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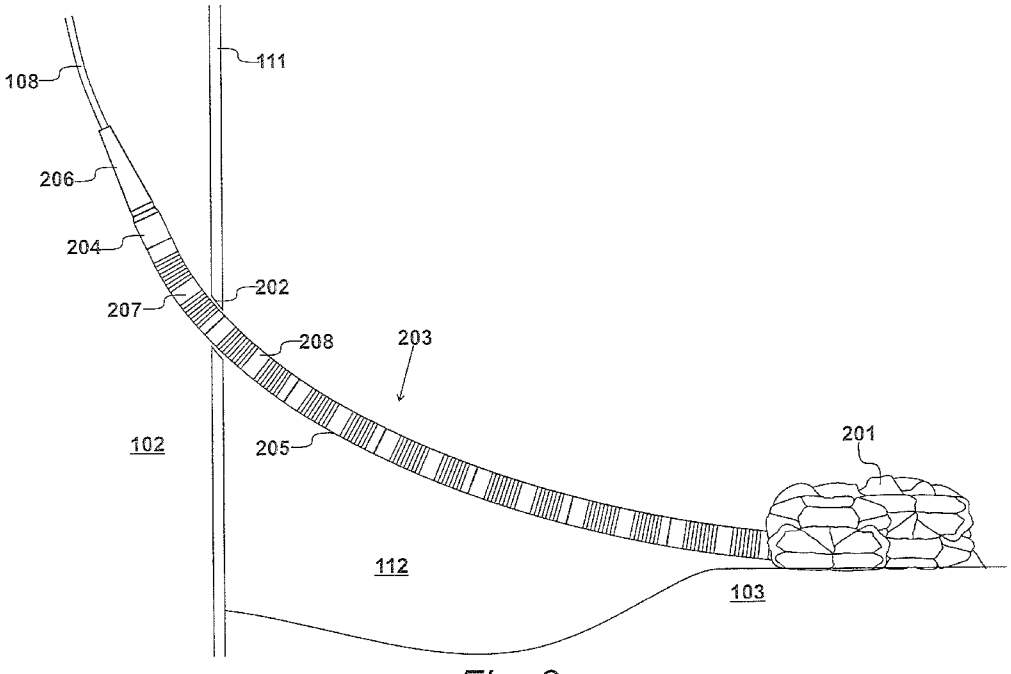


Fig. 2

(57) Abstract: Protection for a cable, piping or tubing comprises a bend stiffener. This includes at least one element comprising a tubular wall having a substantially smooth inner surface, which defines circumferential recesses along at least part of its length. Each recess has an open end at the circumference of the wall, a base, and sloping sides that are closer to each other at the base than at the open end. Each recess has a depth of no more than 50% of the thickness of the tubular wall. The bend stiffener may include a number of such elements connected together. The cable protection may also include a clamp attached to the bend stiffener.

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Cable Protection

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims priority from UK Patent Application No. 20 02 835.3, filed 27 February 2020 and UK Patent Application No. 20 19 504.6 filed 10 December 2020.

BACKGROUND OF THE INVENTION

The present invention relates to a bend stiffener for a cable, and a cable protector including such a bend stiffener.

Undersea cables, for example those connected to offshore wind turbines, are generally buried for most of their length. However, sections of the cable, for example at the base of a wind turbine, are in the water above the seabed and require protection. Similar concerns apply to flexible piping and tubing used in other settings.

Bend stiffeners are known, being tubular sheets of flexible plastic that allow a contained cable to bend but add stiffness. These are not generally used to protect long lengths of cable. Instead, bend restrictors are generally used for the span of cable running from the seabed to the base of a wind turbine, in the area known the scour area. These permit bending, but lock out at a minimum radius to prevent the cable from over-bending.

The known way of connecting a cable to the base of a wind turbine is to provide a protector including a latching head and a bend restrictor, through both of which the cable runs freely. The latching head latches to the base of the turbine and the bend restrictor protects the cable in the scour area.

BRIEF SUMMARY OF THE INVENTION

According to a first aspect of the present invention, there is provided a bend stiffener according to claim 1. According to a second aspect of the invention, there is provided a method of protecting a cable or tubing according to claim 16. According to a third embodiment of the invention, there is provided a method of installing an electrical cable in an off-shore wind turbine according to claim 24.

Embodiments of the invention will be described, by way of example only, with reference to the accompanying drawings. The detailed embodiments show the best mode known to the inventor and provide support for the invention as claimed. However, they are only exemplary and should not be used to interpret or limit the

scope of the claims. Their purpose is to provide a teaching to those skilled in the art. Components and processes distinguished by ordinal phrases such as "first" and "second" do not necessarily define an order or ranking of any sort.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

Figure 1 illustrates an offshore wind turbine including an electrical cable;

Figure 2 shows a cable protector used to protect the cable shown in Figure 1;

Figure 3 shows a first embodiment of an element that is part of the cable protector shown in Figure 2;

Figure 4 is a view of the two half-shells making up the element shown in Figure 3;

Figure 5 is a view of the two half-shells shown in Figure 4 joined together;

Figures 6a and 6b illustrate the effect of bending the element shown in Figure 3;

Figure 7 illustrates a clamp shown in Figure 2;

Figure 8 illustrates a half-shell making up the clamp shown in Figure 7;

Figures 9a, 9b, 9c and 9d illustrate the stages of fitting together pieces to make the cable protector shown in Figure 2;

Figure 10 shows a second embodiment of an element that is part of the cable protector shown in Figure 2;

Figure 11 is a view of the two half-shells making up the element shown in Figure 10;

Figure 12 is a view of the two half-shells shown in Figure 11 joined together; and

Figure 13 illustrates an installation vessel installing a cable during the installation of the wind turbine shown in Figure 1.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

Figure 1

A wind turbine **101** is of a type known as a monopile turbine. It comprises a monopile **102** embedded in the seabed **103**. A transition piece **104** is attached to the top of monopile **102**, and a tower **105** is on top of transition piece **104**. Tower **105** comprises the generator **106** and blades **107**. The foundation of the monopile descends below the seabed and is not shown here.

Cable **108** connects turbine **101** to the rest of the wind farm, allowing

generated energy to be provided to a transformer station. The cable runs under the seabed, exits the seabed under a protective structure **109**, passes through the scour area **112**, and enters the monopile **102**, terminating at a control box **110**. Further cabling (not shown) runs through the tower to connect the control box to the generator.

Monopile **102** is a hollow steel tube 5 m in diameter, and the thickness of the wall **111** is 15 cm. Cable **108** passes through an aperture in wall **111**. It is not necessary for this aperture to be sealed, as water may enter the monopile. The known method of passing the cable through the aperture is to provide a steel latching head around the cable, which attaches permanently to the apparatus and extends slightly outside it. There are several disadvantages with this method, as follows.

The latching head, being made of steel and having moving parts, may be subject to corrosion and may mechanically fail. Additionally, the steel can cause wear on the cable, particularly since the cable is free to move. (It is necessary for the cable to be free to move because once the latching head is in place, the cable must be pulled up to the top of the monopile.) Next, at the point where the cable exits the latching head it is subject to the current of the sea, and therefore tends to move back and forth with the waves; this creates a potential failure point as the cable may kink where it exits the latching head. Use of a bend restrictor increases the diameter of the cable, meaning that it may move more with the waves. The point where the cable exits the latching head is therefore still a potential failure point.

In the example shown in Figure 1, the support structure of wind turbine **101** is provided by monopile **102**. Other sizes of monopile are suitable for various depths of water. Additionally, many other support structures are known and envisaged for offshore wind turbines, such as tripods, jackets, multi-piles, and so on. Alternatively, the support structure may be a floating structure rather than one with a foundation in the seabed. In all cases, there is a necessity to have a length of cable running from the seabed to the support structure. The cable may then pass inside the support structure, as with the monopile, or may follow it upwards to the tower. In all such cases, there is a necessity for passing the cable either into or around the support structure for connection to the control box, and protecting the cable where it is exposed to sea water and wave action.

Figure 2

Figure 2 illustrates a portion of monopile wall **111** and the free span of cable **108** in scour area **112**. As is typical, the cable is protected from scouring by rocks **201**

at the point where it exits seabed **103**. There is then a free span of a few metres before the cable enters angled aperture **202** in wall **111**. Cable **108** is protected by cable protector **203**, which comprises a clamp **204** and bend stiffener **205**. A nose bend stiffener **206** is also provided at the front of cable protector **203**.

Bend stiffener **205** covers cable **108** from protective rocks **201** to inside monopile **102**. Thus, there is no potential failure point caused by kinking, because the entire free span of the cable is protected by a single bend stiffener. This is achieved by clamping clamp **206** to cable **108** and attaching it to bend stiffener **205**, before pulling the cable through aperture **202**. Because cable protector **203** is not attached to wall **111** of monopile **102**, the cable can be pulled through until a sufficient amount of bend stiffener is on the inside of monopile **102**, thus preventing any kinking at the point where the cable exits wall **111**.

Further advantages of this system are that bend stiffener **205**, being made of polyurethane, does not cause wear on aperture **202** in the same way that a steel latching head does, and nor does it cause wear on the cable inside. Cable wear is further reduced by the fact that it is clamped by clamp **206**, and thus does not move within cable protector **203**. A further advantage of this system is that because the cable protector is not attached to monopile **102**, less load is transferred to the monopile during severe weather conditions.

Therefore, cable protector **203**, in addition to being significantly cheaper to manufacture because it is made of polyurethane rather than steel and has no moving parts, offers greater reliability than existing systems and therefore should reduce maintenance costs.

Bend stiffener **205** is made up of a number of identical elements such as elements **207** and **208**, which will be described further with respect to Figure 3. However, in a cable or tubing protection system for a wind turbine having a clamp and bend stiffener, other types of bend stiffener could be used.

Figure 3

Figure 3 shows element **207**, which in combination with a number of identical elements forms bend stiffener **205**. Element **207** is a first embodiment of an element suitable for forming bend stiffener **205**, and a second embodiment of a suitable element is shown in Figure 10.

Element **207** is a circular tube, which in this embodimentis 1 m long, with an external diameter of 28 cm. The internal diameter is 10.5 cm, allowing a snug fit for a

cable having a 10 cm diameter. However, other sizes could be used to accommodate different sizes of cable. The length of 1 m minimises the number of elements required to form a bend restrictor without making a single element too unwieldly. However, longer or shorter elements could be used. Dashed lines **306** and **307** indicate the inner surface of the tube, which is smooth and creates an inner void **309**, which is substantially cylindrical with an internal recess **310** at one end to allow joining to an adjacent element. Element **207** has an outer and inner circular cross section, as this allows the element to bend equally in all directions. However, if it were desired that the element allowed more bending in one direction than another, the element might have a different shaped cross section. For example, an oval would permit more bending on its long side than on its short side.

