wire engaging the sleeve and being dragged transversely to the rope-like structure.

[0032] Additionally or alternatively, in the above embodiments, each sleeve may be configured to provide a frictional force between the sleeve and the inner support, or the inner support structure, that is sufficiently low for the sleeve to rotate when a trawl wire engages the sleeve and is dragged transversely to the rope-like structure. Additionally or alternatively, each sleeve may be configured to provide a frictional force between the sleeve and the inner support, or the inner support structure that is smaller than the frictional force between the sleeve and a trawl wire engaging the sleeve and being dragged transversely to the rope-like structure.

[0033] Additional or alternative features of the above aspects are described in the detailed description below and in the appended claims. Further objects may also be construed from the detailed description.

DETAILED DESCRIPTION

[0034] Each sleeve may have a cylindrical outer shape for being oriented along the rope-like structure, and/or a ring-shaped cross-section. The outer surface of the sleeve may be corrugated and/or have a corrugated outer surface. The corrugated outer surface may comprise circumferential grooves and ridges for allowing a trawling wire with diameter between 10-70 mm, between 20-60 mm, or between 30-50 mm, that is dragged transversely to the rope-like structure to fall into a groove. The above

features contribute to increasing the contact surface between the sleeve and a transversely dragging trawling wire, which reduces the abrasion on the sleeve.

[0035] The corrugated outer surface may end at a circumferential edge configured to contact a neighboring sleeve, wherein the circumferential edge is spaced apart from the bottom of a circumferential groove, or located at the top of a circumferential ridge, or located on the side slope of a circumferential groove or ridge. This has the effect that, if a trawl wire is engaging the sleeve at the circumferential edge, the risk of the trawl wire falling between sleeves is reduced. Each sleeve may be configured to form a separation to the rope-like structure, the inner support, or the inner support structure, for allowing the sleeve to freely rotate. The separation may also allow a bending of the rope-like structure without deforming the sleeve. This is particularly advantageous if the sleeve is manufactured of a rigid material, such as steel.

[0036] Each sleeve may be a unitary body, which has the advantage of a high structural strength. Such a sleeve typically must be mounted on the rope-like structure from one of the ends of the rope-like structure, or formed around the rope like structure, for example by molding during manufacturing of the rope-like structure. Alternatively, each sleeve may be composed of a plurality of portions that are mounted together to form the sleeve. For example, if the sleeve is a cylinder, it may be composed of two cylinder halves that can be screwed together or snapped together by a click-fit. This has the advantage that the sleeve can be mounted at any point on pre-existing rope-like structure, which is particularly advantageous in retrofitting, for example in the in-situ refurbishing of the fourth aspect. Similarly, each inner support may be composed of a plurality of portions that may be mounted together to form the inner support.

[0037] Each first spacer of a sleeve may comprise a circumferential ridge on the inside of the sleeve. For example, if the sleeve is a cylinder, the first spacer may be a set of coaxial rings on the inside of the cylinder. Each second spacer may comprise a circumferential ridge on the inside of the sleeve, and/or a circumferential ridge on the outside of an inner support or support structure. For example, if the inner support is a cylinder, the second spacer may be a set of coaxial rings on the outside of the inner support.

[0038] Each sleeve or inner support may be pliable. Pliable is here understood to encompass the sleeve having a non-self-supporting structure. For example, the sleeve may be composed of a tubular soft material. The sleeve may be composed of a weave or fabric of fibers or strands. The fibers or strands may comprise polyethylene. The weave or fabric may comprise fibers or strands of Dyneema®.

[0039] Each sleeve may be flexible in a direction transverse to the rope-like structure, and/or elastic in a direction along the rope-like structure. This allows the sleeve to bend and/or stretch with the rope-like structure, which reduces the wear on the sleeve and rope-like structure. Each sleeve may have an elasticity along the rope-like structure that is equal to or greater than the longitudinal elasticity of the rope like structure. This contributes to preventing gaps from forming between sleeves, in particular if used in combination with the longitudinally locking of neighboring sleeves, as described above in relation to the second aspect. That a sleeve is elastic also has the advantage that it will return to its original shape and size after being stretched, thus preventing sleeves from being pressed and locked together when the rope-like structure contracts subsequent to being stretched.

[0040] Each sleeve may be configured to have at least the same, or a smaller bending radius, than the rope-like structure, thus allowing it to bend in the same way as the rope-like structure, for example when winded on a reel. This contributes to preventing gaps between sleeves. The material of each sleeve or inner support may have an elastic modulus approximately equal to or smaller than that of the lengthy body.

[0041] Additionally or alternatively, each sleeve may have a self-supporting or rigid structure for preventing a load acting on the sleeve from the outside to deform the sleeve. The sleeve may be configured to withstand a transverse load from a transversely running trawl wire that is below 10, 30, 50, or 70 kN without deforming. The sleeve may comprise a corrugated portion with circumferential grooves and ridges for allowing the sleeve to bend and/or stretch with the rope-like structure. This is particularly advantageous if the sleeve is of a rigid or semirigid material.

[0042] The guard or guard system may have a total density that is below the minimum density of water. This has the effect that the total weight of the rope-like structure in water is reduced with the guard or guard system mounted thereon.

