(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
31 October 2019 (31.10.2019)

WIPO | PCT

(10) International Publication Number
WO 2019/207031 A1

(51) International Patent Classification:
F16L 11/08 (2006.01) *B32B 1/08* (2006.01)
F16L 58/16 (2006.01)

(21) International Application Number:
PCT/EP2019/060592

(22) International Filing Date:
25 April 2019 (25.04.2019)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
PA201800184 26 April 2018 (26.04.2018) DK

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report (Art. 21(3))*

(54) **Title:** AN UNBONDED FLEXIBLE PIPE AND A METHOD FOR PRODUCING AN UNBONDED FLEXIBLE PIPE

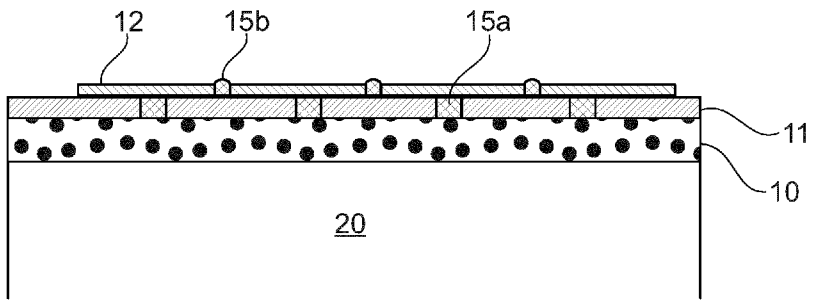

Fig. 5

(57) **Abstract:** The present invention relates to an unbonded flexible pipe for offshore 5 transport of fluid comprising oil and gas comprising an internal pressure sheath surrounded by an outer sheath, such that an annulus is formed between the internal pressure sheath and the outer sheath, and wherein one or more steel armour layers are located in the annulus between the internal pressure sheath and the outer sheath. The internal pressure sheath 10 comprises an extruded polymer liner wound with consecutive windings of metal and polymer tape. The metal tape has two substantially parallel metal tape side edges extending in the longitudinal direction of the metal tape and where a void is formed along these metal tape edges upon winding. The polymer tape has two substantially parallel polymer tape side edges 15 extending in the longitudinal direction of the polymer tape and where a void is formed along these polymer tape edges upon winding. At least a part of the voids are filled by a pliable filler material.

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AN UNBONDED FLEXIBLE PIPE AND A METHOD FOR PRODUCING AN UNBONDED FLEXIBLE PIPE

TECHNICAL FIELD

The present invention relates to unbonded flexible pipes for offshore transport of fluid comprising oil and gas.

BACKGROUND

Unbonded flexible pipes are extensively used in the oil industry e.g. for transport of hydrocarbons such as oil and gas. One example on such transport is conveying of hydrocarbons from a subsea installation to a vessel floating on the sea surface. The unbonded flexible pipe is terminated at each end in an end-fitting which connects the unbonded flexible pipe to the subsea installation and the vessel, respectively.

Unbonded flexible pipes of the present type are for example described in the standard "Recommended Practice for Flexible Pipe", ANSI/API 17 B, fifth Edition, May 2014, and the standard "Specification for Unbonded Flexible Pipe", ANSI/API 17J, fourth edition, May 2014. The unbonded flexible pipes usually comprise an internal pressure sheath – often referred to as an innermost sealing sheath or inner liner, which forms a barrier against the outflow of the fluid which is conveyed in the bore of the pipe, and a plurality of armor layers. Normally the pipe further comprises an outer protection layer, often referred to as the outer sheath, which provides mechanical protection of the armor layers. The outer protection layer may be a sealing layer sealing against ingress of sea water. In certain unbonded flexible pipes one or more intermediate sealing layers are arranged between armor layers. The different layers are terminated in the end-fitting, meaning that the layers are fastened and locked in the end-fitting by use of e.g. mechanical means, welding, or potting using e.g. a filled epoxy resin. Thus, the end-fitting forms

a transition between the unbonded flexible pipe and a connection on the vessel, on the subsea installation or between two pipes.

The armor layers usually comprise or consist of one or more helically wound elongated armoring elements, where the individual armor layers are not bonded to each other directly or indirectly via other layers along the pipe.

When the armor layers are wound at an angle larger than 55° relative to the pipe center axis, they are classified as pressure armor layers, whereas armor layers wound with an angle of less than 55° are classified as tensile armor layers. By using un-bonded wound elements, the pipe becomes bendable and sufficiently flexible to roll up for transportation. The unbonded flexible pipe may comprise a carcass which is an armor layer arranged on the inner side of the internal pressure sheath in the bore. The pipe also comprises one or more pressure armors and/or one or more tensile armors arranged on the outer side of the internal pressure sheath.

In this text, the term "unbonded" means that at least two of the layers including the armoring layers and polymer layers are not bonded to each other. In practice, the known pipe normally comprises at least two armor layers located outside the internal pressure sheath and optionally an armor structure, a carcass, located inside the internal pressure sheath.

The annular space or spaces outside the internal pressure sheath, which houses the steel armour layers are usually referred to as the annulus or annuli.

The flexible pipes may for example be applied for carrying the fluids between a hydrocarbon reservoir located under the seabed either to a junction point between subsea structures or from the seabed to a floating structure. The fluid may be a hydrocarbon fluid, such as natural gas or oil as well as water, CO_2 or a mixture hereof depending upon the nature of the hydrocarbon reservoir. The fluid may also be an injection fluid such as water, supercritical CO_2 or methanol.

In general, flexible pipes are expected to have a lifetime of about 20 years in operation.