Element **207** has a knuckle **305** at the opposite end from internal recess **310**, and joining is achieved by enclosing the knuckle of one element within the internal recess of another element. As will be described further with respect to Figure 4, element **207** comprises two half-shells with crenelated edges, and line **311** shows the edges of the two half-shells fitted together. The view from the other side of element **207** is almost identical, save that the crenellated joining line is slightly different.

Element **207** is made from polyurethane with a Shore Hardness of 65D; any other suitable material of a suitable hardness could be used.

The tubular wall **308** of the element is 8.75 cm thick along most of its length, except at internal recess **310**, and defines circumferential recesses, such as recesses **301** and **302**, along its length. In this embodiment, the recesses are grouped into a first set **303** of nine recesses, and a second set **304** of eight recesses. However, any other arrangement could be used. The circumferential recesses provide dynamic bend stiffening along the length of element **207**.

Each circumferential recess such as recess **301** is V-shaped with a slightly curved base. When a force is applied to element **207**, it will bend in the direction of the force. On the concave side of the bend the recesses will close up, as shown in Figures 6a and 6b, while on the convex side the recesses will open out. This allows bending to take place when a smaller force is applied, compared with a bend stiffener without recesses. However, as the force is increased and the recesses close up further, the element becomes stiffer. In other words, the amount of force required to continue the bend increases with the bending of the element. This provides dynamic bend stiffness, as will be described further with reference to Figures 6a and 6b.

In order for this dynamic bend stiffness to be present, the depth of each recess, such as recess **301**, should be no more than 50% of the thickness of the tubular wall **308** of the element. In the embodiment of Figure 3, the depth of each recess is around 20% of the thickness of the wall. Recesses that are deeper than this will tend to allow unrestricted bending rather than dynamic bend stiffness.

The effect of this dynamic bend stiffness is that force applied to one place on the bend stiffener will tend to be spread along the length of the stiffener, thus reducing the likelihood of a single part of the bend stiffener over-bending and causing a kink.

Figure 4

Element **207** comprises two substantially identical half-shells **401** and **402** which are bolted together around cable **108**. Half-shell **401** comprises a wall **403**, on the outside of which are defined recesses such as recess **410**. Half-shell **402** comprises a wall **411**, on the outside of which are also defined recesses such as recess **412**. When joined together, wall **403** and wall **410** form tubular wall **308** of element **207**, the recesses match to form circumferential recesses **301**, and internal cylindrical void **309** is formed. It can be seen that tubular wall **308** has a smooth inner surface **409**; thus the wall **308** of the element is not corrugated, but defines recesses on its outer surface only.

Each half-shell has two long edges. Long edge **404** of half-shell **401** is visible, and long edges **405** and **406** of half-shell **402** are visible. Each long edge is a cross section through the tubular wall which is complementary to the corresponding wall on the other half-shell.

In this embodiment, the long edges are crenellated, causing them to fit together as can be seen in Figure 3. The crenellation prevents a single long joining line that could open when the element bends, which could allow particulate matter to enter the bend stiffener and abrade the cable.

Using identical elements minimises the cost of tooling and therefore of manufacture. However, in other embodiments, the half-shells could be hinged together using some form of hinging element, in which case they would be quicker to fit around the cable as the number of bolting points would be reduced; in that case, it might be that only the non-hinged long edges are crenelated.

The knuckle **305** of each element is held within an adjacent element. Internal recess **310** of element **207** holds the knuckle of an adjacent element. Additionally, clamp **206** is formed with a knuckle as will be shown in Figure 7, and therefore the

first element in the bend stiffener that is adjacent to the clamp is attached to it by this means. Other attachment means to connect elements together could be used.

Each of the half-shells defines bolt holes such as bolt hole **407** and washer slots such as washer slot **408**. To fix two half-shells together a washer is placed in washer slot **408**, and a bolt is placed in hole **407** and passed through the washer. It is then self-tapped into the other half-shell. In this embodiment six bolt points are provided. However, other methods of connecting the shells could be used.

Figure 5

Figure 5 shows element **207** after half-shells **401** and **402** have been placed together and bolted around an example cable **503**, which almost fills cylindrical void **309**. Bolts **501** and **502** are shown.

Element **207** may be used on its own as shown in this Figure, or with a number of identical elements to form any length of bend stiffener. The embodiment shown herein of the cable protector for an offshore wind turbine is only one example of how it may be used. This dynamic bend stiffener may replace other bend stiffeners and bend restrictors in any suitable setting, for example protection of other undersea electric cables, protection of gas and oil piping and tubing, and so on.

Figures 6a and 6b

As described with reference to Figure 3, element **207** provides dynamic bend stiffening. This is illustrated in Figures 6a and 6b.

Each circumferential recess, such as recess **601**, has an open end **602** at the circumference of the tubular wall (the inside diameter of which is shown at dashed lines **306** and **307**), and a base **603**. The sides **604** and **605** are sloped to form a substantially V-shaped cross-section, so that the sides are closer to each other at the base than at the open end, and base **603** has a curvature.

When element **207** is unbent, the distance between the sides **604** and **605** at the open end is 16.5 mm and the space between adjacent recesses is 23 mm. Each recess is 20.5 mm deep, and the sides slope at an angle of 72° from the horizontal. This shape, size and spacing of the recesses has been determined to work well in an undersea setting for protection of a wind turbine cable. Other shapes, sizes and spacing of recesses may be used to allow more or less bend in the bend stiffener, depending on requirements.

In Figure 6a, a force **611** has been applied. This causes recesses **612** and **613** to start to close up and allow bending, to create a concave curve on the side on

which the force is applied, while on the convex side the same recesses open up slightly. The curvature of the recesses facilitates this opening up.

In Figure 6b, force **611** is increased. Slot **612** and **613** are now almost entirely closed on the concave side. The effect of the closing of the recesses is that the tubular wall becomes thicker within the recesses. This makes the element more difficult to bend at this point. Thus, the adjacent recesses **614** and **615** also begin to close, because at those points less force is required to bend the element than at recesses **612** and **613**. As these also start to close, bending continues at the next adjacent recesses **616** and **617**, as again less force is required to bend at these points. Thus, rather than all the force being applied to one point of the bend stiffener, it is spread along its length by the provision of dynamic stiffness.

Eventually, when all the recesses are closed, the bend stiffener will tend to lock out, as the only way it can continue to bend is by deformation of the polyurethane which takes considerably more force. Thus, the effect of the dynamic bend stiffener is to provide dynamic stiffness when smaller forces are applied, but to behave like a bend restrictor under large forces. This means it can replace a bend restrictor without loss of functionality. However, this behaviour will vary by choice of material. A more flexible material will deform to allow further bending after the recesses are closed, whereas a less flexible material will not bend further and will provide bend restriction.

The element can be designed to lock out at an appropriate bend radius. The radius is dependent upon the depth of the recesses relative to the thickness of the wall: deeper recesses will lock out at a smaller radius (ie allow more bending). Recesses deeper than around 50% of the thickness of the wall would allow a bend radius approaching zero, and therefore a suitable recess depth would be less than this.

Thus there is herein described a bend stiffener comprising an element, such as element **207**, which comprises a tubular wall, such as wall **308,** having a substantially smooth inner surface. The wall defines circumferential recesses, such as recess **301**, along at least part of its length, each recess having an open end at the circumference of the wall and a base, and having sides that slope away from the base. The depth of each recess is no more than 50% of the thickness of the wall.

Figures 7 and 8

Clamp **204** is illustrated in Figure 7. It comprises two half-shells, one of which is shown in Figure 8 as half-shell **801**. The clamp is a substantially cylindrical tube,

having an inner diameter the same or slightly smaller than the diameter of cable **108**. The two half-shells are placed around cable **108** and bolted together through bolt holes such as holes **701** and **702**. These are tightened until the clamp is immovable on the cable.

The clamp includes a knuckle **703** which is identical in size and shape to the knuckle **305** of element **207**. In order to attach clamp **204** to a length of bend stiffener elements, a first element is attached around the clamp, such that knuckle **703** fits within a recess, such as recess **310**. Other attachment means could be used.

The clamp narrows at its front end **704** in order to attach a nose bend stiffener **206**. This is bolted on through holes such as hole **802**. The nose bend stiffener serves to prevent the cable kinking where it exits the front of the clamp, but in other embodiments it may be omitted, may be of a different type, or may be attached by other means.

Figures 9a, 9b, 9c and 9d

Figures 9a to 9d show the stages of construction of cable protector **203**. First, as shown in Figure 9a, cable **108** is threaded through nose bend stiffener **206**. This is a conical tube, with the wall thickening from the front to the back. The internal diameter is wider than the diameter of cable **108**, to allow the cable to pass freely through it. The nose bend stiffener **206** is positioned at a point in the cable such that there is a predetermined length of cable **901** at the nose end. In the embodiment herein described, this would be approximately the distance from the aperture **202** in monopile **102** to the control box **110**.

As shown in Figure 9b, clamp **204**, in two half-shells, is then clamped onto cable **108**. Once in position, the front of the clamp is bolted to nose bend stiffener **206**. These are now immovably attached to cable **108**.

As shown in Figure 9c, a first bend stiffener element **207** is added. The two half-shells are placed around cable **108** and knuckle **703** of clamp **204**, and bolted together. Element **207** is now attached to the back of clamp **204**.

As shown in Figure 9d, a further bend stiffener element **208** is then attached in the same way to element **207**. This continues until a desired length of bend stiffener **205** is achieved.

Thus there is disclosed herein a cable or tubing protector comprising a plurality of connected elements, such as elements **207** and **208**. Each has a knuckle held within a recess of an adjacent element. The exception is the two end elements, which

have either a recess or a knuckle free. In this embodiment, there is also provided a clamp having a knuckle, held within the recess of an end element.

Figure 10

Figure 10 illustrates a second embodiment of an element suitable for forming bend restrictor **205**. Element **1001** is a circular tube, which in this embodiment is 1 m long, with an external diameter of 28 cm. The The internal diameter is 10.5 cm, allowing a snug fit for a cable having a 10 cm diameter. However, other sizes could be used to accommodate different sizes of cable. The length of 1 m minimises the number of elements required to form a bend restrictor without making a single element too unwieldly. However, longer or shorter elements could be used. Dashed lines **1002** and **1003** indicate the inner surface of the tube, which is smooth and creates an inner void **1004**, which is substantially cylindrical with an internal recess **1005** at one end to allow joining to an adjacent element. Element **1001** has an outer and inner circular cross section, as this allows the element to bend in all directions. However, if it were desired that the element allowed more bending in one direction than another, the element might have a different shaped cross section. For example, an oval would permit more bending on its long side than on its short side.

Element **1001** has a knuckle **1006** at the opposite end from internal recess **1005**, and joining is achieved by enclosing the knuckle of one element within the internal recess of another element.