[0043] Each sleeve and/or inner guard may be manufactured in part or in full of metal, such as steel, and/or a polymer, such as polyethylene or polyurethane. Polymers typically have the advantage of low density. Thus, the amount of polymer in a sleeve may be adjusted to increase the buoyancy of the rope system it forms part of. Additionally or alternatively, each sleeve and/or inner may be manufactured in part or in full of polyethylene, polypropylene, nylon, polytetrafluoroethylene (Teflon), polyoxymethylene (POM), or PVC.

[0044] Each sleeve may be manufactured of a fiber-reinforced polymer, such as one of the abovementioned polymers. The fiber reinforcement may comprise steel fibers. The fibers may be predominantly oriented along the rope-like structure, or oriented along the rope-like structure. The fiber reinforcement typically has the effect that the friction between the sleeve and a transversely running trawling wire is increased, thus making it easier for the sleeve to rotate, which reduces the abrasion on the sleeve.

[0045] Each sleeve and/or the inner guard may be of a transparent material, or have a transparent portion, for allowing ocular inspection of the rope-like structure from

outside the guard. The transparent portion may extend over the complete sleeve in a direction along the rope-like structure. Thus, by rotating the sleeve, the complete portion of the rope-like structure that is covered by the sleeve can be inspected. The rope-like structure may experience damage from other sources than abrasion, for example by overload or faults in production or handling that show first after some use, and the above suggested features allows for such damage to be detected. It should be noted that traditional protective materials in the field fiber rope protection are not transparent and would therefore prevent inspection of the rope-like structure.

[0046] Alternatively or additionally, for each sleeve, a portion or the whole of the sleeve may have an outer layer with a color that is different from the color of the sleeve beneath or under the outer layer. For example, a sleeve may be painted with a white layer on top of a red layer, where the white layer constitutes the outer layer, and the red layer defines the color of the sleeve beneath the outer layer. If a sleeve is damaged, the outer layer may come off and the damage becomes easier to detect by inspection.

[0047] The length of each sheet may be between 1.2-2 times the inner diameter of the sheet. Alternatively, the length may be between 1.4 and 1.8, or approximately 1.6, times the inner diameter. It has been found that these relations are suitable for many of the properties and materials mentioned above.

[0048] The diameter of the sleeve depends on the diameter of the lengthy body it protects. A typical fiber mooring line may vary in diameter between 100-300mm. The minimum thickness of the sleeve may be 4 mm and a maximum thickness may be 20 mm. The thickness of a sheet may be configured for added buoyancy and the desired bending or stretching properties. If the density of the material is lower than that of water, an increased thickness improves the buoyancy. The maximum thickness may thus be increased if extra buoyancy is needed. However, the flexibility of the sheet is typically reduced at the same time.

BRIEF DESCRIPTION OF DRAWINGS

[0049]

Fig. 1A is a perspective view of an embodiment.

Fig. 1B is a cross-sectional side view of the embodiment in Fig. 1A.

Fig. 2A is a perspective view of another embodiment.

Fig. 2B is a cross-sectional side view of the embodiment in Fig. 2A.

Fig. 3A is a perspective view of yet another an embodiment.

Fig. 3B is a cross-sectional side view of the embodiment in Fig. 3A.

Fig. 4A is a perspective view of yet another an embodiment.

Fig. 4B is a cross-sectional side view of the embodiment in Fig. 4A.

Fig. 5A is a perspective view of yet another an embodiment.

Fig. 5B is a further perspective view of the embodiment in Fig. 5A.

Fig. 6A is an enlarged view of the connection between sleeves corresponding to the embodiment of Fig. 1A.

Fig. 6B is an enlarged view of the connection between sleeves corresponding to the embodiment of Fig. 3A.

Fig. 7A is a cross-sectional view illustrating the working principle of an embodiment without inner support.

Fig. 7B is a cross-sectional view illustrating the working principle of an embodiment with inner support.

Fig. 8 is a schematic cross-sectional view illustrating an example of the forces acting on a sleeve.

DETAILED DESCRIPTION OF DRAWINGS

[0050] Figs. 1A and 1B illustrate an embodiment of a guard system 10 for protecting a sub-surface rope-like structure 20, such as a fiber rope. The profile of the rope-like structure 20 is indicated by dashed lines in Fig. 1B. The guard system 10 is composed of several guards 12 placed in sequence on the rope-like structure 20, of which two are shown in the figures. Each guard 12 comprises a sleeve 14 that is placed and fits around a portion of the rope-like structure 20, thus forming a string of sleeves 14 protecting it.

[0051] The sleeve 14 has a body 22 in the form of a cylinder. The sleeve further has two spacers 16 in the form of rings on the inside of the body 22, thus forming a space 18 between the sleeve 14 and the rope-like structure 20. The spacers 16 further engaging the rope-like structure 20 when subjected to external loads. When the sleeve 14 is centered on the rope-like structure 20, there is a separation between the spacers 16 and the rope-like structure, which makes it possible for the sleeves 14 to freely rotate with respect to the rope like structure 20.