Unbonded flexible pipes are e.g. used for the transport of oil and gas at large or intermediate sea depths. The mentioned construction is particularly well suited for the transport of oil and gas from subsea sources to installations at sea level where the oil and gas are being treated or forwarded for further processing such as for example by compression, filtering, separation, distillation and/or further treatment.

The armouring layers surrounding the internal pressure sheath may for example comprise one or more pressure armour layers comprising one or more armouring profiles or strips, which are wound around the internal pressure sheath at a large angle, e.g. larger than 80°, relative to the centre axis of the pipe. This or these pressure armour layers primarily compensate for radial forces in the pipe. The armouring layers surrounding the internal pressure sheath may also usually comprise one or more tensile armouring layers which are wound at a relative small angle, such as between 10° and 50°, relative to the centre axis of the pipe. This or these tensile armour layers primarily compensate for axial forces in the pipe. The armouring layers are typically made of steel. A typical unbonded flexible pipe is for example described in WO 00/36324.

To avoid prohibitively large radial deformations of the tensile armouring layers due to torsion, axial compression and/or bending of the pipe, a holding layer may be wound at a large angle around the tensile armouring layer(s). This armouring layer is usually of very flat profiles in the form of fibre reinforced polymeric tapes e.g. as described in US2010101675.

During operation water and gasses tend to diffuse from the bore of the pipe into the annulus or annuli of the pipe. Over time the diffused gasses may cause the pressure in the annulus to rise, which may lead to bust of the outer sheath. To prevent this, gas vent valves are normally mounted in the

termination of pipes, such that the gas pressure in the pipe annulus is relieved when significantly exceeding ambient pressure, as. e.g. described in API 17B, 5.2.4.

Ingress of gas and water into the annulus may result in simultaneous appearance of gas and condensed water on the exposed steel surfaces of the armour. This may lead to localized corrosion of the steel armour elements located in the annulus, eventually leading to premature failure of the pipe.

In order to mitigate corrosion of the armour layers attempts have been made to prevent aggressive gasses such as hydrogen sulphide and carbon dioxide from reaching the annulus. One strategy for preventing these gasses reaching the armour wires is described in US2011120583A. Herein the pressure sheath is filled with a reactive compound which reacts with diffusing gasses before they reach the annulus and thus the armour wires. Another strategy for preventing gasses from reaching the annulus is described in WO 05/028198 according to which an impermeable film is applied between the bore and the annulus.

WO16074681 discloses a method of installing an unbonded flexible pipe, wherein at least a part of the annulus is filled with a corrosion promoting liquid to thereby provide an even corrosion, which is less damaging to the pipe compared to localized corrosion.

US2011195208 discloses a method of protecting the armour layers by applying a boron holding grease or fluid or oil for the purpose of increasing acid resistance and/or corrosion resistance of the armour element.

FR3046208 discloses a flexible pipe in which a barrier layer of metal strips is provided between the internal pressure sheath and the annulus of the pipe. A polymer material is also inserted in the barrier layer.

However, even in flexible pipes with a barrier layer, corrosive gases may diffuse through minor local leaks in the barrier into the annulus of pipe and

cause local corrosion of the armour layers, which eventually may lead to failure of the pipe.

DISCLOSURE OF THE INVENTION

An object of the present invention is to provide a flexible pipe in which the risk of local corrosion of the armour layers is reduced.

The invention also provides a solution in which the risk of undesired pressure build-up in the annulus of the flexible pipe is reduced.

A conventional unbonded flexible pipe always comprises an internal pressure sheath, which forms the bore in which the fluid to be transported is conveyed; the internal pressure sheath may be reinforced with a carcass located in the bore of the pipe. Thus, the internal pressure sheath is substantially fluid tight, meaning that no liquids or gases should be able to pass through the internal pressure sheath. However, as the internal pressure sheath frequently comprises a polymer material, such as polyethylene or polyvinylidene diflouride, gases are during time able to pass through by diffusion, i.e. the internal pressure sheath is not entirely gas tight. The diffusing gasses may be water (H_2O), carbon dioxide (CO_2), hydrogen sulfide (H_2S) and methane (CH_4) as well as smaller amounts of higher hydrocarbons. When the gases diffuse through the internal pressure sheath, the gasses enter the annulus formed between the internal pressure sheath and the outer sheath and may cause corrosion of the armour layers in the annulus. Even if the pipe is provided with a barrier layer between the internal pressure sheath and the annulus, gasses may diffuse through tiny leaks in the barrier layer and cause local corrosion. This problem is hugely magnified if the barrier layer contains closed channels, as a leaking from such a channel may lead to local corrosion from leaked gas collected along the closed channel.

The local corrosion in the annulus may eventually cause failure of the pipe.

Thus, in one aspect the present invention relates to an unbonded flexible pipe for offshore transport of fluid comprising oil and gas comprising an internal pressure sheath surrounded by an outer sheath, such that an annulus is formed between the internal pressure sheath and the outer sheath, and wherein one or more steel armour layers are located in the annulus between the internal pressure sheath and the outer sheath. The internal pressure sheath comprises an extruded polymer liner wound with consecutive windings of metal and polymer tape. The metal tape has two substantially parallel metal tape side edges extending in the longitudinal direction of the metal tape and where a void is formed along these metal tape edges upon winding. The polymer tape has two substantially parallel polymer tape side edges extending in the longitudinal direction of the polymer tape and where a void is formed along these polymer tape edges upon winding. At least a part of the voids are filled by a pliable filler material.

The flexible pipe comprises a bore formed by the internal pressure sheath. The pipe also comprise a centre axis and the internal pressure sheath is substantially symmetrical around the centre axis.

The internal pressure sheath according to the invention comprises an extruded polymer liner, which on the outside is wound with consecutive windings of metal and polymer tape, the windings may be alternately stacked metal and polymer tape. Thus, the extruded polymer liner forms the bore of the pipe.