As will be described further with respect to Figure 11, element **1001** comprises two half-shells. Holes **1014**, **1015**, **1016, 1017** and **1018** provide fixing points to hold the half-shells together, and line **1019** shows the edges of the two half-shells. The view from the other side of element **1007** is identical.

Element **1001** is made from polyurethane with a Shore Hardness of 56D; any other suitable material of a suitable hardness could be used.

The tubular wall **1007** of the element is 8.75 cm thick along most of its length, except at internal recess **1005**, and defines circumferential recesses, such as recesses **1008** and **1009**, along its length. In this embodiment, the recesses are grouped into four sets of recesses: first set **1010** of four recesses, second set **1011** of five recesses, third set **1012** of five recesses, and fourth set **1013** of four recesses. The circumferential recesses provide dynamic bend stiffening along the length of element **1001**.

This embodiment and the embodiment shown in Figure 3 differ in their

arrangement of recesses. The arrangement may be varied still further, and may be dependent upon the hardness of the material used, the length and width of the element, the thickness of the wall, and the depth of the recesses.

Each circumferential recess such as recess **1008** is V-shaped with a slightly curved base. This curvature is shown more clearly in Figure 10 than in Figure 3, but the recesses are substantially similar in both embodiments. When a force is applied to element **1001**, it will bend in the direction of the force. On the concave side of the bend the recesses will close up, as shown in Figures 6a and 6b, while on the convex side the recesses will open out. This allows bending to take place when a smaller force is applied, compared with a bend stiffener without recesses. However, as the force is increased and the recesses close up further, the element becomes stiffer. In other words, the amount of force required to continue the bend increases with the bending of the element.

In order for this dynamic bend stiffness to be present, the depth of each recess, such as recess **1008**, should be no more than 50% of the thickness of the tubular wall **1007** of the element. In the embodiment of Figure 10, the depth of each recess is around 30% of the thickness of the wall. Recesses that are deeper than this will tend to allow unrestricted bending rather than dynamic bend stiffness.

The effect of this dynamic bend stiffness is that force applied to one place on the bend stiffener will tend to be spread along the length of the stiffener, thus reducing the likelihood of a single part of the bend stiffener over-bending and causing a kink.

Figure 11

Element **1001** comprises two substantially identical half-shells **1101** and **1102** which are pinned together around a cable. Half-shell **1101** comprises a wall **1103**, on the outside of which are defined recesses such as recess **1104**. Half-shell **1102** comprises a wall **1105**, on the outside of which are also defined recesses such as recess **1106**. When joined together, wall **1103** and wall **1105** form tubular wall **1007** of element **1001**, the recesses match to form circumferential recesses such as recess **1008**, and internal cylindrical void **1004** is formed. It can be seen that tubular wall **1007** has a smooth inner surface **1107**; thus the wall **1007** of the element is not corrugated, but defines recesses on its outer surface only.

Each half-shell has two long edges. Long edge **1108** of half-shell **1101** is visible, and long edges **1109** and **1110** of half-shell **1102** are visible. Each long edge is a cross section through the tubular wall which is complementary to the

corresponding wall on the other half-shell. The half-shells are fixed together by means of complementary projections and depressions along the long edges.

Half-shell **1102** defines a number of cylindrical projections that are upstanding from its long edges. Small projections **1111** and **1112** are at either end of long edge **1110** and large projection **1113** is in roughly the centre, between second and third sets of recesses **1011** and **1012.** Large projections **1114** and **1115** are upstanding from long edge **1109**, between the first and second sets of recesses **1010** and **1011** and the third and fourth sets of recesses **1012** and **1013** respectively. Each projection defines a hole for a fixing pin, orthogonal to the long axis of the half-shell.

Opposite each projection, the opposing long edge defines a depression of a reciprocal size and shape. Thus long edge **1109** defines small depressions **1116** and **1117** at either end. and large depression **1118** in roughly the centre, between second and third sets of recesses **1011** and **1012**. Similarly, long edge **1110** defines large depressions **1119** and **1120** between the first and second sets of recesses **1010** and **1011** and the third and fourth sets of recesess **1012** and **1013** respectively. In the wall of each half-shell are defined holes, orthogonal to the long axis of the half-shell and lined up with each depression. For example, hole **1015** in half-shell **1102** is lined up with depression **1119**. Each hole continues on the other side of the depression, for example hole **1121** is a continuation of hole **1015**.

Half-shell **1101** is identical and therefore has identical projections and depressions in its long edges, of which only one can be seen, small projection **1122**.

To join half-shells **1101** and **1102**, the projections are fitted into their reciprocal depressions on the other half-shell. For example, projection **1122** is fitted into depression **1116.** Nylon pins (not shown) are used to hold the half-shells together. For example, a pin is passed through hole **1015,** through the hole in the projection, and into continuation hole **1121**. The pin is hammered into place, and held by a friction fit. In this example, five pins are fitted on each side. Alternative arrangements of the projections and depressions, and alternatives to the hammered nylon pin (such as a threaded bolt) could be used.

This method of joining the half-shells together, with alternating projections and depressions, and pins in both half-shells, serves the same function as the crenallation of the first embodiment, ie preventing the joining line **1019** between the half-shells opening up when element **1001** bends. Such an opening could allow particulate matter to enter the bend stiffener and abrade the cable.

Using identical elements minimises the cost of tooling and therefore of

manufacture. However, in other embodiments, the half-shells could be hinged together using some form of hinging element, in which case they would be quicker to fit around the cable as the number of bolting points would be reduced. In that case, it might be that the projections, depressions and holes for pins would only be present on one of the long edges. Thus, two embodiments have been described that use different methods of joining half-shells to form an element. Other suitable joining methods could also be used.

To join two elements together, the knuckle **1006** of each element is held within an adjacent element. Internal recess **1005** of element **1001** holds the knuckle of an adjacent element. Additionally, as with the first embodiment, the first element in the bend stiffener that is adjacent to clamp **204** is attached to it by engaging with knuckle **703**. Other attachment means to connect elements together could be used.

Figure 12

Figure 12 shows element **1001** after half-shells **1101** and **1102** have been placed together around an example cable **1201**, which almost fills cylindrical void **1004**. Pins have been hammered into the holes **1014** to **1018**.

Element **1001** may be used on its own as shown in this Figure, or with a number of identical elements to form any length of bend stiffener, in the same way as shown in Figure 9. Further, since this embodiment differs from the first embodiment only in the method of fixing the half-shells together and the arrangement of the recesses, the two embodiments (or another embodiment) could be joined together if necessary to form a bend stiffener.

Figure 13

Installation of cable **108** in monopile **102** is illustrated in Figure 13. Typically, such installation is carried out by a self-elevating installation vessel **1301**. This is a boat that, after navigating to the required position offshore, elevates itself on a number of legs, such as leg **1302**. This ensures that the vessel is kept in position during installation of wind turbines and provides a foundation for the lifting of the heavy components. However, for the installation of cable an anchored boat may be sufficient.

Vessel **1301** has a crane **1303** including a hoist rope **1304**. Underwater, the installation is assisted by a remotely operated underwater vehicle (ROV) **1305**, which is preferred for reasons of cost and safety to a human diver. This is wirelessly connected to control equipment on board vessel **1301**, for control by an operator. It

includes a camera to provide an underwater view to the operator.

Before the cable is installed, a messenger wire **1306** is fed through the monopile and out through aperture **202** with the assistance of ROV **1305**, and the underwater end is then passed back up to installation vessel **1306**.

Cable **108** is held on spool **1307** on vessel **1301**. On the vessel, cable protector **203** is installed, leaving a predetermined length of cable **901** ahead of the front end. Either element **207** or element **1001** may be used to form the bend stiffener **205**.

Cable **108** is then attached to messenger line **1306** which is attached to hoist rope **1304**, so that the cable can be pulled into position using crane **1303**. When the end of cable **108** reaches the top of transition piece **104**, a visual check is made using ROV **1305** that the clamp **204** and front portion of bend stiffener **205** have entered through aperture **202**. The cable is then secured and the messenger wire **1306** disengaged.

The remainder of the cable is then unspooled to the seabed before being buried. Typically, installation vessel **1301** includes a trenching unit or other cable burial equipment.

This method of installing a cable for an offshore wind turbine is simpler than the known methods, in which the cable protection system includes a latching head. In such a method, a check must be made using the ROV that the latching head has installed correctly. Because the cable is pulled along the seabed, the water is often murky and it can be difficult to ascertain this. Once the cable is detached from the latching head and pulled freely through the cable protection system to the top of the monopile, it is not then possible to exert any force on the latching head if it is not in the correct position. Therefore, maintenance can only be achieved using a ROV having manipulator features, or a human diver.

By contrast, using the method described herein, it is only necessary to confirm that at least some of the bend stiffener has entered the aperture, which is considerably easier to ascertain visually in murky water. Further, because cable **108** is permanently attached to cable protector **203**, if it later transpires that the cable protector is not in quite the right position it is a simple matter to raise or lower the cable using a crane or winch.

Further advantages with the system described herein relate to maintenance. In all of the known systems, once the latching head is in place it is not designed to be removed. Some systems include removal tools, but these are generally difficult to use

and require use of an ROV with manipulator features or a human diver. Therefore if there is any failure of the protection system, it is a difficult matter to remove it and replace it. However, cable protector **203** includes no metal or moving parts and is therefore unlikely to fail.

Thus, there is described herein a method of installing an electrical cable in an offshore wind turbine having a support structure, which in this example is monopile **202**. It comprises the steps of attaching a clamp, which in this example is clamp **204**, to the cable, and attaching a bend stiffener, which in this example is bend stiffener **205**, to the back end of the clamp such that it surrounds the cable. The cable is passed into the support structure, such that the clamp enters structure front end first, and pulled upwards until it reaches a desired height.

CLAIMS

1. A bend stiffener, comprising:

an element comprising a tubular wall having a substantially smooth inner surface;

wherein said tubular wall defines circumferential recesses along at least part of its length,

each recess having an open end at the circumference of the wall, a base, and sloping sides that are closer to each other at the base than at the open end, and having a depth of no more than 50% of the thickness of the tubular wall.

2. A bend stiffener according to claim 1, wherein said element further comprises attachment means at each end, for attachment to identical elements.

3. A bend stiffener according to claim 2, wherein said attachment means comprises a tubular knuckle at one end of said element and a recess at the other end of said element, wherein the knuckle fits within the recess of an identical element.

4. A bend stiffener according to any of claims 1 to 4, wherein said element comprises two complementary half-shells configured to be attached together, each said half shell having two long edges, each long edge comprising a cross-section of the tubular wall.

5. A bend stiffener according to claim 4, wherein said half-shells are substantially identical.

6. A bend stiffener according to claim 4, further comprising at least one hinging element connecting adjacent long edges of said half-shells.