[0052] The sleeve 14 has a male end 24 where the body 22 is thinner and the outer diameter of the body 22 is smaller. The other end of the sleeve 14 is a female end 26 where the body 22 is thinner, but the inner diameter of the body 22 is greater so that it can receive a male end 24 of a neighboring sleeve 14, as is illustrated in Fig. 1B. This way, the neighboring sleeves 14 in the string are overlapping. The male end 24 and the female end 26 extend in the direction of the rope-like structure 20, thus allowing for a limited longitudinal relative movement of the sleeves 14 with a maintained covering of the rope-like structure 20.

[0053] There is a small separation between the mating male end 24 and female end 26, which is shown in Fig. 6A that is an enlarged view of the connection between sleeves 14. The separation makes it possible for the neighboring sleeves14 to rotate freely with respect to one another.

[0054] Figs. 2A and 2B illustrate another embodiment of a guard system 10 for protecting a sub-surface rope-like structure 20. Features in common with the earlier described embodiment have been given the same number indexing. The guard system 10 illustrated here differs from the one in Figs. 1A and 1B in that the sleeve 14, or circular-cylindrical body 22, is composed of two portions 28, where each portion 28 is a half-cylinder. The two portions 28 are locked together by cooperating plugs 30 and sockets 32.

[0055] Figs. 3A and 3B illustrate another embodiment of a guard system 10 for protecting a sub-surface rope-like structure 20. Features in common with the earlier described embodiments have been given the same number indexing. The guard system 10 illustrated here differs from the one in Figs. 2A and 2B in that in that the male end 24 has an outward protruding flange 34 and the female end 26 has an inward protruding flange 36. The outer diameter of the outward protruding flange 34 is greater than the inner diameter of the inward protruding flange 36, and male end 24 and the female end are overlapping so that the flanges restricting the relative movement between the neighboring sleeves 14 in a direction along the rope-like structure 20.

[0056] There is a small separation between the mating male end 24 and female end 26, and also a separation between the outward protruding flange 34 and the inward protruding flange 36, which is shown in Fig. 6B being an enlarged view of the connection between sleeves 14. These separations make it possible for the neighboring sleeves14 to rotate freely with respect to one another, and also to cooperatively restricting the relative movement of the sleeves 14 along the rope like structure to a limited interval or span.

[0057] Figs. 4A and 4B illustrate another embodiment of a guard system 10 for protecting a sub-surface rope-like structure 20. Features in common with the earlier described embodiments have been given the same number indexing. The guard system 10 illustrated here differs from the embodiment in Figs. 3A and 3B in that the cylindrical body 22 is corrugated, thus having a corrugated outer surface with circumferential grooves 38 and ridges 40 into which a trawling wire can fall. Further, the inner surface of the cylindrical body 22 is also corrugated, where each ridge forms a spacer 16 and each groove forms a space between the sleeve 14 and the rope-like structure. The corrugated outer surface of the neighboring sleeves 14 ends at a circumferential edges 25 and 27 that contact each other. On the male end 24, the circumferential edge 25 is located on the side slope of a circumferential groove, and on the female end 26, the circumferential edge 27 is located on the side slope of a circumferential ridge.

[0058] Figs. 5A and 5B illustrate an embodiment of a guard system 110 for protecting a sub-surface rope-like structure, such as a fiber rope. The guard system 110 is composed of several guards 112 placed in sequence on the rope-like structure, of which two are shown in the figure 5B. Each guard 112 comprises an inner support 142 that is attached to the rope-like structure (not shown). Together, the inner supports 142 constitute an inner support structure 144.

[0059] Each inner support 142 has a body 146 in the form of a circular cylinder, that is composed of two portions 148, where each portion 148 is a half-cylinder. The The two portions 148 are locked together around the rope-like structure by cooperating plugs 150 and sockets 152. The inner diameter of the inner support 142 corresponds to the outer diameter of the rope-like structure, which means that it becomes attached and fixed to the rope like structure, as is shown in Fig. 7B. In one embodiment, the inner support 142 is connected to the rope-like structure by placing a band of a water-expanding elastomer between the inner support 142 and the rope-like structure, thus locking the inner support 142 to the rope-like structure when the complete structure is placed in water.

[0060] A sleeve 114 is placed around each inner support 142. The sleeve 114 has a body 122 in the form of a circular cylinder. The sleeve 114 is composed of two portions 128, where each portion 128 is a half-cylinder. The two portions 128 are locked together around the inner support 142 by cooperating plugs 30 and sockets 32.

[0061] The inner support 142 has a pair of circumferential ridges 156 on its outside, and the sleeve 114 has a circumferential ridge 154 on its inside that is positioned between the circumferential ridges 156 of the inner support 142 when the two portions 128 are locked together. The inner diameter of the circumferential ridge 154 of the sleeve 114 is smaller than the outer diameter of the circumferential ridges 156 of the inner support 142, which restricts the movement of the sleeve 114 along the rope like structure.

[0062] The circumferential ridge 154 of the sleeve 114 has a slightly higher profile than the circumferential ridges 156 of the inner support 142 and constitutes a spacer 116 that forms a space 118 between the sleeve 114 and the inner support 142, see further Fig. 7B. The spacer 116 further engages the inner support 142 when the sleeve 114 is subjected to an external load. There is a separation between the spacer 116 and the inner support 142, which makes it possible for the sleeve 114 to freely rotate with respect to the inner support 142.