The terms "inside" and "outside" a layer of the pipe is used to designate the relative distance to the centre axis of the pipe, such that "inside a layer" means the area encircled by the layer with a shorter radial distance to the pipe axis than the layer and "outside a layer" means the area not encircled by the layer and not contained by the layer, i.e. with a longer radial distance to the axis.

Both the metal tape and polymer tape comprises side edges and when the tape is wound with consecutive windings, voids are formed in interspaces between neighboring side edges. The voids may be between side edges of the metal tape and between side edges of the polymer tape. Voids may also be formed between a side edge of a metal tape and a side edge of a polymer tape.

When the tapes, metal and polymer tape, are helically wound around the pipe, the voids form a hollow channel and closed channel extending around the pipe in a helical pattern. Gasses may be able to collect in the hollow channel and accidental leak into the annulus of the pipe. According to the invention the hollow channel is filled with the pliable filler material, such that at least at part of the hollow channel is filled.

In an embodiment the polymer tape is wound on the outside of the extruded polymer liner such that the polymer tape forms a layer on the extruded polymer liner, and the metal tape is wound on the outside of this layer of polymer tape. In this embodiment there is substantially no physical contact between the extruded polymer liner and the metal tape. The metal may also be wound on the outside of the extruded polymer liner such that there is physical contact between the extruded polymer liner and the metal tape. The metal tape and the polymer tape may also be wound in such a way that there is contact between the extruded polymer liner and both the metal tape and the polymer tape. Winding is also possible using a tape cut from a multilayered structure of metal and polymer.

The metal tape and the polymer tape may be wound around the extruded polymer liner as alternately stacked layers.

The longitudinal direction of the tape is the direction where the tape has its longest extension. The width of the tape is substantially perpendicular to the longitudinal direction. When the tape is wound on the pipe the tape will form

a helix around the pipe and the longitunal direction of the tape will generally not be parallel with the centre axis of the pipe.

The term "substantially" should herein be taken to mean that ordinary product variances and tolerances are comprised.

The polymer material of the polymer tape is preferably polymer material selected from the group consisting of polyolefins, such as polyethylene and polypropylene; polyamide, such as poly amide-imide, polyamide-11 (PA-11) and polyamide-12 (PA-12); polyimide (PI); polyurethanes; polyureas; polyesters; polyacetals; polyethers, such as polyether sulphone (PES); polyoxides; polysulfides, such as polyphenylene sulphide (PPS); polysulphones, such as polyarylsulphone (PAS); polyacrylates; polyethylene terephthalate (PET); polyether-ether-ketones (PEEK); polyvinyls; polyacrylonitrils; polyetherketoneketone (PEKK); copolymers of the preceding; fluorous polymers such as polyvinylidene diflouride (PVDF), homopolymers and copolymers of vinylidene fluoride ("VF2 "), homopolymers and copolymers of trifluoroethylene ("VF3 "), copolymers and terpolymers comprising two or more different members selected from the group consisting of VF2, VF3, chlorotrifluoroethylene, tetrafluoroethylene, hexafluoropropene, and hexafluoroethylene.

The material of the metal tape is preferably selected from a metal foil, and preferably the metal of the foil is selected from carbon steel, stainless steel, gold, aluminum alloys, titanium alloys, copper alloys and nickel alloys. The tapes may either be plain polymer tape, plain metal tape or tapes coated or laminated with other metals, ceramics or organic coatings. Barrier layers made of such metals are known to provide substantially gas-tight barriers.

The extruded polymer liner is preferably made from polymer material selected from the group consisting of polyolefins, such as polyethylene and polypropylene; polyimide, polyamide, such as polyamide-11 (PA-11) and polyamide-12 (PA-12); polyurethanes; polyureas; polyesters; polyacetals;

polyethers, such as polyether sulphone (PES); polyoxides; polysulfides, such as polyphenylene sulphide (PPS); polysulphones, such as polyarylsulphone (PAS); polyacrylates; polyethylene terephthalate (PET); polyether-ether-ketones (PEEK); polyvinyls; polyacrylonitrils; polyetherketoneketone (PEKK); copolymers of the preceding; fluorous polymers such as polyvinylidene diflouride (PVDF), homopolymers and copolymers of vinylidene fluoride ("VF2 "), homopolymers and copolymers of trifluoroethylene ("VF3 "), copolymers and terpolymers comprising two or more different members selected from the group consisting of VF2, VF3, chlorotrifluoroethylene, tetrafluoroethylene, hexafluoropropene, and hexafluoroethylene.

The outer sheath of the pipe is preferably made from polymer material, such as polyethylene, polypropylene, polyamide, polyvinyldiene fluoride or a combination of such materials. Preferably, the outer sheath is an extruded layer.

It is well known in the art of flexible pipes how to provide an extruded layer in the flexible pipe.

The pliable filler material is a material, which is flexible and capable of adaptively filling out the voids formed between neighboring windings of tape. The pliable filler is capable of adapt to the voids e.g. by deformation.

Upon bending of the pipe, the formed void or channel will locally alter its dimension, reducing the void side on the concave side of the bend pipe and increasing the void volume on the convex side of the bed pipe, such that the entire total void volume will remain substantially constant. During bending of the pipe, the pliable filler should transfer through the channel from the concave side of the pipe to the convex side of the pipe. Thus, the pliable material is softer than the material of the polymer tape, typically more than 3 times softer than the polymeric tape material.

Consequently, in an embodiment the hardness of the polymer tape material is more than 3 times harder than the pliable filler material.