7. A bend stiffener according to any of claims 4 to 6, wherein for at least one long edge of each of said half-shell, said edges are crenellated along at least part of their length, such that the edges interlock when joined together.

8. A bend stiffener according to any of claims 4 to 6, wherein:

one half-shell comprises a projection upstanding from one long edge; and

the other half-shall has a reciprocal depression defined in one long edge;

such that said projection fits into said depression when said half-shells are placed together along their long edges.

9. A bend stiffener according to claim 8, wherein each long edge of each half shell has at least one such projection and at least one such depression, such that said projections and depressions fit together when said half-shells are placed together along their long edges.

10. A bend stiffener according to claim 9, wherein for at least one of said depressions a first hole is defined through the tubular wall of the element to said depression, and a second hole is defined in the projection that is reciprocal with said depression, and said element further comprises a pin pushed through said first hole and said second hole to hold said half-shells together.

11. A bend stiffener according to any of claims 1 to 7, wherein said tubular wall has a substantially circular cross-section.

12. A bend stiffener according to any of claims 1 to 11, wherein each said recess has a substantially V-shaped cross-section.

13. A bend stiffener according to claim 12, wherein the base of each recess is curved.

14. A cable or tubing protector comprising a plurality of connected elements according to any of claims 1 to 13 such that at each end there is an end element,

wherein the knuckle of each element, excepting one of said end elements, is held within the recess of its adjacent element.

15. A cable protector according to claim 14, further including a clamp having a knuckle, wherein the knuckle of the clamp is held within the recess of one of

said end elements.

16. A method of protecting a cable or tubing, comprising the steps of:

obtaining a first element, formed in two complementary half-shells and comprising a tubular wall having a substantially smooth inner surface,

said tubular wall defining circumferential recesses along at least part of its length, and

each recess having an open end at the circumference of the wall, a base, and sloping sides that are closer to each other at the base than at the open end, and having a depth of no more than 50% of the thickness of the tubular wall;

placing said half-shells around said cable and closing said element; and

joining said half-shells together.

17. A method according to claim 16, wherein said half-shells are hinged together.

18. A method according to either of claims 16 or 17, further including the step of:

placing a second element, identical to said first element, around said cable adjacent to said first element; and

attaching said second element to said first element.

19. A method according to claim 18, wherein said first element has a knuckle at one end and said second element has a recess at one end, and said second element is attached to said first element by placing said recess around said knuckle before closing said element.

20. A method according to any of claims 16 to 19, wherein at least one pair of complementary edges of said half-shells are crenellated along at least part of their length, such that the half-shells interlock when joined together.

21. A method according to any of claims 16 to 20, wherein:

one half-shell comprises a projection upstanding from one long edge; and

the other half-shall has a reciprocal depression defined in one long edge;

such that said projection fits into said depression when said half-shells are placed together along their long edges.

22. A method according to claim 21, wherein a first hole is defined through the tubular wall of the element to said depression, and a second hole is defined in said projection, and said step of joining said half-shells comprises pushing a pin through said first hole and said second hole.

23. A method according to any of claims 16 to 22, further comprising the step of, before attaching said first element:

obtaining a clamp having a knuckle at one end; and

clamping said clamp around said cable;

wherein said step of attaching said first element further includes the step of placing a recess at the end of said first element around the knuckle of said clamp before closing said first element.

24. A method of installing an electrical cable in an offshore wind turbine having a support structure, comprising the steps of:

attaching a clamp to said cable, said clamp having a front end and a back end;

attaching a bend stiffener to the back end of said clamp such that it surrounds said cable;

passing said cable into said support structure, such that said clamp enters the structure front end first; and

pulling said cable upwards until it reaches a desired height in said wind turbine.

25. A method according to claim 24, wherein said support structure comprises a wall defining an aperture, and wherein said cable, said clamp and at least part of said bend stiffener is passed through said aperture.

26. A method according to claim 24, wherein said bend stiffener comprises a bend stiffener according to any of claims 1 to 13.

