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— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

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(54) Title: STRAIN SENSING CABLE

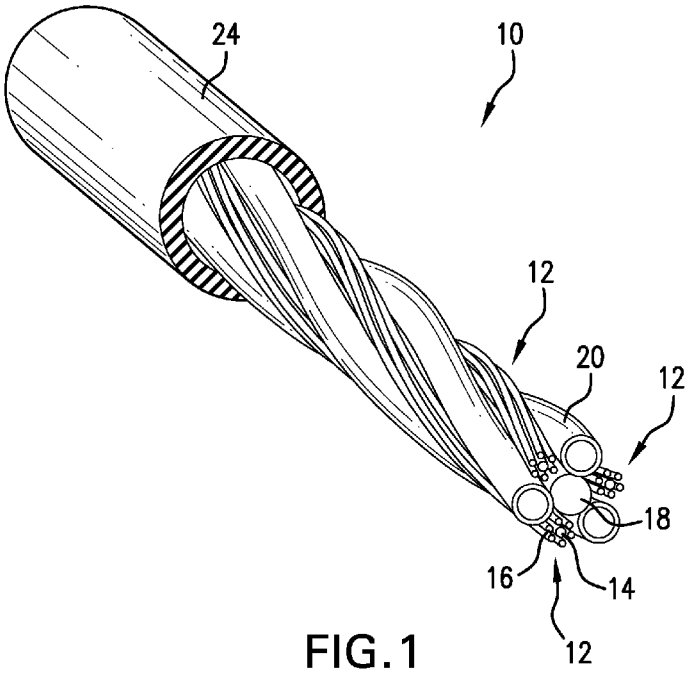

FIG. 1

(57) Abstract: A sensing cable, including an outer cladding; and at least one sensing bundle contained within the cladding, each sensing bundle having a sensing fiber wrapped straintransmissively by at least one strand. A method of sensing strain is also included.

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STRAIN SENSING CABLE

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Application No. 13/483694, filed on May 30, 2012, which is incorporated herein by reference in its entirety.

BACKGROUND

[0002] Cables, particularly fiber optic cables, are used ubiquitously in the downhole drilling and completions industry. These cables are used for enabling a variety of downhole conditions and parameters, such as temperature, vibration, sound, pressure, strain, etc. to be monitored. Due chiefly to their pervasive use, there is an ever-present desire in the industry for alternate styles of sensing cables, particularly for enhancing the ability to more accurately sense a specific parameter such as strain.

SUMMARY

[0003] A sensing cable, including an outer cladding; and at least one sensing bundle contained within the cladding, each sensing bundle having a sensing fiber wrapped strain-transmissively by at least one strand.

[0004] A method of sensing strain including deploying a cable having at least one at least one sensing bundle contained within a cladding, each sensing bundle having a sensing fiber wrapped strain-transmissively by at least one strand; and transmitting strain to the fiber via the at least one strand.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] The following descriptions should not be considered limiting in any way. With reference to the accompanying drawings, like elements are numbered alike:

[0006] Figure 1 is a perspective view of a strain-sensing cable according to an embodiment disclosed herein with a cladding partially stripped off;

[0007] Figure 2 is a cross-sectional view of the cable of Figure 1; and

[0008] Figure 3 is a perspective view of a strain-sensing cable according to another embodiment disclosed herein.

DETAILED DESCRIPTION

[0009] A detailed description of one or more embodiments of the disclosed apparatus and method are presented herein by way of exemplification and not limitation with reference to the Figures.

[0010] Referring now to Figure 1, a cable assembly 10 is illustrated. The assembly 10 includes at least one braid or bundle 12 for improving a strain-sensing capability of the cable 10. Specifically, each of the bundles 12 includes a fiber 14 that is wrapped with or surrounded by a plurality of strands 16. The fibers 14 are arranged for sensing one or more downhole conditions or parameters such as temperature, pressure, strain, acoustics, etc. In one embodiment, the fibers 14 are optical fibers. In a further embodiment, the fibers 14, in the form of optical fibers, include fiber Bragg gratings for enabling the aforementioned sensing capabilities.

[0011] The strands 16 are included to facilitate the transfer of strain directly to the fibers 14 so that the cable 10 can be used, e.g., to measure strain in a tubular string or downhole component. To this end, the strands 16 are wrapped, wound, or secured, e.g., helically, spirally, circumferentially, etc., about each of the fibers 14. The number of the strands 16 and the number of turns of the strands 16 per unit length of the fibers 14 may vary in different embodiments. In one embodiment, the strands 16 are stainless steel, although it is to be appreciated that other materials can alternatively be used that exhibit good strain transfer capabilities (e.g., resiliency, ductility, etc.) and resistance to downhole conditions (e.g., maintain good strain transmission to the fibers 14 in high temperature or high pressure environments, etc.).