[0063] The sleeve 114 has a male end 124 where the body 122 is thinner and the outer diameter of the body 122 is smaller. The other end of the sleeve 114 is a female end 126 where the body 122 is thinner but the inner diameter of the body 122 is greater so that it can receive a male end 124 of the neighboring sleeve 14. This way, the neighboring sleeves 114 in the string are overlapping. The male end 124 and the female end 126 extend in the direction of the rope-like structure, thus allowing for a longitudinal relative movement of the sleeves 114 with a maintained the covering of the rope-like structure. There is a small separation between the mating male end 124 and female end 126 that makes it possible for the neigh-

boring sleeves14 to rotate freely with respect to one another. The male end 124 and the female end 126 have an outward protruding flange 134 and inward protruding flange 136, respectively. However, the separation between the flanges is sufficiently large so that the movement of the sleeve 114 is restricted by the abovementioned circumferential ridges.

[0064] Fig. 7A is a cross-sectional view illustrating the working principle of an embodiment without inner support, such as those described in relation to Figs. 1-4. A trawl wire 42 is dragged transversely across the sleeve 14 in the direction indicated by the straight arrow. This causes the sleeve 14 to freely rotate with respect to the rope-like structure 20, as indicated by the curved arrow. A space 18 is formed between the sleeve 14 and the ropelike structure 20 by a spacer (not shown).

[0065] Fig. 7B is a cross-sectional view illustrating the working principle of an embodiment with inner support, such as the one described in relation to Fig. 5. A trawl wire 158 is dragged transversely across the sleeve 114 in the direction indicated by the straight arrow. This causes the sleeve 114 to freely rotate with respect to the inner support 142 that is attached to the rope-like structure 120, as indicated by the curved arrow. A space 118 is formed between the sleeve 114 and the inner support 142 by a spacer (not shown).

[0066] Fig. 8 is a schematic cross-sectional view illustrating the forces from a trawl wire 160 acting on ropelike structure or sleeve around a ropelike structure 162. Typically, the trawl wire 160 has a diameter of 28-34 mm, but larger diameters are possible. The maximum trawl wire interference length depends on the trawling depth. Two examples are given here, in which a maximum interference length of 780 m is assumed.

[0067] In the first example a 4000 kg load Ton the trawl wire 160 is assumed. With a deflection angle φ between 0-17°, the contact force R between the trawl wire 160 and the rope-like structure or sleeve 162 will be in the range 0-32 kN. In the second example, a 7000 kg load Ton the trawl wire 160 is assumed. With a deflection angle φ between 0-27°, the contact force R between the trawl wire 160 and the rope-like structure or sleeve 162 will be in the range 0-50 kN. The trawl wire pull-over velocity can be assumed to be 2.2 m/s, and the abrasive force, which is assumed to be applied close to perpendicular to the rope like structure or sleeve 162 (or within a span +/- 10° thereof). In the above embodiments, the guards are configured by choice of materials and dimensions to withstand and function under the conditions of the above two examples.

[0068] In the above embodiments, the sleeves and the inner supports are manufactured of polyurethane. In one embodiment that is not illustrated, the guard is a sleeve that is composed of a tube formed weave of Dyneema®.

ITEMLIST

[0069]

10	guard system
12	guard
14	sleeve
16	spacer
18	space
20	rope-like structure
22	body
24	male end
25	edge
26	female end
27	edge
28	portion
30	plug
32	socket
34	outward flange
36	inward flange
38	groove
40	ridge
42	trawl wire
116	spacer
118	space
120	rope-like structure
122	body
128	portion
114	sleeve
134	outward flange
12436	inward flange
142	inner support
144	inner support structure
146	body
148	portion
150	plug
152	socket
154	circumferential ridge
156	circimferential ridge
158	trawl wire
160	trawl wire
162	rope like structure or sleeve

Claims

1. A guard for protecting a sub-surface rope-like structure, the guard comprising a sleeve configured to be placed around a portion of the rope-like structure and to freely rotate around to the rope-like structure.

2. The guard according to claim 1, wherein the sleeve comprises a first spacer positioned on its inside for forming a space between the sleeve and the rope-like structure and for engaging the rope-like structure.

3. The guard according to any of the claims 1-2 further comprising an inner support configured to be attached to the rope-like structure and to prevent the sleeve from contacting the rope-like structure, and the sleeve is further configured to engage the inner

support when freely rotating with respect to the rope-like structure.

4. The guard according to claim 3, wherein the sleeve and the inner support are further configured for co-operatively restricting the movement of the sleeve along the rope like structure.

5. The guard according to any of the claims 3-4, wherein the sleeve has a first circumferential ridge on its inside, and the inner support has a second circumferential ridge on its outside, wherein the inner diameter of the first circumferential ridge is smaller than the outer diameter of the second circumferential ridge for restricting a movement of the sleeve along the rope like structure.

6. The guard according to any of the claims 3-5 further comprising a second spacer positioned between the sleeve and inner support for forming a space between the sleeve and the inner support.

7. A guard system for protecting a section of a sub-surface rope-like structure, the guard system comprises a first plurality of sleeves configured to be placed in a string on the rope-like structure for jointly covering the section, wherein each sleeve is configured to be placed around a portion of the rope-like structure and to freely rotate around to the rope-like structure.