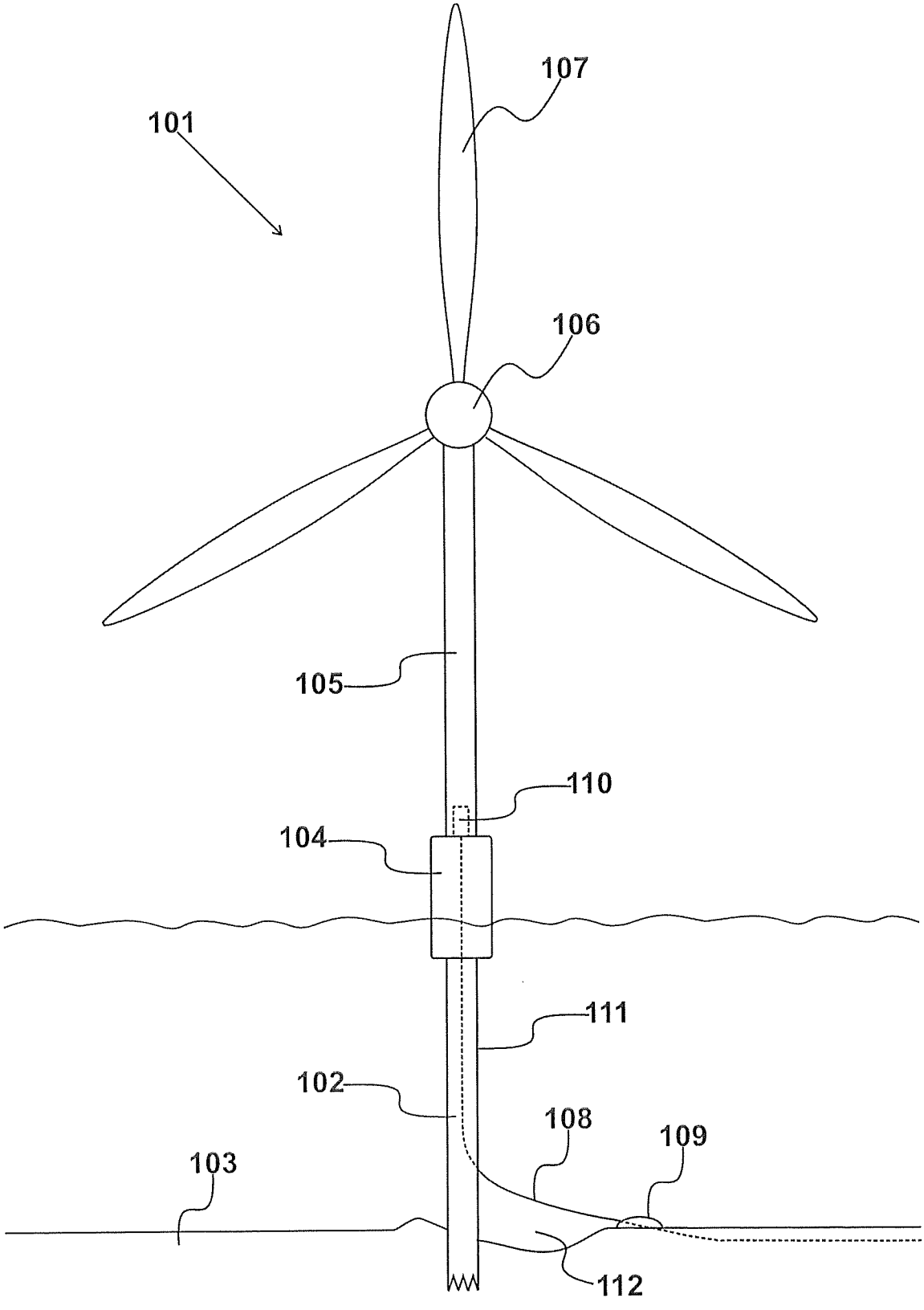


Fig. 1

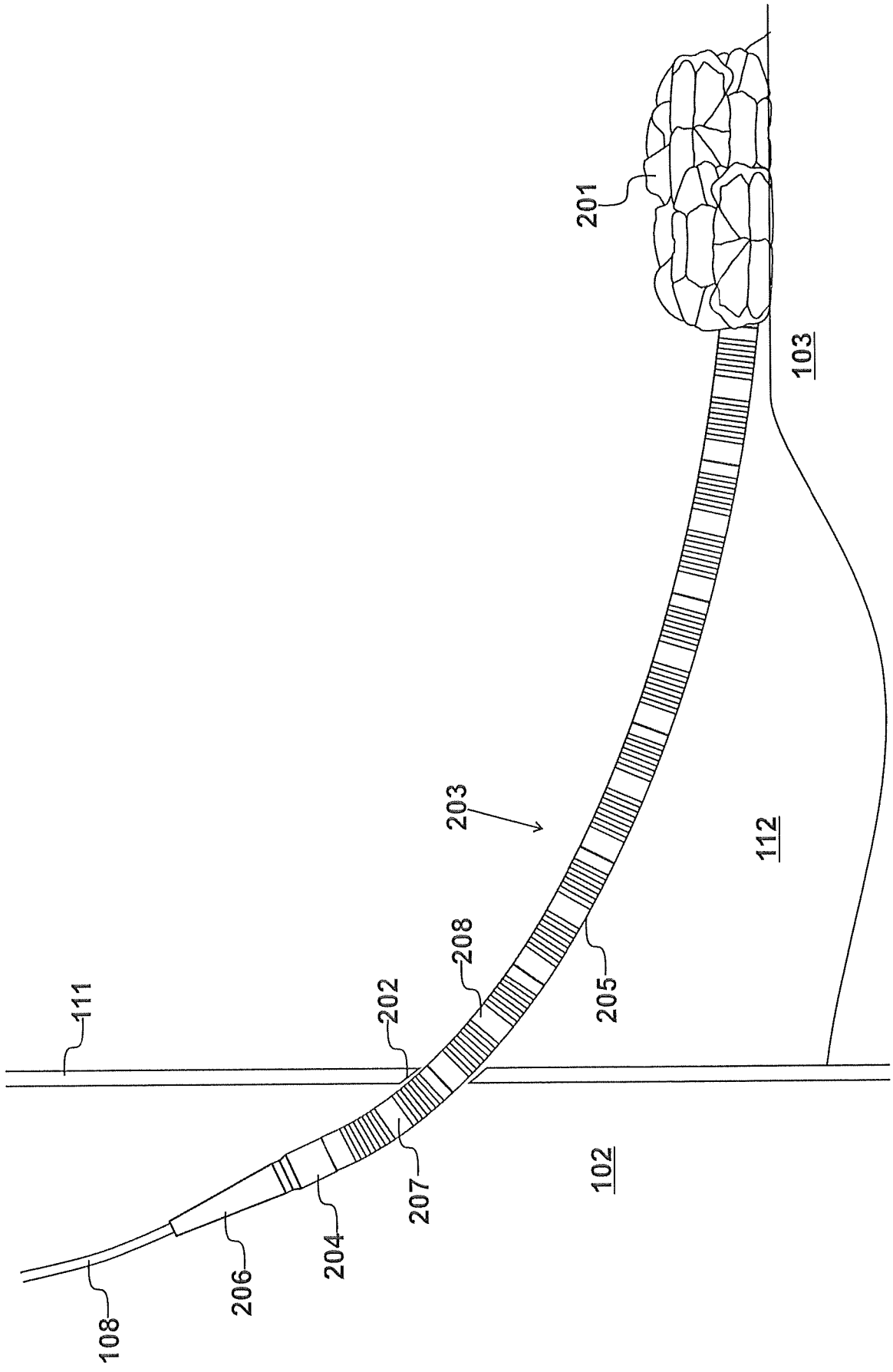


Fig. 2

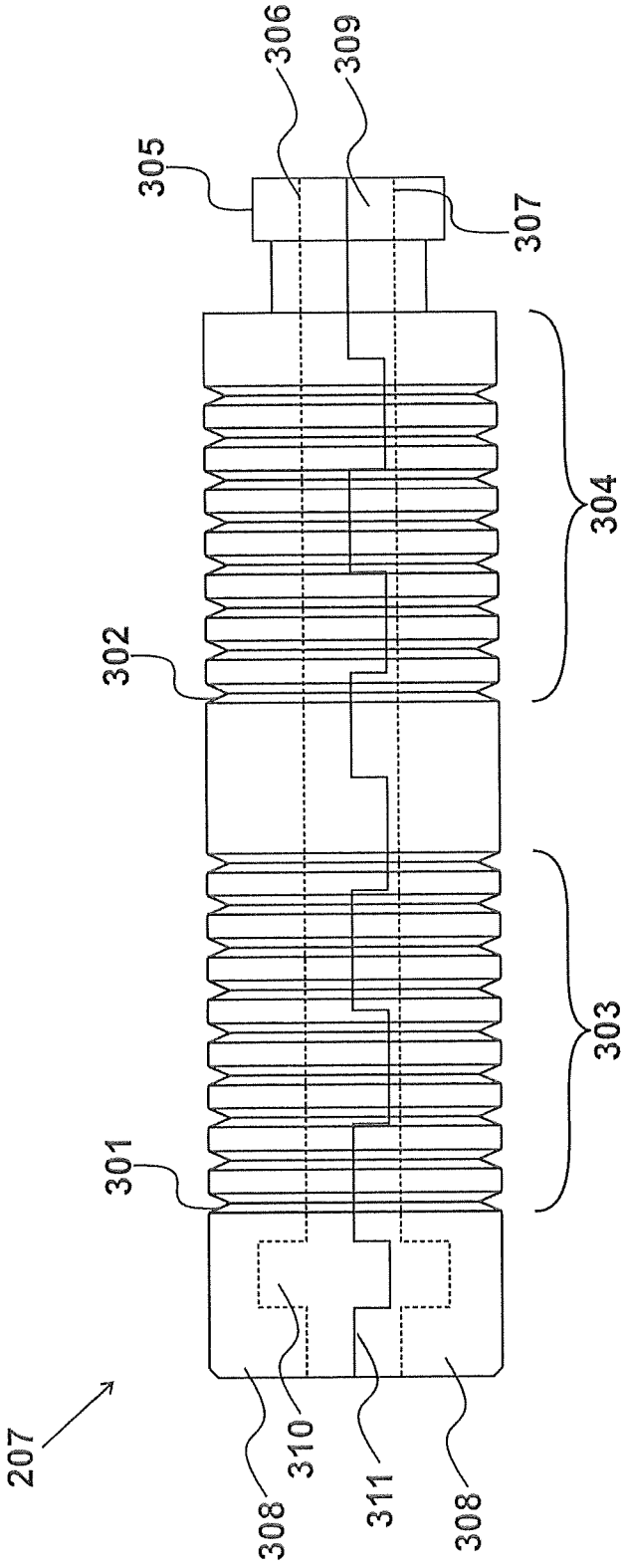


Fig. 3

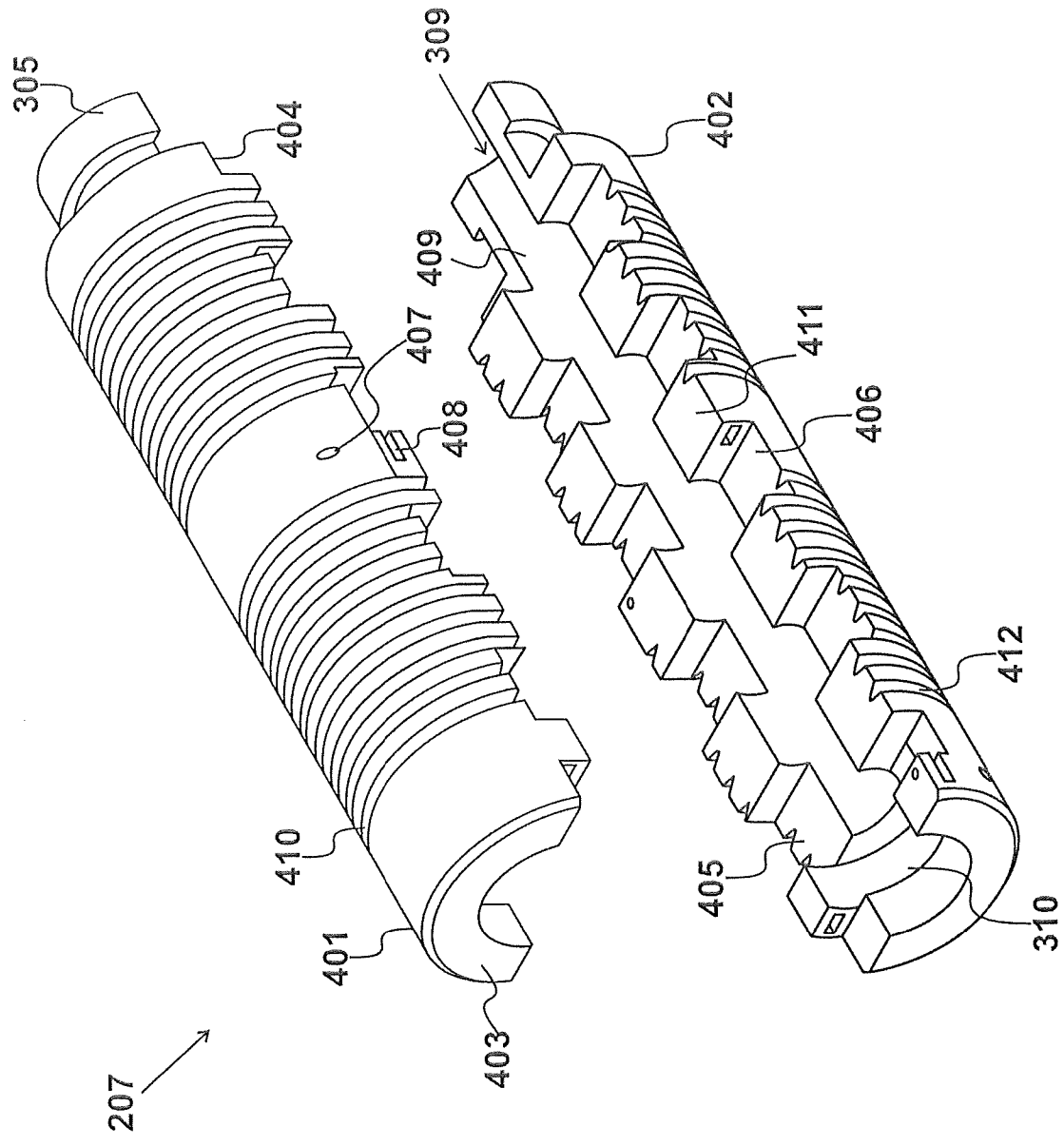


Fig. 4

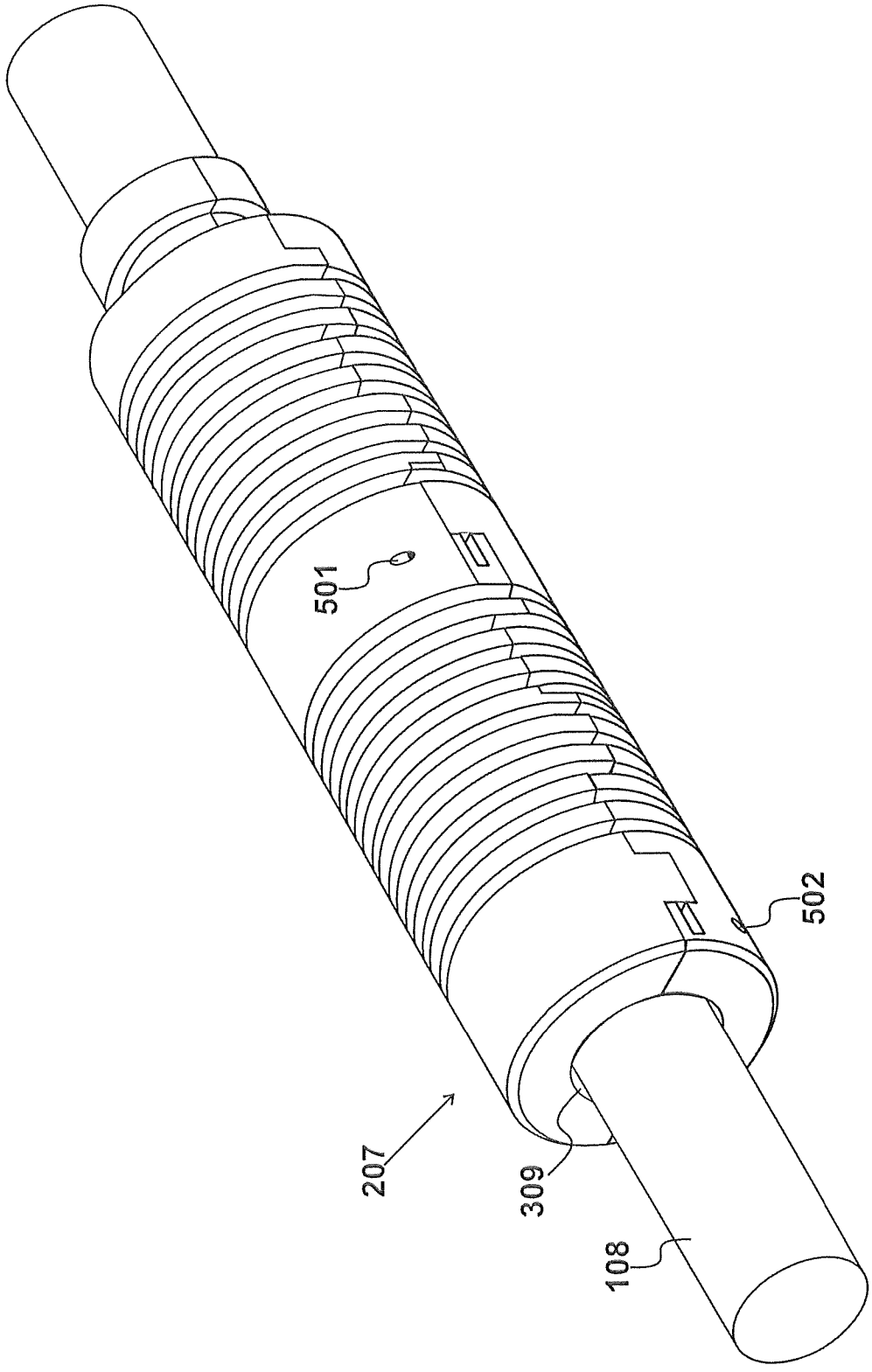


Fig. 5

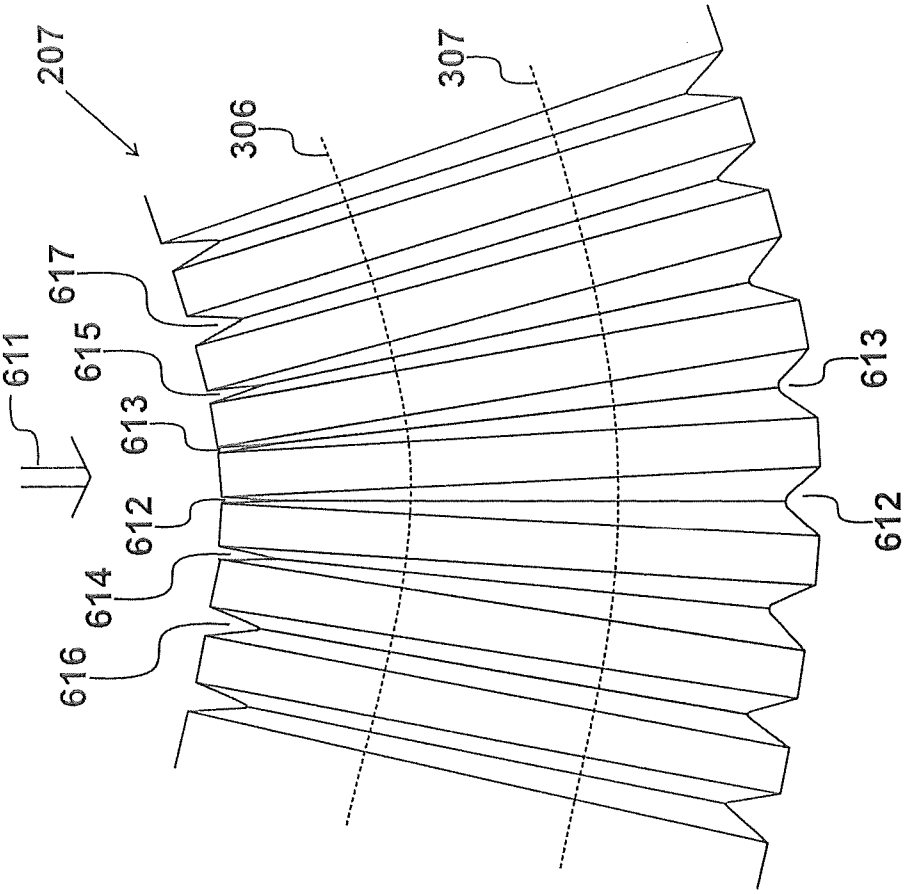