[0012] Similar to the strands 16 being wrapped or wound about the fibers 14 in each of the bundles 12, the bundles 12 in the embodiment of Figure 1 are wrapped or wound, e.g., helically, spirally, circumferentially, etc., about a core or central wire 18. The gauge, material, properties, etc. of the central wire 18 can be selected for setting the properties of the cable 10, such as ductility, flexibility, conformability, radial compression strength, tensile strength, etc. In the illustrated embodiment, the bundles 12 are interspaced about the central wire 18 with a plurality of tubes 20. It should of course be appreciated that the tubes 20 could be optional in some embodiments and that any number of the tubes 20 and the bundles 12 could be included in any desired arrangement or pattern (e.g., a sequence that is alternating/non-alternating, repeating/non-repeating, randomized, etc.). An internal passageway through ach of the tubes 20 enables, e.g., one or more sensing fibers 22 (e.g., resembling the fibers 14 but without the strands 16) to be located within the tubes 20 for

sensing a variety of non-strain related properties (e.g., temperature, pressure, acoustics, etc.). In one embodiment, the tubes 20 and the sensing fibers forming assemblies according to known fiber in metal tube (FIMT) techniques by sealing one or more fibers resembling the fibers 22 within the tubes 20. According to known FIMT techniques, the tubes 20 may be filled with a gel or fluid to aid in the operation of the tubes 20 and/or the cable 10. It is additionally noted that the tubes 20 also play a role in setting the properties and performance of the cable 10, for example, by increasing the compressive strength of the cable 10 in order to avoid the cable 10 collapsing in high pressure downhole applications. It is to be appreciated that ones of the tubes 20 could be replaced with solid wires resembling the central wire 18, that the central wire 18 could be hollow and resemble one of the tubes 20, or other modifications could be made to the cable 10.

[0013] The cable 10 includes a cladding or sheath 24 to further protect and set the properties of the cable 10 as well as to maintain the assembled arrangement of the components (e.g., to maintain the strands 16, bundles 12, and tubes 20 being wrapped around their corresponding components). Additionally, a cavity 26 formed by the empty space within the cladding 24 located between the bundles 12, the central wire 18, and/or the tubes 20, can be filled with a polymer or other filler material, e.g., for achieving the aforementioned objectives of the cladding 24. In one embodiment the filler material in the cavity 26 is a plastic elastomer, such as that marketed under the trade name Hytrel® and made commercially available from E. I. du Pont de Nemours and Company (DuPont).

[0014] An alternate embodiment is illustrated in Figure 3, namely, a cable 10'. The components of the cable 10' generally resemble those in the cable 10 and have thus been numbered in accordance with the above-discussed embodiment where appropriate. While the bundles 12 are spirally wrapped in the cable 10, a plurality of bundles 12' in the cable 10' extends axially within the cladding 24 in a non-spiraling manner (but otherwise resemble the bundles 12). A plurality of tubes 20' are also shown extending axially in a non-spiraling manner, but otherwise resemble the tubes 20 discussed above. For example, the bundles 12' and/or the tubes 20' in the cable 10' may extend straight along the central member 18, in parallel with the central member 18, concentrically with the cladding 24 in lieu of the central member 18, etc. It is noted that a cross-section of the cable 10' would generally resemble the illustration of Figure 2. The cable 10' may have particular benefits, for example, in a shape-sensing application in which strain measurements by the fibers 14 are utilized in calculating or determining the shape of a component about or with which the cable 10 is installed.

[0015] While the invention has been described with reference to an exemplary embodiment or embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the claims. Also, in the drawings and the description, there have been disclosed exemplary embodiments of the invention and, although specific terms may have been employed, they are unless otherwise stated used in a generic and descriptive sense only and not for purposes of limitation, the scope of the invention therefore not being so limited. Moreover, the use of the terms first, second, etc. do not denote any order or importance, but rather the terms first, second, etc. are used to distinguish one element from another. Furthermore, the use of the terms a, an, etc. do not denote a limitation of quantity, but rather denote the presence of at least one of the referenced item.

CLAIMS

What is claimed is:

1. A sensing cable, comprising:

an outer cladding; and

at least one sensing bundle contained within the cladding, each sensing bundle having a sensing fiber wrapped strain-transmissively by at least one strand.

2. The sensing cable of claim 1, further comprising a central member about which the at least one bundle is circumferentially wrapped.

3. The sensing cable of claim 1, wherein the at least one bundle extends axially and non-spirally within the outer cladding.

4. The sensing cable of claim 3, further comprising a central member concentrically included in the outer cladding, wherein the at least one bundle extends in parallel with the central member.