8. The guard system according to claim 7, wherein each sleeve of the first plurality is configured to rotate freely with respect neighboring sleeves of the first plurality.

9. The guard system according to any of the claims 7-8, wherein one or more sleeves of the first plurality comprises a first spacer positioned on its inside for forming a space between each of the one or more sleeves and the rope-like structure.

10. The guard system according to any of the claims 7-9, wherein neighboring sleeves in the string are configured to overlap for allowing a relative movement of the neighboring sleeves along the rope-like structure with the covering of the rope-like structure maintained.

11. The guard system according to any of the claims 7-10, wherein neighboring sleeves in the string are longitudinally locked to one another for restricting a relative movement between the neighboring sleeves along the rope-like structure.

12. The guard system according to any of the claims 7-11 further comprising an inner support structure configured to be attached to the rope-like structure, and one or more sleeves of the first plurality are configured to engage the inner support structure when freely rotating with respect to the rope-like structure.

13. A sub-surface rope system comprising a rope-like structure for sub-surface environments and guard system for protecting a section of the rope-like structure, wherein the guard system comprises a first plurality of sleeves that are placed in a string on the rope-like structure for jointly covering the section, wherein each sleeve is placed around a portion of the rope-like structure and is freely rotatable around to the rope-like structure.

14. The sub-surface rope system according to claim 13, wherein the guard system further comprises any of the features of claims 8-12.

15. A method of in-situ refurbishing of a sub-surface rope system forming part of an offshore mooring, the sub-surface rope system comprising a rope-like structure and guard system for protecting a section of the rope-like structure, wherein the guard system comprises a first plurality of sleeves that are placed in a string on the rope-like structure for jointly covering the section, wherein each sleeve is placed around a portion of the rope-like structure and is freely rotatable around to the rope-like structure, the method comprising removing a sleeve of the first plurality from its place in the string, placing a new sleeve at the corresponding place in the string, wherein the new sleeve configured to function as a sleeve of the first plurality.