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Fig. 6b

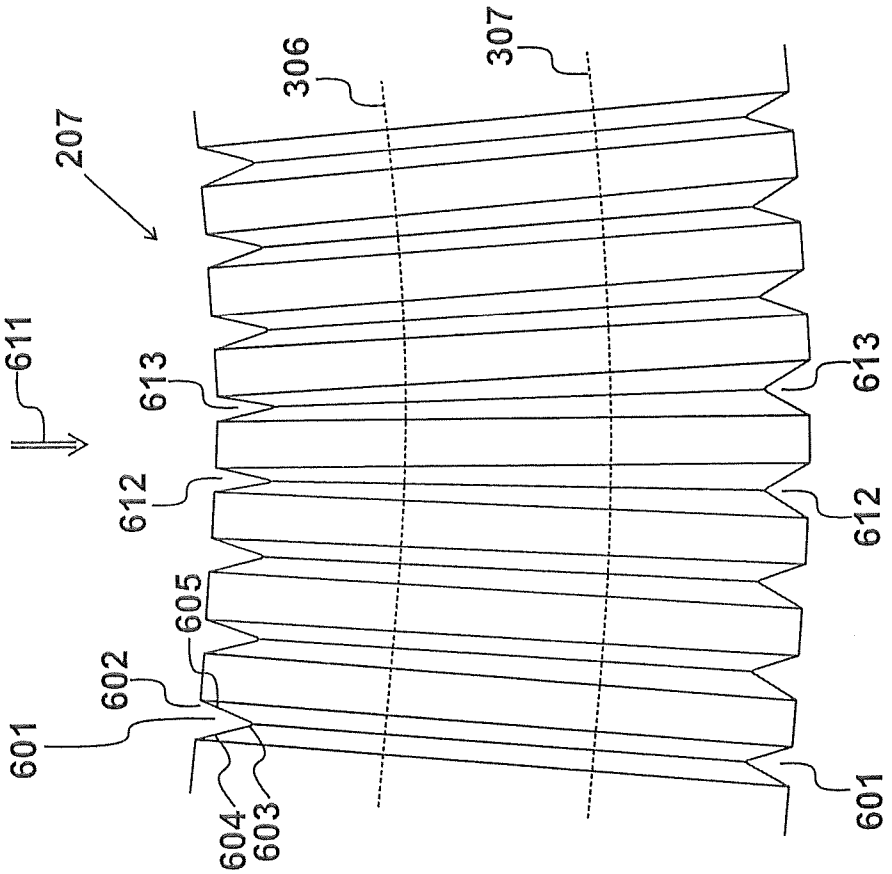

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Fig. 6a

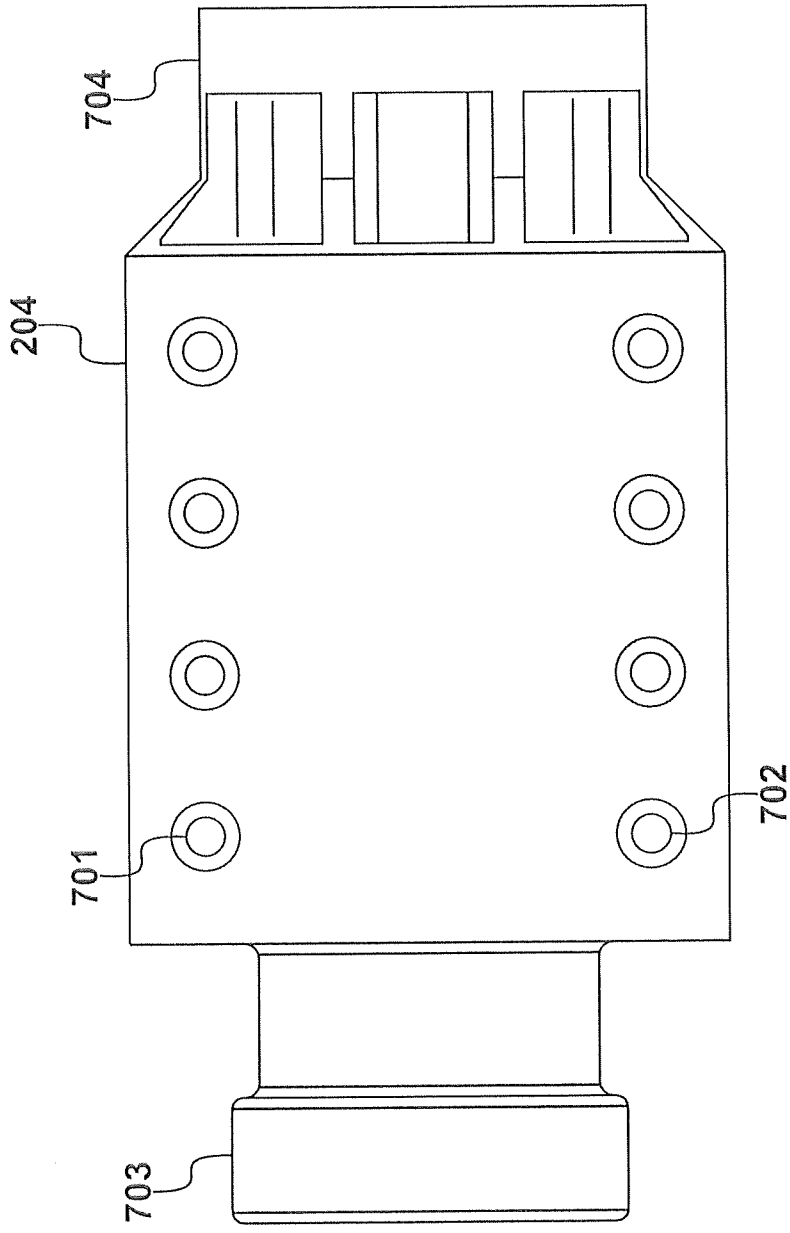


Fig. 7

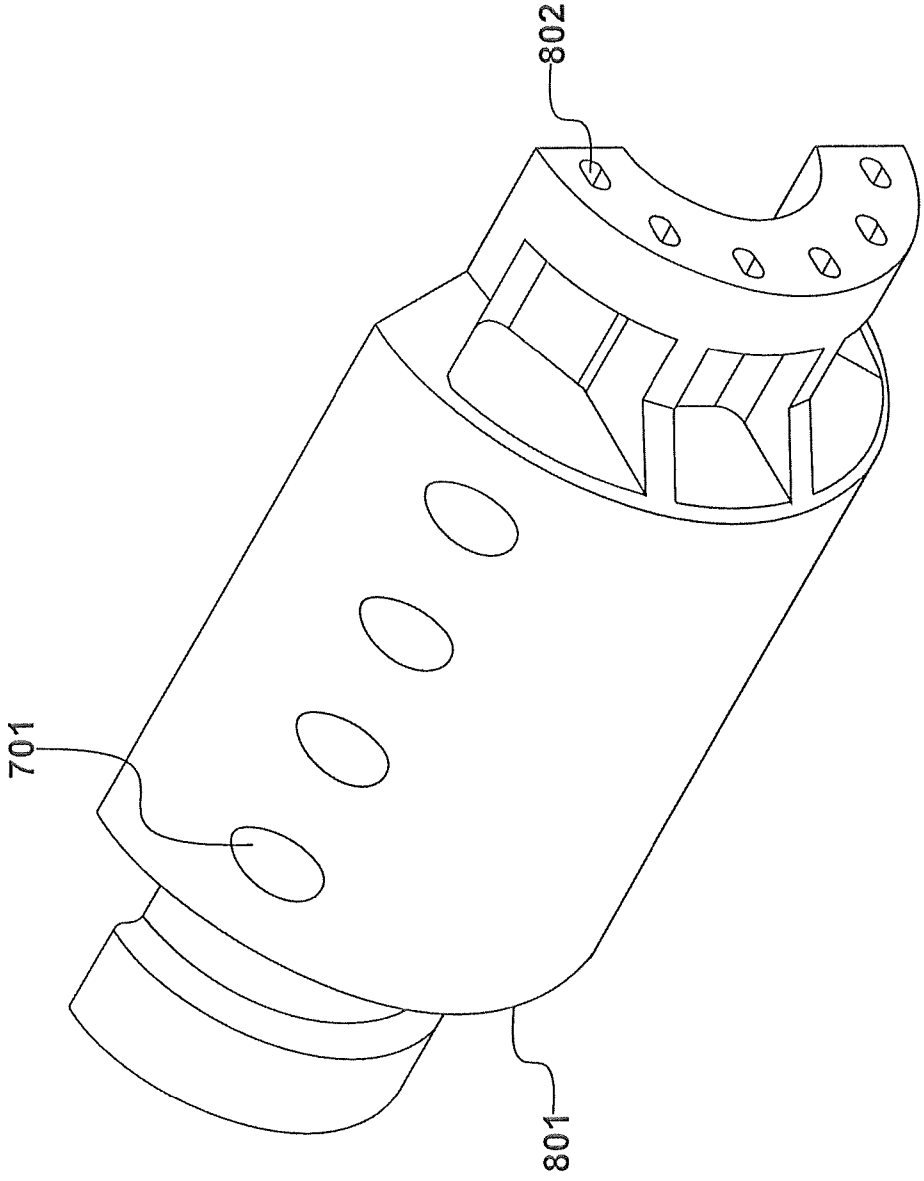
