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(54) Title: UMBILICAL

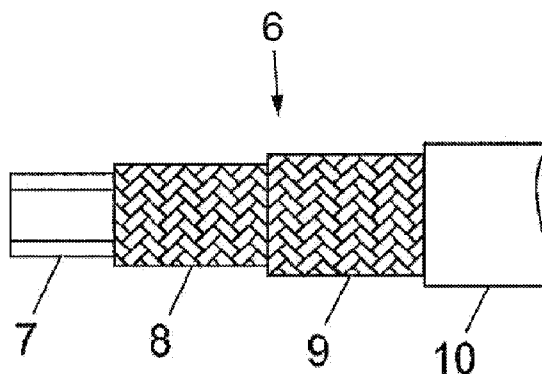


Fig. 2

(57) Abstract: A subsea flexible umbilical comprising a plurality of umbilical components, at least one umbilical component comprising a reinforced hose having a liner and one or more reinforcing layers, at least one reinforcing layer formed with Stretch Broken Carbon Fibre (SBCF) yarns. The umbilical achieves the benefit of the improved mechanical properties of SBCF yarns discussed, whilst avoiding any increase in overall weight of the umbilical.



Umbilical

The present invention relates to a subsea flexible umbilical for use in the offshore
5 production of hydrocarbons, including for use in deep water applications.

An umbilical for use in the offshore production of hydrocarbons generally comprises
a group of one or more types of elongated active umbilical components, such as
electrical cables, optical fibre cables, steel pipes and/or hoses; all cabled together
10 for flexibility, over-sheathed, and when applicable, armoured for mechanical
strength. Umbilicals are typically used for transmitting power, signals,
hydrocarbons, and/or working fluids (for example for fluid injection, hydraulic
power, gas release, etc.) to and from a subsea installation.

15 The umbilical cross-section is generally circular, the elongated elements being
wound together either in a helical or in a S/Z pattern. In order to fill the interstitial
voids between the various umbilical elements and to obtain the desired
configuration, filler components may be included within the voids.

20 ISO 13628-5 "Specification for Subsea Umbilicals", provides standards for the design
and manufacture of such umbilicals.

Subsea umbilicals are now being installed at increasingly deeper water depths,
commonly being deeper than 2000m. Such umbilicals therefore have to be able to
25 withstand the increasingly severe loading conditions during their installation and
their service life.

Meanwhile, to overcome the problem of conveying increasingly aggressive or
corrosive hydrocarbons through umbilicals, it is known to use one or more fully
30 metal tubes or metal tubing, which are able to withstand the corrosive properties of
the liquid or gaseous products being conveyed, whilst providing the mechanical
strength for the loading conditions. Such tubes are commonly made of stainless

steel such as duplex or super duplex grades for example. However, the use of metallic tubes or tubing obviously increases the overall weight of the subsea umbilical, especially during laying at increasingly deeper water depths, which therefore requires increasing reinforcement in the pipeline to support the increased loading. As the weight of the umbilical increases, more of the total stress capacity of the umbilical must be devoted to tensioning stresses during laying, so that less of the total stress capacity is available for any bending stresses.

In addition, heavier umbilicals require more robust handling equipment, such as winches, spools, clamps, tensioners etc. Any increase in the use of metallic tubes or tubing also decreases the flexibility of the umbilical, whilst it is still desired that the umbilical has sufficient flexibility to be 'reelable' with conventional equipment etc. Reeling is the most convenient form of pipeline transportation and laying, generally from a reel in the reel-laying method known in the art.

Another well-known way to convey fluids in umbilicals is to use thermoplastic hoses. Thermoplastic hoses typically comprise a thermoplastic polymeric liner covered by one or more reinforcement layers being covered by a protective polymer sheath. The purpose of the reinforcement layer(s) is to contain the pressure in the liner. Each reinforcement layer generally comprises high tenacity organic fibres such as aramid fibres. These fibres are generally applied in the form of woven or interwoven braid, with braiding angles ranging from 30° to 70° depending on the application and the desired properties of the hose.