When the pliable filler is based on rubber or polymer material, the pliable filler material has a hardness below 90 shore OO (measured with type OO durometer according to ASTM D2240 using the shore OO scale). The pliable filler material may have a hardness in the range 5 to 90 shore OO.

To obtain good filling properties of the pliable filler material the compressive modulus of the polymer tape in an embodiment is as least two times larger than the compressive modulus of the pliable filler material.

In an embodiment the pliable filler material is made from polymer material selected from natural rubber, latex, synthetic rubber, thermoplastic polymer and elastomer polymer.

The pliable filler material is may be chosen from organic solids and in an embodiment the pliable filler material selected is from petroleum jelly, grease, vax, bitumen or any combinations thereof optionally filled with solid particles, fibres and/or additives.

The solid particles and/or additives can be selected from silicates, oxides, polymers and/or metal, such as granular metallic particles having an electrode potential, which is lower than the metal of the metallic armouring layer. Examples of silicates include clay silicates selected from kaolinite, such as dickite, halloysite, nacrite and serpentine; smectite, such as pyrophyllite, talc, vermiculite, sauconite, saponite, nontronite, hectorites (magnesiosilicates) and montmorillonite (bentonite); Illite; or chlorite.

The solid particles may also comprise chemically active products which may neutralize acidic gasses such as metal oxides selected from Fe_2O_3, PbO, ZnO, NiO, CoO, CdO, CuO, SnO_2, MoO_3, Fe_3O_4, Ag_2O, CrO_2, CrO_3, Cr_2O_3, TiO, TiO_2 or Ti_2O_3, and/or such as alkaline and alkaline-earth oxides selected from of CaO, $Ca(OH)_2$ or MgO.

Moreover, the solid particles may comprise chemically active products selected from the group consisting of metal carbonates, metal chlorides, the

hydrated forms of metal carbonates and metal chlorides, the hydroxylated forms of metal carbonates and metal chlorides, alkaline carbonates, alkaline-earth carbonates, alkaline chlorides, alkaline-earth chlorides, the hydrated forms of alkaline carbonates, alkaline-earth carbonates, alkaline chlorides, alkaline-earth chlorides and the hydroxylated forms of alkaline carbonates, alkaline-earth carbonates, alkaline chlorides, and alkaline-earth chlorides.

In an embodiment the pliable filler material is a cross-linked gel or comprises cross-linked gel particles. Cross-linked gels may provide a good filling and form a barrier for diffusing gasses in the pipe.

The pliable filler material should be applied in an amount to substantially fill the voids in the barrier layer and in an embodiment the amount of the pliable filler material is the range 1 to 40 cm^3 per meter length of the flexible pipe, such as in the range 1 to 30 cm^3 per meter length of the flexible pipe, preferably in the range 1 to 20 cm^3 per meter length of the flexible pipe.

The pliable filler material should obtain its filling properties at the operating temperatures of the flexible pipe in an embodiment the pliable filler material is pliable in a temperature range from about 0 to 140 ^oC. The pliable filler material should not experience any phase transformations effecting its function in this temperature range.

Preferably the pliable filler material does not dissolve in water and in an embodiment the pliable filler material has solubility in water of less than 0.1g/l, such than less than 0.001g/l, and preferably the pliable filler material is hydrophobic.

In an embodiment the polymer tape is adhered to the metal tape. This embodiment may facilitate simple and efficient winding of the tapes onto the extruded polymer liner.

The polymer tape may be bonded to the metal tape by means of physical or chemical bonding. Thus, in an embodiment the polymer tape is bonded to the

metal tape by gluing using an adhesive. Alternatively, the polymer tape may be bonded to the metal tape by a chemical reaction between the metal tape and the polymer material of the polymer tape. Yet another possibility is to coat the metal tape with a polymer, which is compatible with the polymer material of the polymer tape. Thus, the polymer coating and the polymer tape may fuse together when the coated the metal tape is covered with the polymer tape.

Both a physical and chemical bonding will provide a good adhesion between the metallic tape and the polymer tape.

The metal tape is conveniently bonded the polymer tape with its entire surface facing the polymer tape, i.e. the surface of the metal tape facing the polymer tape is bonded to the polymer tape in its entire extension. Thus, such a bonding is a coherent bonding and not a pointwise bonding. The coherent bonding is an interface bonding between two surfaces in which all contacting surfaces are bonded. Thus, a very strong bonding can be formed between the metal tape and the polymer tape.

The bonding property may be measured by a peel test for tearing the metal tape and the polymer tape from each other, e.g. using ASTM D3330. Preferable the bonding has a peel strength using ASTM D3330 of at least 300 N/m, such as at least 500 N/m, such as at least 700 N/m.

The metal tape should be relatively easy to handle and wind around the extruded polymer liner and in an embodiment the metal tape has a width in the range 1 to 10 cm, such as a width in the range 1 to 15 cm, and a thickness in the range 0.05 cm to 0.5 cm, such as a thickness in the range 0.01 cm to 0,8 cm.

Also the polymer tape should be relatively easy to handle and wind around the extruded polymer liner and in an embodiment the polymer tape has a

width in the range 1 to 10 cm, such as a width in the range 1 to 15 cm, and a thickness in the range 0.1 cm to 2 cm, such as a thickness in the range 0.1 cm to 3 cm.

Preferably, the applied metal tape and polymer tape have the same width, while the tapes may have different thickness.

The metal tape and the polymer tape may be wound with the same or different winding angles and in an embodiment the metal tape is wound with a winding angle in the range 70 to 89 degrees.

In an embodiment the polymer tape is wound with a winding angle in the range 70 to 89 degrees.

Preferably, the metal tape and the polymer tape is wound in the same direction and angle, however, for some applications the tapes are crosswound.

The flexible pipe comprises at least one armour layer in the annulus of the pipe.