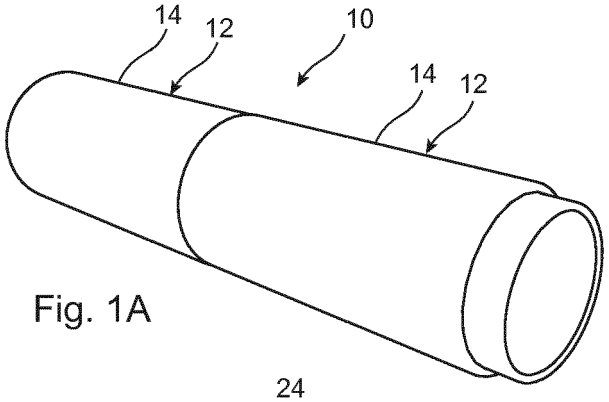


Fig. 1A

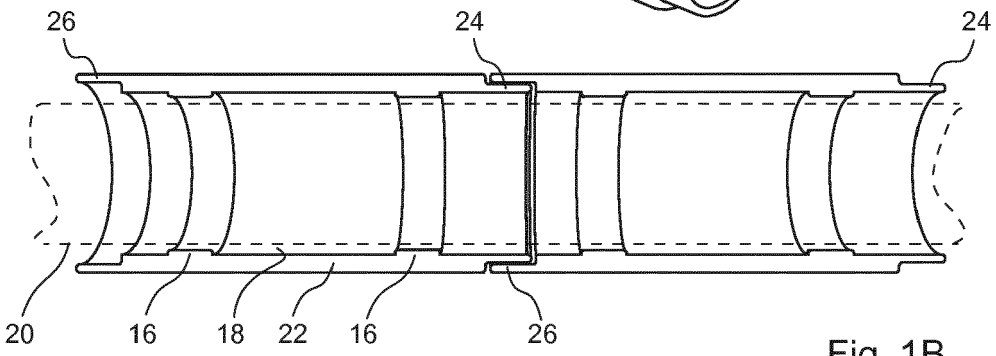


Fig. 1B

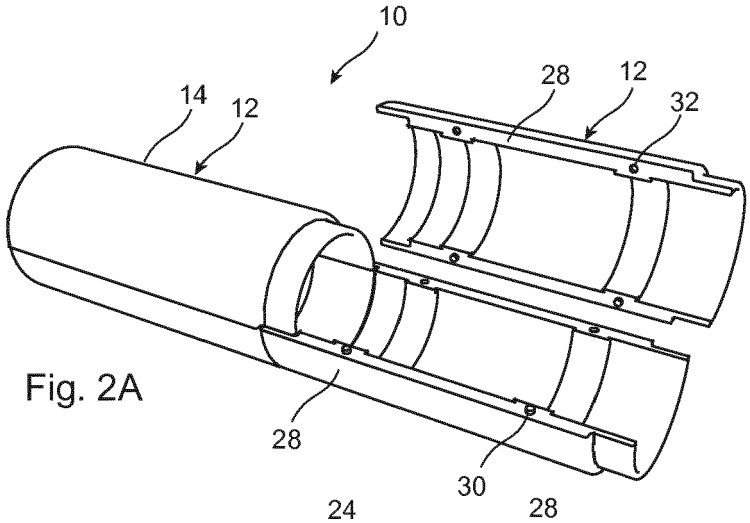


Fig. 2A

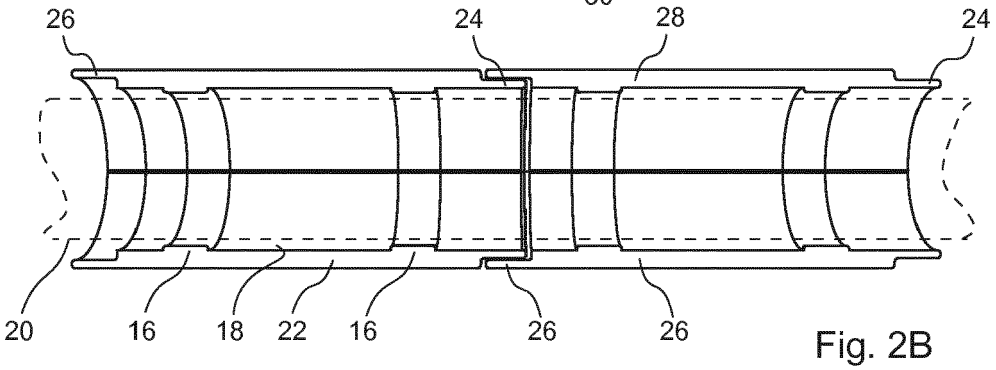


Fig. 2B

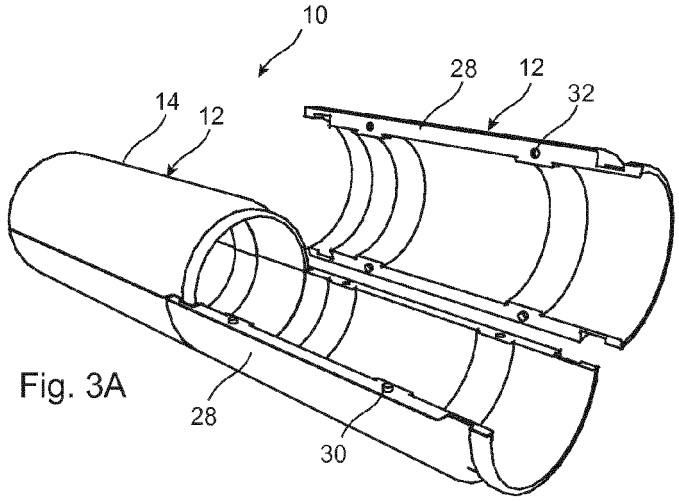


Fig. 3A

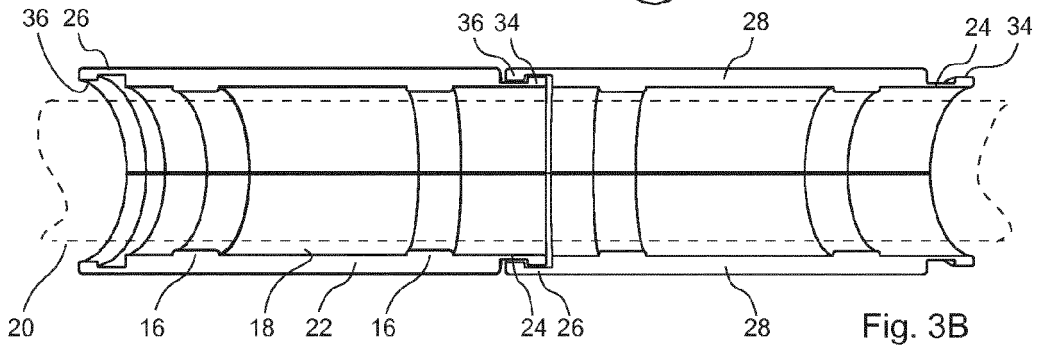


Fig. 3B

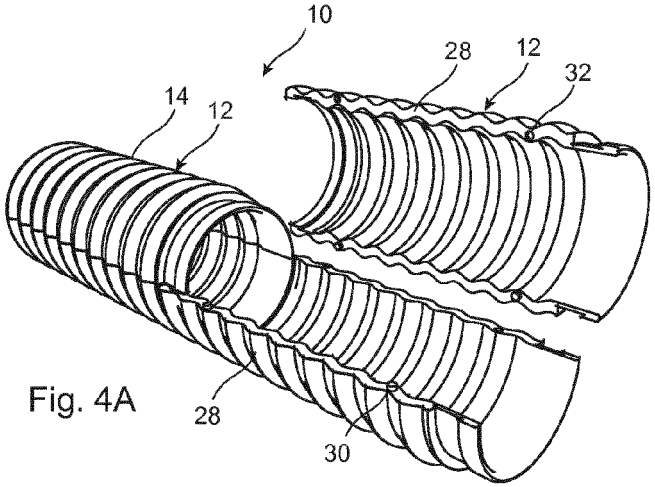


Fig. 4A

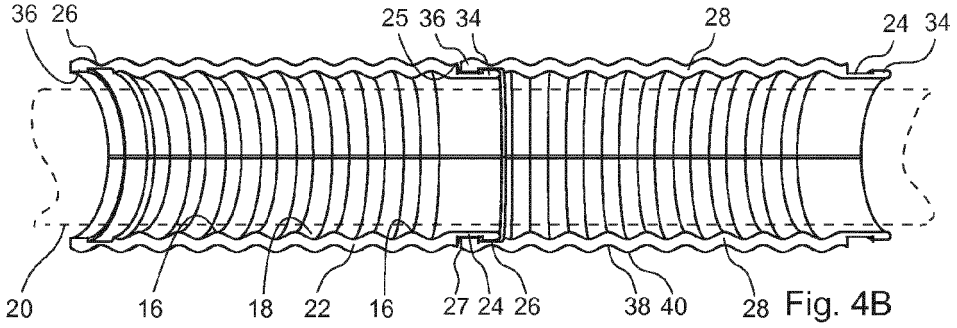


Fig. 4B