These thermoplastic hoses are more flexible and lighter than the steel tubes. However, in severe conditions combining high pressure and high dynamic loading, thermoplastic hoses can have performance limitations.

It is an object of the present invention to provide a subsea, flexible umbilical that overcomes at least one of the above problems.

Thus, according to one aspect of the present invention, there is provided a subsea flexible umbilical comprising a plurality of umbilical components, at least one umbilical component comprising a reinforced hose having a liner and one or more reinforcing layers, at least one reinforcing outer layer formed with Stretch Broken Carbon Fibre (SBCF) yarns.

In this way, the umbilical of the present invention achieves the benefit of the improved mechanical properties of SBCF yarns discussed below, whilst avoiding any increase in overall weight of the umbilical.

The liner may be any suitable material including thermoplastics, elastomerics and/or fluoropolymers, or various combinations thereof, as well as metals, such as, individually or in combination, steel, copper or stainless steel.

Preferably the liner is manufactured by extrusion of a thermoplastic polymer such as polyethylene, polyamide or polyvinylidene fluoride (PVDF).

The thickness of the liner may be in the range 1mm – 5mm.

It is known from EP274970A and US6410126 to be able to convert continuous carbon filaments into discontinuous fibres, typically by slow controlled drawing of the carbon fibres using a cracking technique. The fibres obtained can have variable lengths depending upon the cracking operation, ranging from below 100mm, to 300mm and beyond. In particular it is desired to provide a unidirectional material, yarn or tape of carbon fibres in which the fibres are discontinuous and have a length distribution such that the mean fibre length, that is to say the mid-length of 50% of the fibres in the material, is between approximately 40 and 70% of the length of the longest fibre in the material.

As the carbon fibres formed are discontinuous, they can slide relative to one another during a forming step for producing an end product.

As such, 'Stretch Broken Carbon Fibres' (often abbreviated to SBCFs) are generally described as 'aligned discontinuous fibres'. Materials involving SBCFs have improved 'formability' (relative to continuous fibre-reinforced precursor materials), without the large mechanical performance reductions typical of discontinuous
5 systems (such as random short fibre composites). The mechanical properties of SBCFs are comparable to or close to the continuous form of the same material.

The present invention is not limited to forming the SBCF yarns by cracking or a cracking operation, and other methods of forming SBCF yarns are known in the art
10 including crimping, spread rollers, etc.

The tensile strength and the tensile modulus of 'standard' (long) carbon fibres are much higher than those of the aramid fibres. Indeed the tensile strength of carbon fibres is typically circa 4.8GPa, versus circa 2.2GPa – 3.4GPa for aramid fibres. The
15 tensile modulus of carbon fibres is also significantly higher at 240GPa, as opposed to circa 80 GPa – 120 GPa for aramid fibres. As a consequence, replacing aramid fibres by carbon fibres would initially seem to be a solution to improve the mechanical properties of the thermoplastic hoses.

20 However, standard carbon fibres are very brittle and cannot be braided without being damaged, or at least without losing an important part of their mechanical resistance, which precludes their use in many situations.

In the present invention, it has been found that Stretch Broken Carbon Fibre yarns
25 can be braided around the liner and maintain much of their strength characteristic, behaving more like an aramid yarn. SBCF yarn tensile strength properties are typically lower than those of standard carbon fibres. However, their tensile modulus remains very high, with a lower elongation at break compared to aramid fibres. Furthermore, SBCF yarns are less brittle than standard carbon fibres so that
30 can be braided without damage.

According to an embodiment of the present invention, the SBCF yarns are used on their own to form a reinforcing outer layer of a thermoplastic hose in the umbilical of the present invention.

5 Preferably, the SBCF yarns are braided or twisted or both.

Optionally, the SBCF yarns are helically wound around the liner.