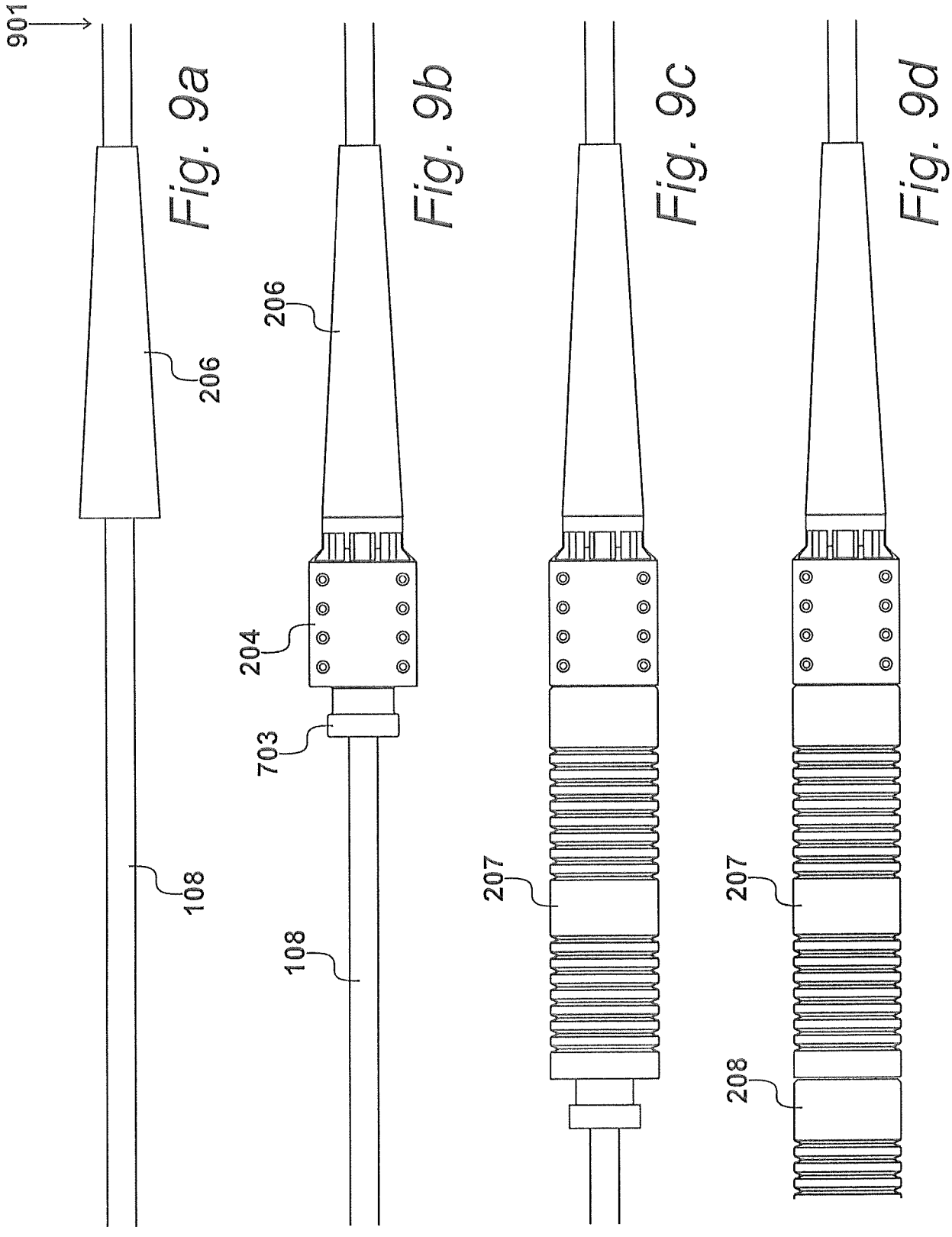


Fig. 8


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Fig. 9a
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Fig. 9b
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Fig. 9c
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Fig. 9d