In an embodiment the flexible pipe comprise at least one pressure armour layer. The pressure armour can be made from metallic elongate members and in an embodiment the pressure armour comprises elongate members wound around the pipe with a winding angle of 55 to 89 degrees, such as up to 89.8 degrees in respect of the axis of the pipe.

In an embodiment flexible pipe comprise at least one tensile armour layer.

Preferably the tensile armour is made from metallic elongate members where the tensile armour the elongate members are wound around the pipe with a

winding angle of 25 to 55 degrees, such as up to 65 degrees in respect of the axis of the pipe.

In an embodiment the flexible pipe comprise a carcass. The carcass is located in the bore of the pipe and protects the internal pressure sheath against sudden pressure drop in the fluid transported in the pipe. The carcass is preferably manufactured from metallic elongate members and the elongate members are wound with a winding angle of about 70 to about 89 degrees in respect of the axis of the pipe to form a tubular member in the bore of the pipe.

The invention also relates to a method for producing an unbonded flexible pipe for offshore transport of fluid comprising oil and gas. The method comprises the step of providing an internal pressure sheath surrounded by an outer sheath such that an annulus is formed between the internal pressure sheath and the outer sheath, and further providing one or more steel armour layers in the annulus between the internal pressure sheath and the outer sheath. According to the method the internal pressure sheath is provided by extruding a polymer liner and wind metal tape and polymer tape around the extruded polymer liner, wherein said metal tape having two substantially parallel metal tape side edges extending in the longitudinal direction of the metal tape and where a void is formed along these metal tape edges upon winding, said polymer tape having two substantially parallel polymer tape side edges extending in the longitudinal direction of the polymer tape and where a void is formed along these polymer tape edges upon winding. The method comprises the step of filling at least a part of these voids with a pliable filler material.

In an embodiment of the method the metal tape, the polymer tape and the pliable filler material are applied onto the surface of the extruded polymer liner in the same winding. The method provides a simple and fast production of the flexible pipe

For the purpose of providing optimum conditions during production the method provides an embodiment where the metal tape, the polymer tape and the pliable filler material is applied onto the surface of the extruded polymer liner at a temperature in the range 18 to 80 °C.

As mentioned the unbonded flexible pipe may comprise several layers. And further layers may be present in the pipe, the layers may be applied as tape or extruded layers, and serve as e.g. insulating layers, antiskid layers, antifriction layers or intermediate layers.

DETAILED DESCRIPTION OF THE INVENTION

The invention will now be described in further details with reference to embodiments shown in the drawing in which:

Figure 1 shows an unbonded flexible pipe;

Figure 2 shows the principle of formation of an internal pressure sheath according to the invention;

Figure 3 shows metal tape and polymer tape layer according to the invention;

Figure 4 shows an embodiment of an internal pressure sheath according to the invention;

Figure 5 shows an embodiment an internal pressure sheath according to the invention; and

Figure 6 shows an embodiment of an internal pressure sheath according to the invention.

The figures are not accurate in every detail but only sketches intended to the show the principles of the invention. Details which are not a part of the invention may have been omitted. In the figures the same reference numbers are used for the same parts.

Figure 1 shows a conventional unbonded flexible pipe 1. The pipe 1 comprises from the inside and outwards a carcass 2 to support the internal pressure sheath 3. The internal pressure sheath 3 is surrounded by a pressure armour 4 and a first tensile armour 5 and a second tensile armour 6. The outermost part of the pipe 1 is the outer sheath 7. Between the internal pressure sheath 3 and the outer sheath 7 is formed an annulus in which the armour layers are located.

Figure 2 shows the formation of an internal pressure sheath 30 according to the invention. The internal pressure sheath 30 comprises an extruded polymer liner 10 which is wound with polymer tape 11 and metal tape 12. The polymer tape 11 is adhered to the metal tape 12, thereby forming a single tape 13 to be wound around the extruded polymer liner 10.

Figure 3 shows the tape 13 wound around the extruded polymer liner 10 in figure 2. The tape 13 comprises a polymer tape 11 and a metal tape which are glued together by a layer of glue 14. Thus, the tape 13 comprising the polymer tape 11 and the metal tape 12, can easily be wound around the extruded polymer liner 10.

Figure 4 shows the internal pressure sheath 30 comprising the extruded polymer liner 10 on which the polymer tape 11 and the metal tape 12 are wound. The voids between consecutive windings are filled with a pliable filler material 15.

In figure 4 the bore of the pipe are indicated by reference number 20.

Figure 5 shows an embodiment of the internal pressure sheath 30 in which the polymer tape 11 and the metal tape 12 are wound offset on the extruded

polymer liner 10. The voids formed between the windings of the polymer tape 11 are filled with a pliable filler material 15a, and the voids formed between the windings of the metal tape 12 are filled with pliable filler material 15b. The pliable filler materials 15a and 15b are identical in this embodiment.

Figure 6 shows an embodiment in which the metal tape 12 is substantially S-shaped. The polymer tape 11 is also S-shaped and the voids formed between consecutive windings are filled with a pliable filler material 15.

The extruded polymer liner 10, the polymer tape 11, the metal tape 12, and the pliable filler material 15 forms an internal pressure sheath which is surrounded by a pressure armour 21.

As mentioned the figures are not accurate in every detail but only sketches intended to the show the principles of the invention. Thus, the unbonded flexible pipes according to the present invention may comprise several other layers and features which are not shown in the figures. Such features may be insulating layers and intermediate layers, end-fittings etc.