10 Preferably, the SBCF yarns are impregnated with a polymer matrix. The polymer matrix may comprise one of: a thermoset resin, a thermoplastic resin, a thermoplastic elastomer resin, a polymer rubber resin, or a combination of same.

The polymer matrix may for example comprise one or more of the group comprising: epoxy resin, phenolic resin, bismaleimide resin, furan resin, rubber, 15 polyether ether ketone (PEEK), phenylene polysulfite (PPS), polyether sulfone (PES), polyetherimide (PEI), or a combination of same.

According to a preferred embodiment, the polymer matrix is a styrene butadiene rubber matrix.

20

According to one embodiment of the present invention, the impregnation of the SBCF yarns with a polymer matrix is formed by commingling: sometimes also termed the "commingled method". However, other methods are known for combining these materials, including the use of powdered thermoplastic matrix 25 materials, and solvent impregnation processes.

Commingled SBCF yarns are manufactured by several companies including Schappes Techniques (France). As an example, the commingled SBCF/nylon yarn is composed of a nylon polymer matrix and a carbon fibre reinforcement. The matrix 30 is a polyamide 12 ('PA12'), and the matrix formulation can be selected on the basis of various criteria such as viscosity, wetting, adhesion, durability and costs. PA12 is a semi-crystalline thermoplastic polymer with a crystallinity of about 41% for

solidification rates between 1 and 100°C/min. For the commingling stage, the nylon filament can come in a staple fibre form with an average diameter of 20 µm. The carbon fibre reinforcement of the commingled SBCF/nylon yarns is produced from 5-7µm diameter continuous carbon filaments which are stretch-broken into
5 filaments which have an average length of 80 mm. The discontinuous nature of this reinforcement will allow the filaments to move in relation to one another when pulled in tension or compression, giving the material formability. The density of the carbon filaments is 1.78 g/cm³. The Schappes Techniques process uses the carbon fibres and staple nylon fibres and blends them in commingled yarns with 6000
10 carbon filaments (6K).

The SBC fibres can be formed from any suitable carbon fibre. Preferably, they are formed from polyacrylonitrile-based carbon fibre in a manner known in the art, following which the carbon fibres are stretch broken.

15 Optionally, the umbilical of the present invention has a reinforced hose comprising a plurality of reinforcing outer layers, each formed with Stretch Broken Carbon Fibre (SBCF) yarns.

20 Optionally, the reinforced hose has an outer sealing polymer sheath.

The subsea flexible umbilical of the present invention may be any umbilical intended to extend between one or more subsea and surface apparatus, device or units, including support umbilicals, fluid transportation umbilicals, risers, or a
25 combination of same.

In one embodiment of the present invention, the umbilical comprises a plurality of umbilical components being one or more selected from the group comprising: electrical cables, optical fibre cables, steel tubes, and thermoplastic hoses, including
30 fluid transportation tubes and/or hoses; in particular a fluid transportation hose.

Preferably, the subsea flexible umbilical is reelable, in particular reelable on and off a reel or spool known in the art, and used in the transportation and/or laying and/or recovery of fluid pipelines.

5 Optionally, the umbilical is greater than 2000m long.

According to a second aspect of the present invention, there is provided a method of forming a subsea flexible umbilical comprising a plurality of umbilical components, at least one umbilical component comprising a reinforced hose having a liner and
10 one or more reinforcing outer layers, at least one reinforcing outer layer being formed with Stretch Broken Carbon Fibre (SBCF) yarns, comprising at least the steps of:

 providing the or each outer layer around the liner to provide a reinforced hose, and

15 forming the umbilical by combining the Stretch Broken Carbon Fibre (SBCF)-reinforced hose with the other umbilical components.

Optionally, the method further comprises the step of providing an outer layer formed from braiding or twisting the SBCF yarns.

20 Also, optionally, the method further comprises the step of impregnating the SBCF yarns with a polymer matrix. The polymer matrix may comprise one of: a thermoset resin, a thermoplastic resin, a thermoplastic elastomer resin, a polymer rubber resin, or a combination of same; as discussed hereinbefore.