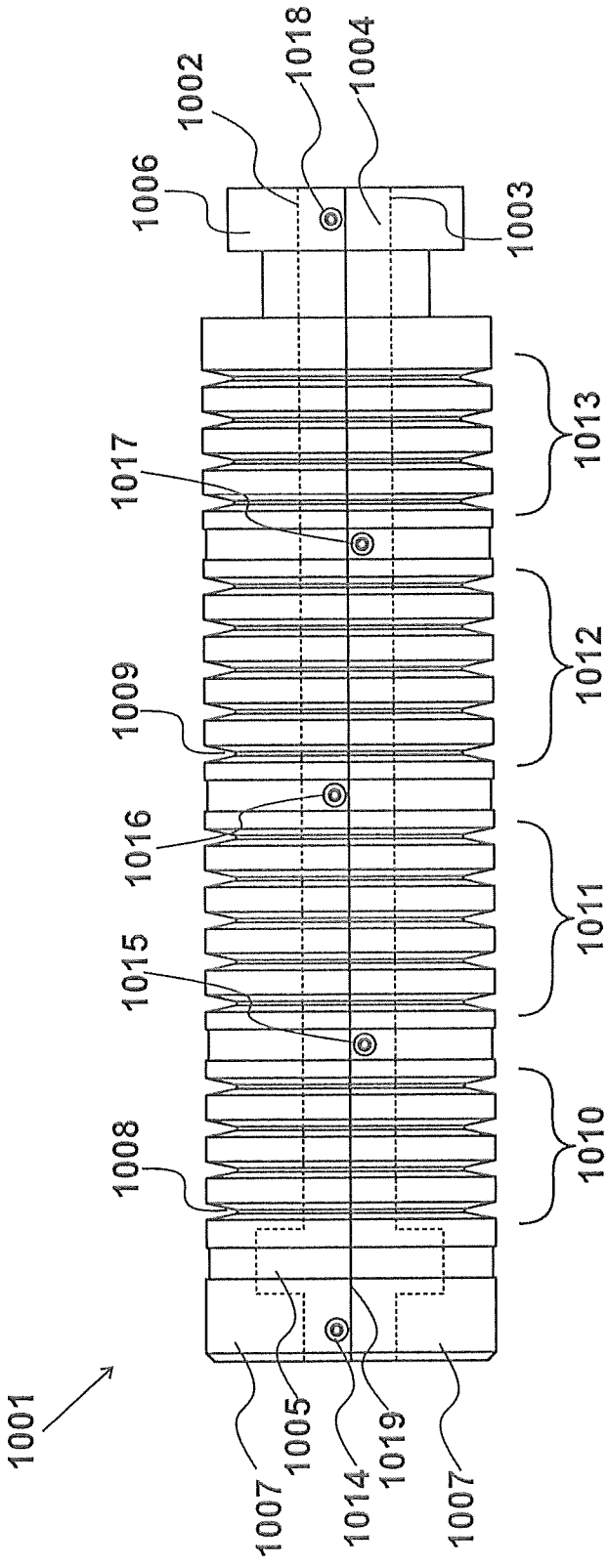

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Fig. 10

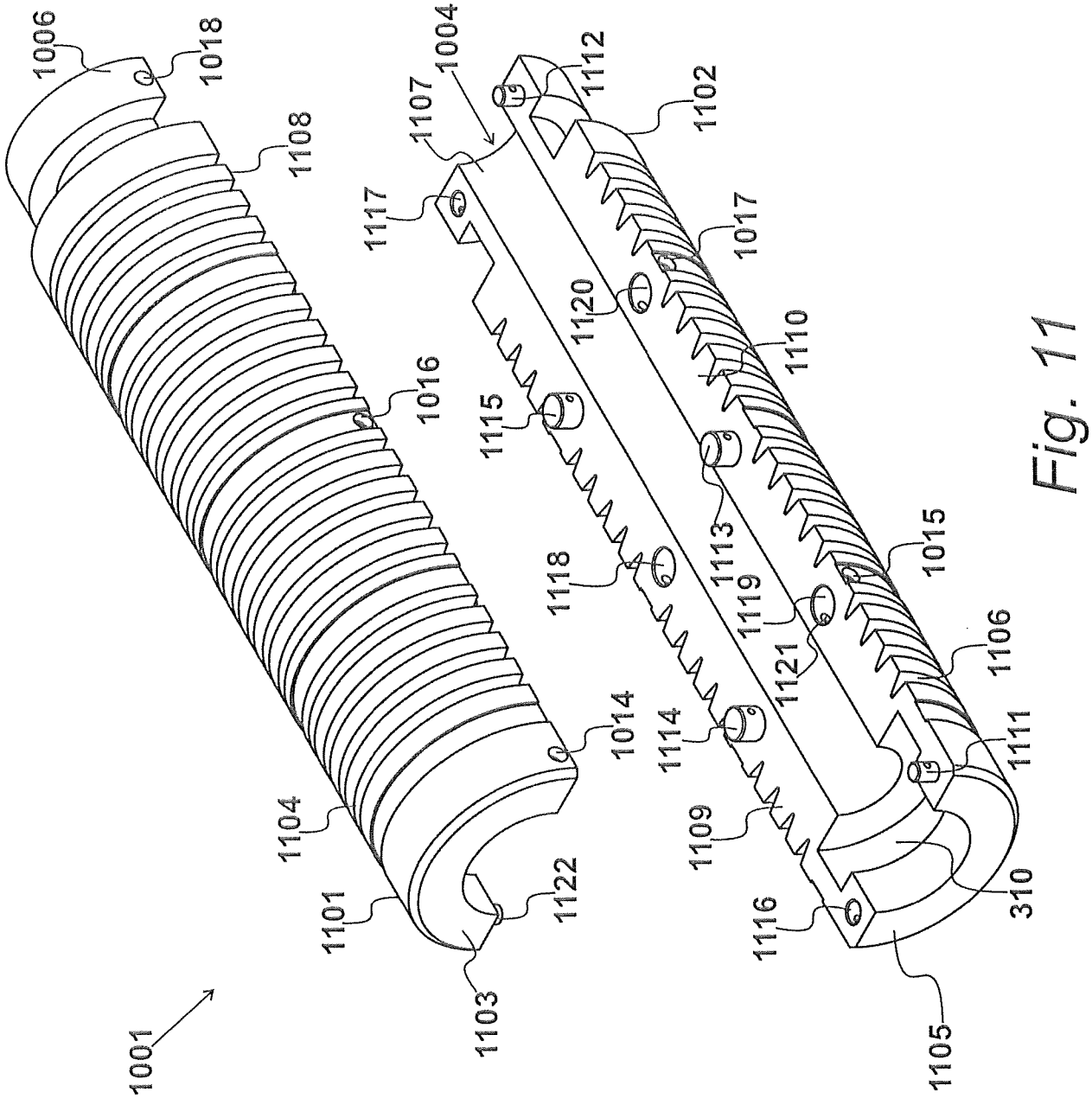

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Fig. 11

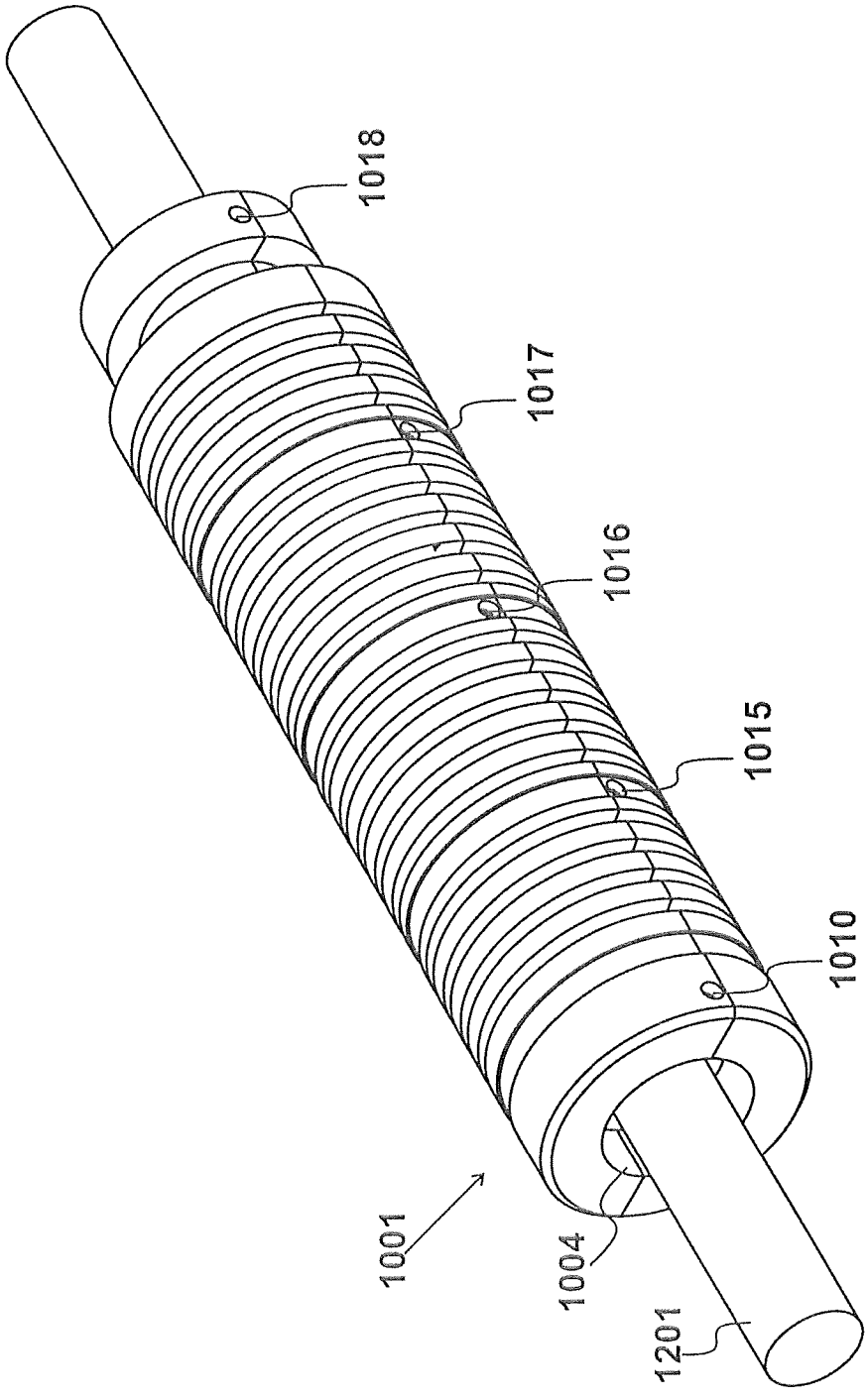


Fig. 12

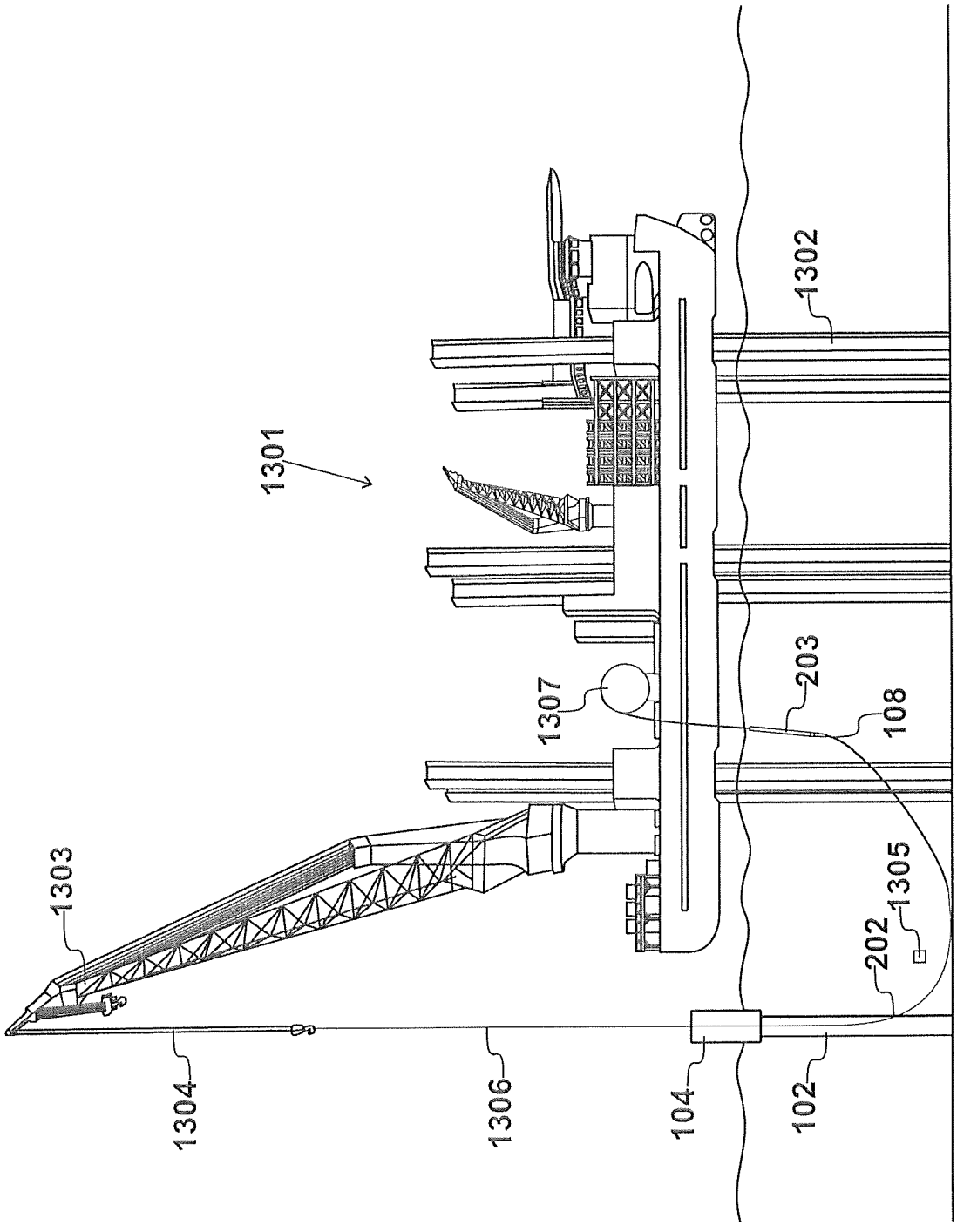


Fig. 13

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2021/000011

A. CLASSIFICATION OF SUBJECT MATTER
INV. H02G1/10 F16L57/02 H02G3/04 H02G9/02
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H02G F16L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

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Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	WO 2016/080827 A1 (LANKHORST ENGINEERED PRODUCTS B V [NL]) 26 May 2016 (2016-05-26) * snap connection elements 15, 16 *; figure 2	9,21

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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Date of the actual completion of the international search	Date of mailing of the international search report
19 April 2021	30/04/2021

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Ruppert, Christopher

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Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2021/000011

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	WO 2011/141494 A1 (SEAPROOF SOLUTIONS AS [NO]; BANG-ANDRESEN HENRIK [NO] ET AL.) 17 November 2011 (2011-11-17) abstract; claims 7-9; figures 1-3 -----	23-26

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
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