CLAIMS

1. An unbonded flexible pipe for offshore transport of fluid comprising oil and gas comprising

an internal pressure sheath surrounded by

an outer sheath

such that an annulus is formed between the internal pressure sheath and the outer sheath, wherein one or more steel armour layers are located in the annulus between the internal pressure sheath and the outer sheath, and

wherein the internal pressure sheath comprises

an extruded polymer liner wound with

consecutive windings of metal and polymer tape,

said metal tape having two substantially parallel metal tape side edges extending in the longitudinal direction of the metal tape and where a void is formed along these metal tape edges upon winding, said polymer tape having two substantially parallel polymer tape side edges extending in the longitudinal direction of the polymer tape and where a void is formed along these polymer tape edges upon winding, wherein at least a part of these voids are filled by a pliable filler material.

2. An unbonded flexible pipe according to claim 1, wherein the consecutive windings of metal and polymer tape are alternately stacked.

3. An unbonded flexible pipe according to claim 1 or 2, wherein the compressive modulus of the polymer tape is as least two times larger than the compressive modulus of the pliable filler material.

4. An unbonded flexible pipe according to anyone of the claims 1 to 3, wherein the pliable filler material is made from polymer material selected

from natural rubber, latex, synthetic rubber, silicone rubber, thermoplastic polymer and elastomer polymer.

5. An unbonded flexible pipe according to anyone of the claims 1 to 3, wherein the pliable filler material is selected from petroleum jelly, grease, vax, bitumen or any combinations thereof optionally with solid particles and/or additives.

6. An unbonded flexible pipe according to anyone of the claims 1 to 3, wherein the pliable filler material is a cross-linked gel or comprises cross-linked gel particles.

7. An unbonded flexible pipe according to anyone of the preceding claims, wherein amount of the pliable filler material is the range 1 to 40 cm^3 per meter length of the flexible pipe, such as in the range 1 to 30 cm^3 per meter length of the flexible pipe, preferably in the range 1 to 20 cm^3 per meter length of the flexible pipe.

8. An unbonded flexible pipe according to anyone of the preceding claims, wherein the pliable filler material is pliable in a temperature range of about 0 to 140 ^oC

9. An unbonded flexible pipe according to anyone of the preceding claims, wherein the pliable filler material has solubility in water of less than 0.1g/l.

10. An unbonded flexible pipe according to anyone of the preceding claims, wherein the polymer tape is adhered to the metal tape.

11. An unbonded flexible pipe according to anyone of the preceding claims, wherein the metal tape has a width in the range 1 to 10 cm, and a thickness in the range 0.05 cm to 0.5 cm.

12. An unbonded flexible pipe according to anyone of the preceding claims, wherein the polymer tape has a width in the range 1 to 10 cm, and a thickness in the range 0.1 cm to 2 cm.

13. An unbonded flexible pipe according to anyone of the preceding claims, wherein the metal tape is wound with a winding angle in the range 70 to 89 degrees

14. An unbonded flexible pipe according to anyone of the preceding claims, wherein the polymer tape is wound with a winding angle in the range 70 to 89 degrees

15. An unbonded flexible pipe according to anyone of the preceding claims, wherein flexible pipe comprise at least one pressure armour layer.

16. An unbonded flexible pipe according to anyone of the preceding claims, wherein flexible pipe comprise at least one tensile armour layer.

17. An unbonded flexible pipe according to anyone of the preceding claims, wherein flexible pipe comprise a carcass.

18. A method for producing an unbonded flexible pipe for offshore transport of fluid comprising oil and gas, said method comprising

providing an internal pressure sheath surrounded by

an outer sheath

such that an annulus is formed between the internal pressure sheath and the outer sheath, and providing one or more steel armour layers in the annulus between the internal pressure sheath and the outer sheath,

wherein the internal pressure sheath is provided by

extruding a polymer liner

and wind metal tape and polymer tape around the extruded polymer liner,

wherein said metal tape having two substantially parallel metal tape side edges extending in the longitudinal direction of the metal tape and where a void is formed along these metal tape edges upon winding, said polymer tape

having two substantially parallel polymer tape side edges extending in the longitudinal direction of the polymer tape and where a void is formed along these polymer tape edges upon winding, said method comprises the step of filling at least a part of these voids with a pliable filler material.

19. A method according to claim 18, wherein the metal tape, the polymer tape and the pliable filler material are applied onto the surface of the extruded polymer liner in one winding.

20. A method according to claim 18 or 19, wherein the metal tape, the polymer tape and the pliable filler material is applied onto the surface of the extruded polymer liner at a temperature in the range 18 to 80 ^{o}C.