25 An embodiment of the present invention will now be described by way of example only, and with reference to the accompanying schematic drawings, in which:

Figure 1 is a cross sectional view of a subsea flexible umbilical; and

30 Figure 2 is a side elevation view cross of a thermoplastic reinforced hose according to an embodiment of the present invention.

As illustrated in Figure 1, a subsea flexible umbilical 1 contains a plurality of functional elements, including several thermoplastic hoses 2, and several electric cables generally labelled 3. These functional elements are assembled in a helical or S/Z manner together with fillers 5, and over-sheathed by an outer sheath 4.

5

The umbilical 1 could also include other umbilical components such as optical fibre cables, steel tubes, reinforcing steel or composite rods, electrical power cables, etc., which are not shown in Figure 1.

10 According to the invention, at least one of the thermoplastic hoses 2 is a SBCF-reinforced hose 6.

As illustrated in Figure 2, the at least one SBCF-reinforced hose 6 comprises an inner polymeric liner 7, covered by at least one SBCF reinforcing outer layer 8, 9,
15 and by external polymeric sheath 10. In the embodiment illustrated on Figure 2, the hose 6 comprises two reinforcing outer layers 8, 9. Each reinforcing layer 8, 9 is formed with SBCF yarns which are cross wound and braided together.

Optionally, the hose could be formed with one or more non-SBCF reinforcing layers
20 as well as one or more SBCF reinforcing layers. For example, the inner reinforcing layer 8 could be made with aramid yarns, and the outer reinforcing layer 9 formed with SBCF yarns. Other combinations of SBCF reinforcing layers and aramid reinforcing layers involving two or more reinforcing layers could also be implemented without departing from the present invention.

25

The carbon fibre for the SBCF yarns used is provided from a co-monomer, acrylonitrile, and a solvent catalyst. Following a polymerization process, the so-formed polymer passes through a spinning process to orientate the molecular chains. It is then rinsed and post-treated to produce the acrylic fibre. The acrylic
30 fibre is then oxidized in air at high temperature, and then carbonised within an inert gas at a temperature above 1000°C.

The so-formed carbon fibres then go through a surface treatment process to be formed into fine strands which are stretch broken. During the stretch-breaking process, the fibres are pulled until broken. The individual filaments are still quite long, but they now overlap each other and are aligned with each other. As a result, individual fibres can be bent or deformed more easily, as the fibres on the outer radius can separate at the break points.

The filaments are then included with a styrene butadiene rubber based sizing matrix to give good flexibility. This matrix is subjected to a high twist level to give more fibre-like characteristics. The size of the resultant fibres are relatively small, and several of these fibre lengths can then be combined together, typically by twist multiplying, to form a larger scale product suitable for the hose size.

Significant advantages of a reinforced hose formed with SBCF yarns are a high level of flexibility and inherent fatigue resistance. A conventional carbon fibre product cannot produce in itself an effective long length high pressure thermoplastic hose, and significant damage occurs to the filaments during any braiding process as the carbon fibre has to flex to a tight radii at high speeds under the braiding. In contrast, SBCF yarns, preferably within a flexible matrix, and have a higher degree of twist level, which enables them to be better reinforcement for a high pressure umbilical hose construction.

The use of SBCF fibres also allows continuing use of the high modulus properties of carbon fibre, with an efficient load share across multiple layers.

Furthermore the ultra high temperature properties of carbon fibre enable the operating temperature envelope to be significantly increased when having at least one reinforcing outer layer formed with Stretch Broken Carbon Fibre (SBCF) yarns in umbilical hose line products.