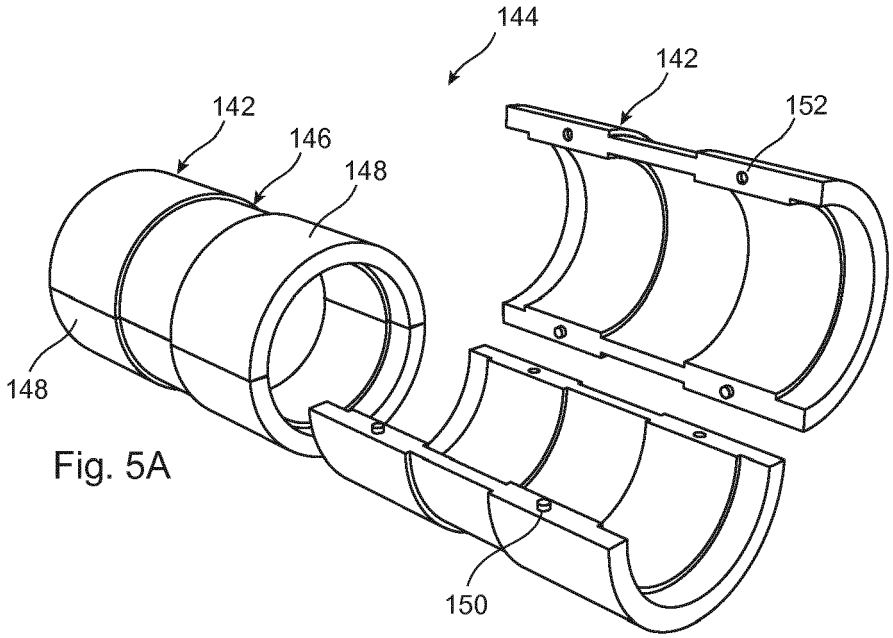

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Fig. 5A

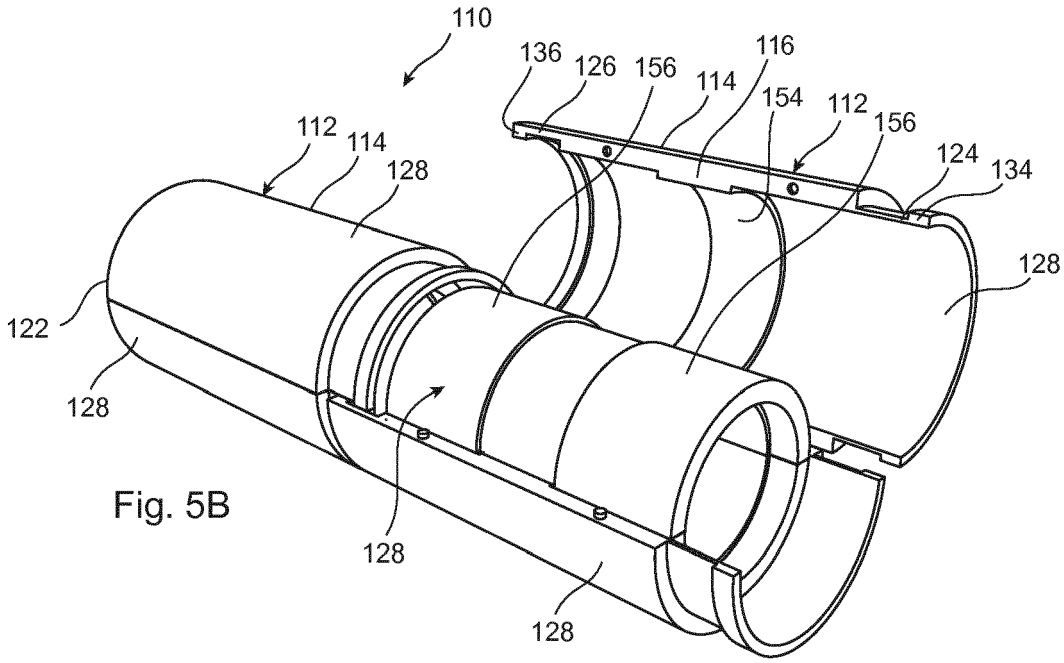

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Fig. 5B

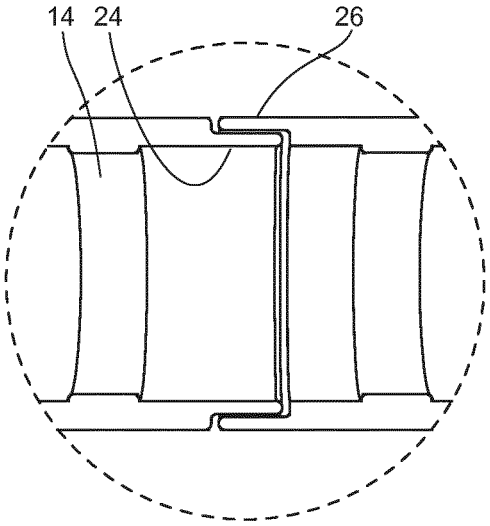


Fig. 6A

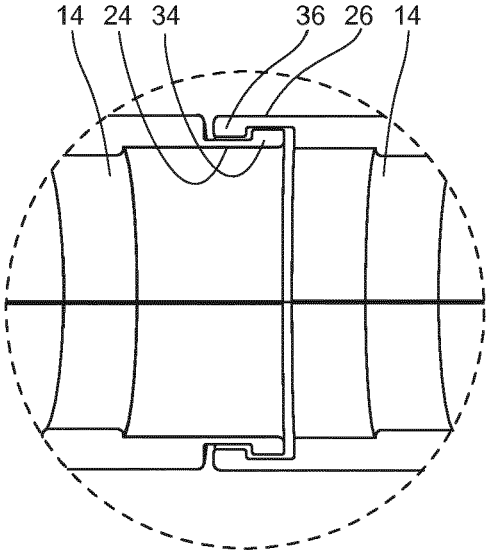


Fig. 6B

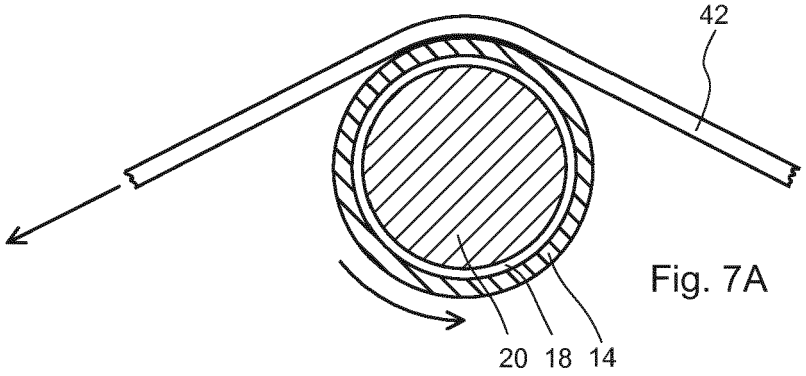


Fig. 7A

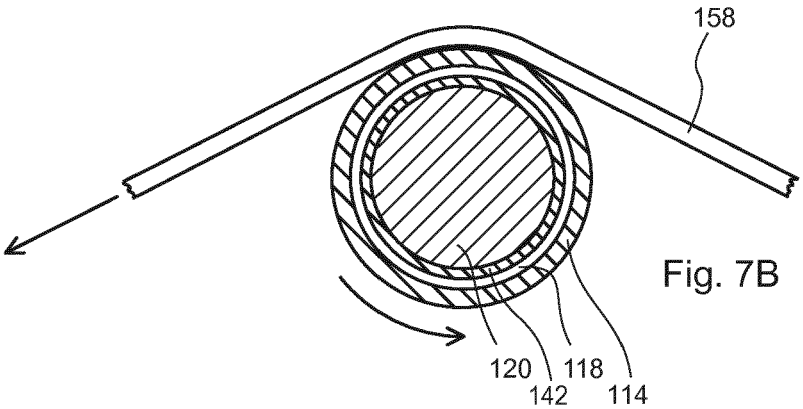
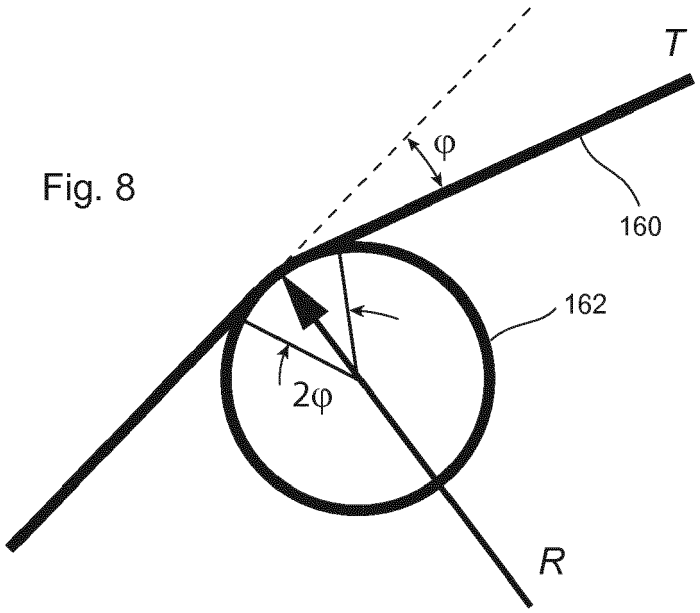


Fig. 7B

Fig. 8



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EUROPEAN SEARCH REPORT

Application Number
EP 15 16 0333

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	23 September 2015	Uhlig, Robert

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EUROPEAN SEARCH REPORT

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Munich	23 September 2015	Uhlig, Robert

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