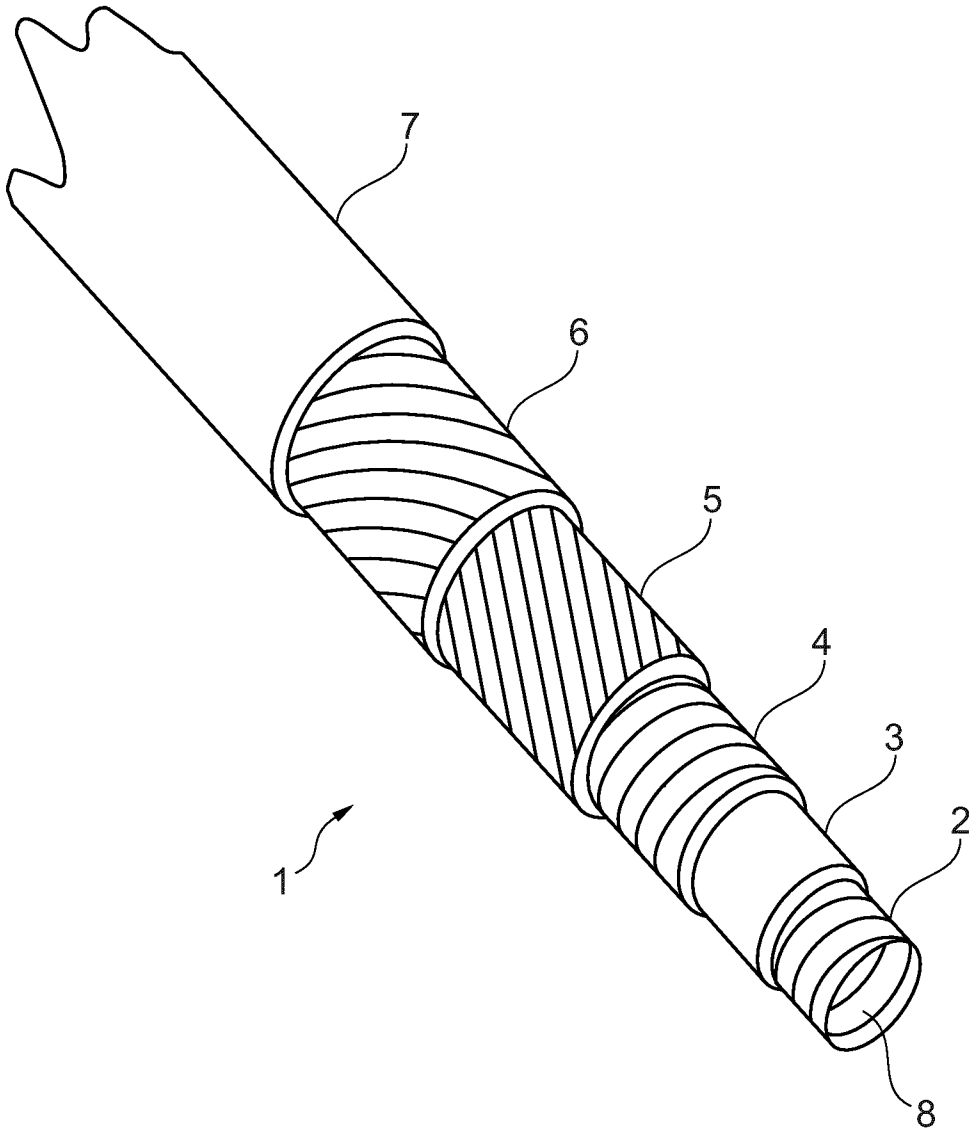

Fig. 1

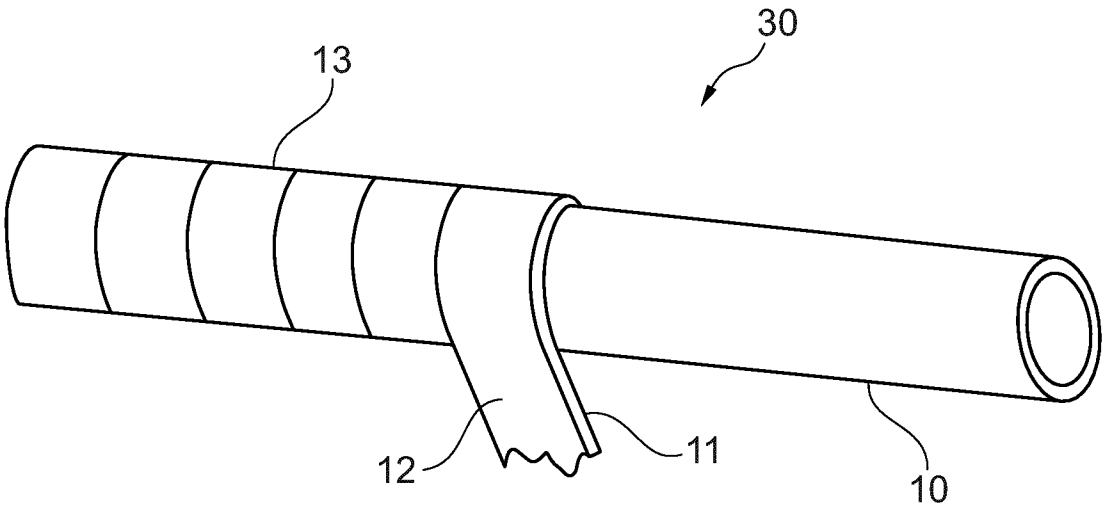

Fig. 2

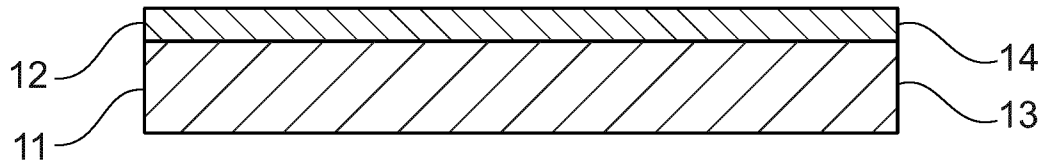

Fig. 3

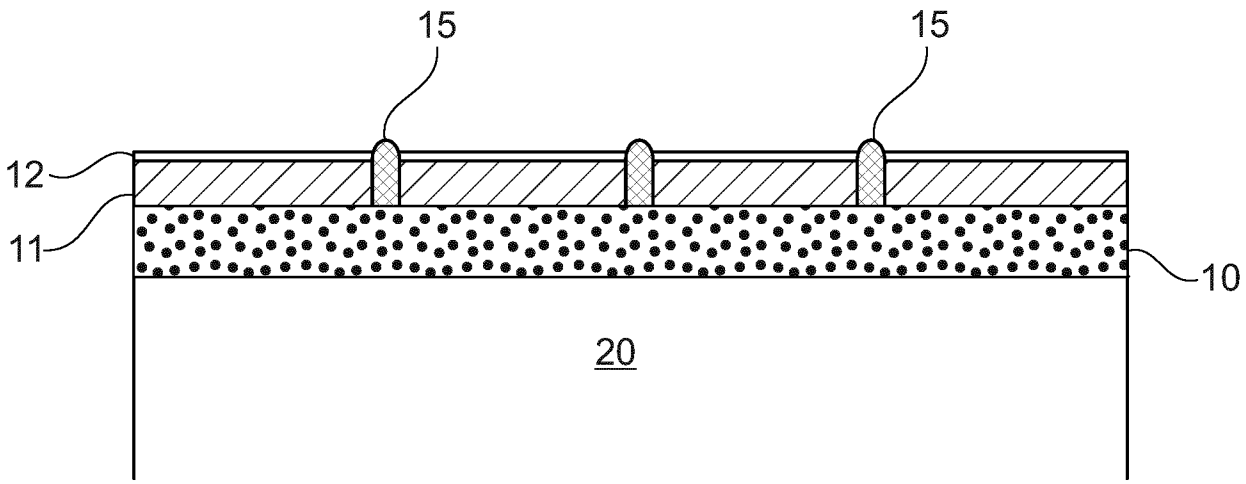

Fig. 4

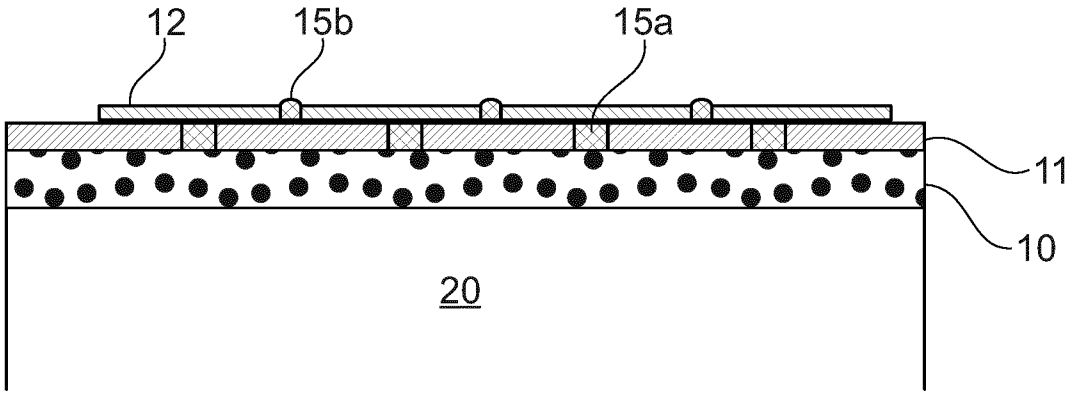

Fig. 5

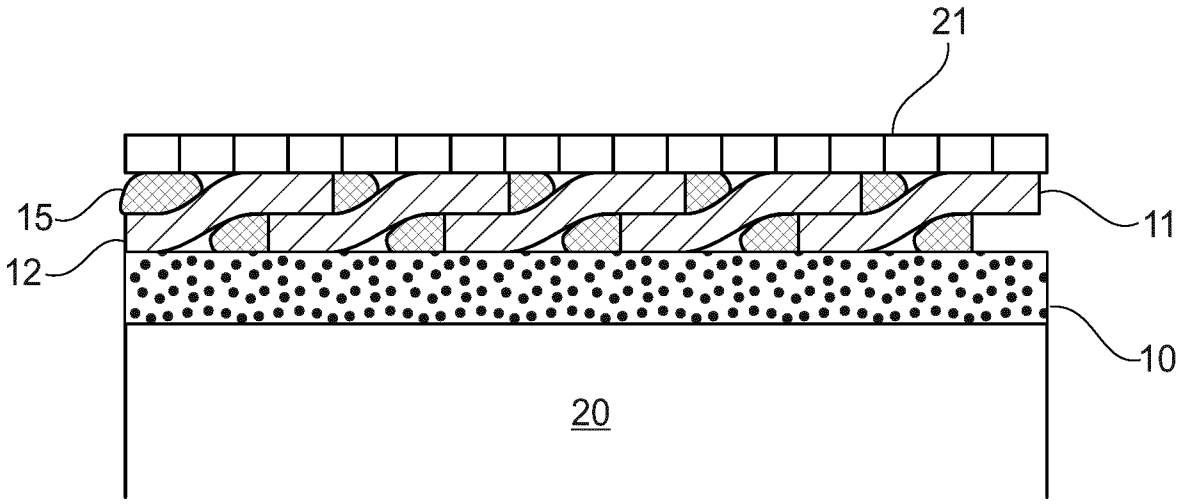

Fig. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2019/060592

A. CLASSIFICATION OF SUBJECT MATTER
INV. F16L11/08 F16L58/16 B32B1/08
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)
F16L B29D B32B

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	FR 3 046 208 A1 (IFP ENERGIES NOW [FR]; TECHNIP FRANCE [FR]) 30 June 2017 (2017-06-30) cited in the application page 3, line 23 - line 25 page 6, line 22 - line 23 page 8, line 7 - line 24 page 10, line 2 - line 23 figures	1-20
X	US 4 706 713 A (SADAMITSU KAZUO [JP] ET AL) 17 November 1987 (1987-11-17) column 3, line 7 - column 4, line 53; figures	1-20
X	WO 2017/211842 A1 (TECHNIP FRANCE [FR]) 14 December 2017 (2017-12-14) page 5, line 34 - page 6, line 7; figures	1-20

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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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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
8 July 2019	17/07/2019

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	dall'Amico, Mauro

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

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2019/060592

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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INTERNATIONAL SEARCH REPORT

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International application No
PCT/EP2019/060592

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