Claims

1. A subsea flexible umbilical comprising a plurality of umbilical components, at least one umbilical component comprising a reinforced hose having a liner and one or more reinforcing outer layers, at least one reinforcing outer layer formed with Stretch Broken Carbon Fibre (SBCF) yarns.
5
2. An umbilical as claimed in claim 1 wherein the SBCF yarns are braided or twisted or both.
10
3. An umbilical as claimed in claim 1 or claim 2 wherein the SBCF yarns are helically wound.
4. An umbilical as claimed in any one of claims 1 to 3 wherein the SBCF yarns are impregnated with a polymer matrix, said polymer matrix comprising one of a thermoset resin, a thermoplastic resin, a thermoplastic elastomer resin, a polymer rubber resin, or a combination of same.
15
5. An umbilical as claimed in claim 4 wherein the polymer matrix comprises one or more of the group comprising: epoxy resin, phenolic resin, bismaleimide resin, furan resin, rubber, polyether ether ketone (PEEK), phenylene polysulfite (PPS), polyether sulfone (PES), polyetherimide (PEI), or a combination of same.
20
6. An umbilical as claimed in claim 4 wherein the polymer matrix is a styrene butadiene rubber matrix.
25
7. An umbilical as claimed in any one of the preceding claims wherein the SBCF yarns are polyacrylonitrile-based carbon fibres.
8. An umbilical as claimed in any one of the preceding claims wherein the reinforced hose comprises a plurality of reinforcing outer layers, each formed with Stretch Broken Carbon Fibre (SBCF) yarns.
30

9. An umbilical as claimed in any one of the preceding claims wherein the plurality of umbilical components are one or more selected from the group comprising: electrical cables, optical fibre cables, steel tubes, thermoplastic hoses
5 including fluid transportation tubes and/or hoses.

10. An umbilical as claimed in any one of the preceding claims wherein the reinforced hose is a fluid transportation hose.

10 11. An umbilical as claimed in any preceding claim wherein the umbilical is reelable.

12. An umbilical as claimed in any preceding claim wherein the umbilical is >2000m long.

15 13. A method of forming a subsea flexible umbilical comprising a plurality of umbilical components, at least one umbilical component comprising a reinforced hose having a liner and one or more reinforcing outer layers, at least one reinforcing outer layer being formed with Stretch Broken Carbon Fibre (SBCF) yarns,
20 comprising at least the steps of:

providing the or each outer layer around the liner to provide a reinforced hose, and

forming the umbilical by combining the Stretch Broken Carbon Fibre (SBCF)-reinforced hose with the other umbilical components.

25 14. A method as claimed in claim 13 further comprising the step of providing an outer layer formed from braiding or twisting the SBCF yarns.

15. A method as claimed in claim 14 further comprising the step of impregnating
30 the SBCF yarns with a polymer matrix, said polymer matrix comprising one of a thermoset resin, a thermoplastic resin, a thermoplastic elastomer resin, a polymer rubber resin, or a combination of same.

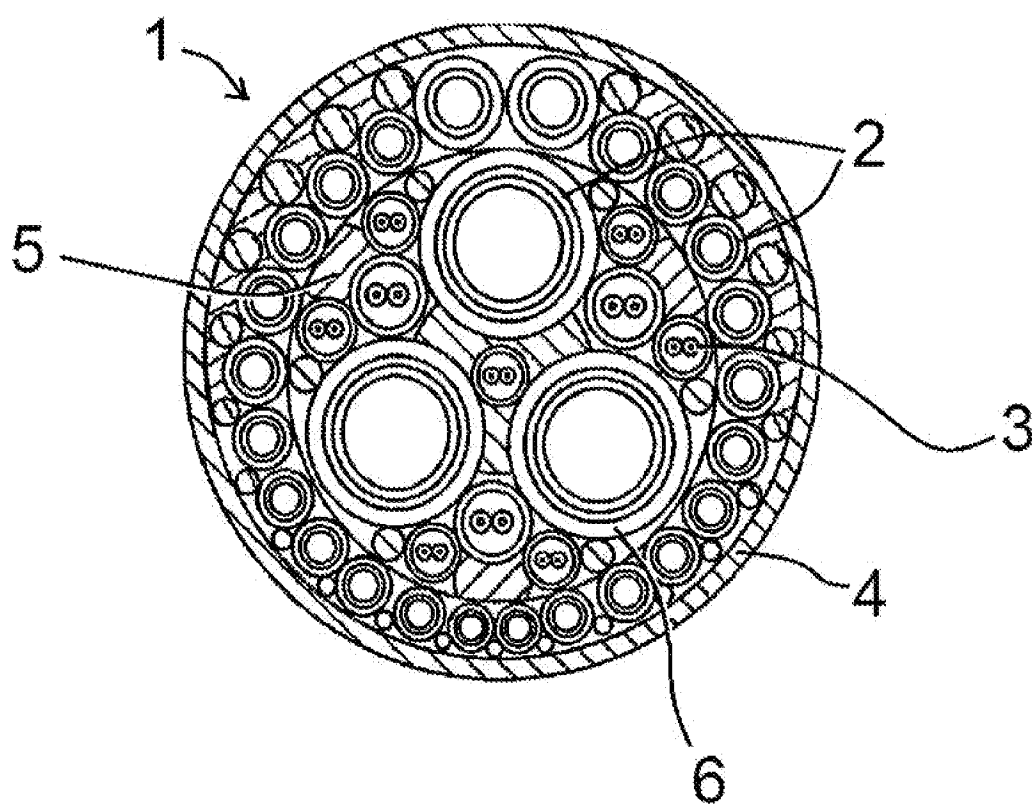


Fig. 1

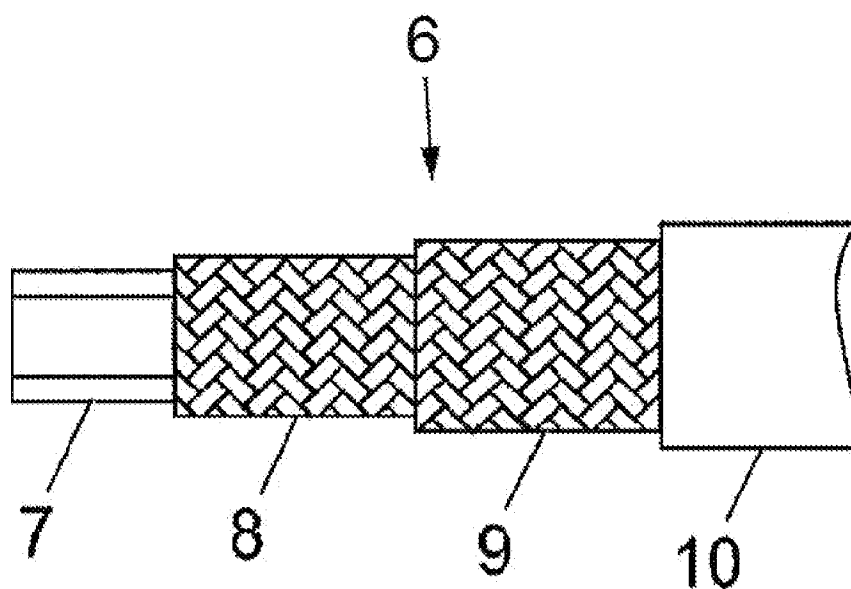


Fig. 2

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2015/002583

A. CLASSIFICATION OF SUBJECT MATTER

INV. F16L11/22 F16L11/08 E21B17/01
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 E21B 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

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Y	US 2013/068337 A1 (SCHUBERT HORST [DE] ET AL) 21 March 2013 (2013-03-21) paragraphs [0003], [0004], [0009], [0010], [0043] - [0064], [0115] - [0119], [0150] - [0153]; figure 1 -----	1-15
Y	EP 2 671 988 A2 (DU PONT [US]) 11 December 2013 (2013-12-11) paragraphs [0001], [0014] - [0016], [0023]; figure 6 ----- -/--	1-15

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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INTERNATIONAL SEARCH REPORT

International application No

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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