5. The sensing cable of claim 1, further comprising a filler material in the cladding encapsulating the at least one sensing bundle.

6. The sensing cable of claim 5, wherein the filler material is a plastic.

7. The sensing cable of claim 1, further comprising at least one tube disposed in the outer cladding.

8. The sensing cable of claim 7, wherein the tube includes at least one additional sensing fiber located therein.

9. The sensing cable of claim 8, wherein the tube and the at least one additional sensing fiber form a fiber in metal tube (FIMT) assembly.

10. The sensing cable of claim 7, wherein the at least one tube and the at least one sensing bundle are included about a central member.

11. The sensing cable of claim 10, wherein the central member is a wire.

12. The sensing cable of claim 10, wherein the at least one tube comprises a plurality of tubes and the at least one sensing bundle comprises a plurality of sensing bundles.

13. The sensing cable of claim 12, wherein the sensing bundles and the tube are alternatingly included about the central member.

14. The sensing cable of claim 12, wherein the sensing bundles and the tubes are circumferentially wrapped about the central member.

15. The sensing cable of claim 1, wherein the fiber includes fiber Bragg gratings.

16. A method of sensing strain comprising:

deploying a cable having at least one at least one sensing bundle contained within a cladding, each sensing bundle having a sensing fiber wrapped strain-transmissively by at least one strand; and

transmitting strain to the fiber via the at least one strand.

17. The method of claim 16, further comprising sensing strain in the fiber by use of fiber Bragg gratings.

18. The method of claim 16, wherein the cable comprises a plurality of the sensing bundles wrapped circumferentially about a central wire.

19. The method of claim 16, wherein the cable further comprises at least one tube in the cladding.

20. The method of claim 19, wherein the at least one tube includes at least one other fiber disposed therein.

21. The method of claim 20, further comprising monitoring an additional condition or parameter with the at least one other fiber.

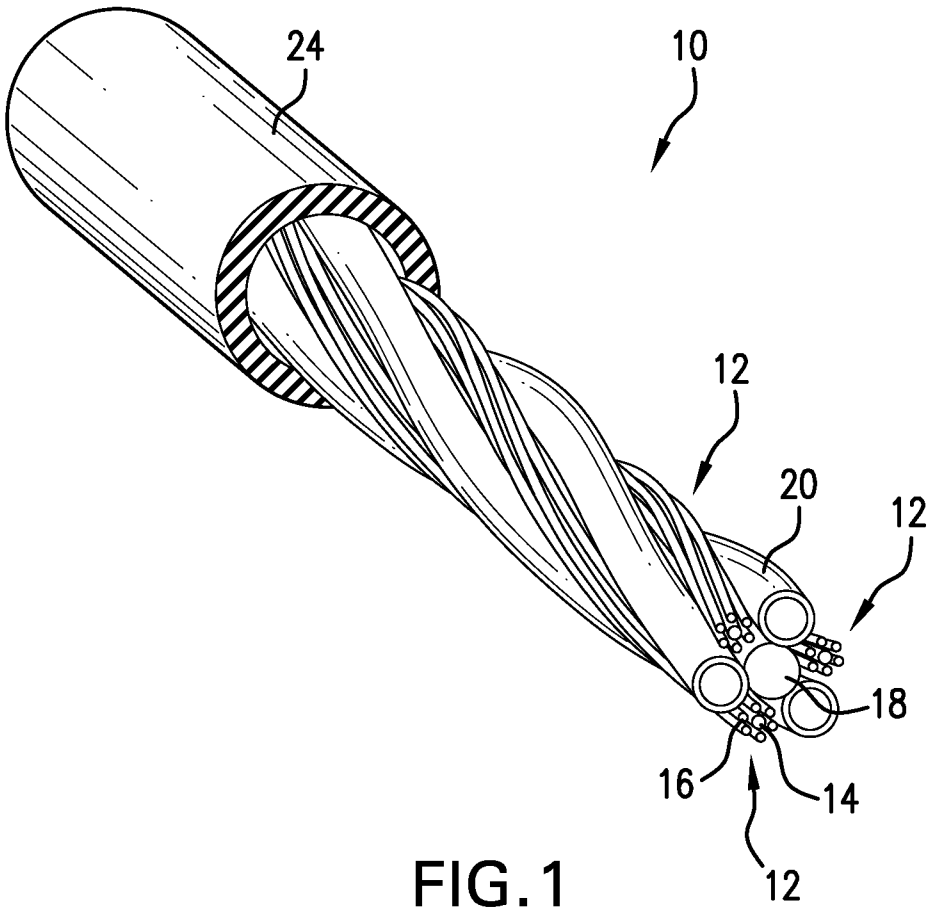

FIG. 1

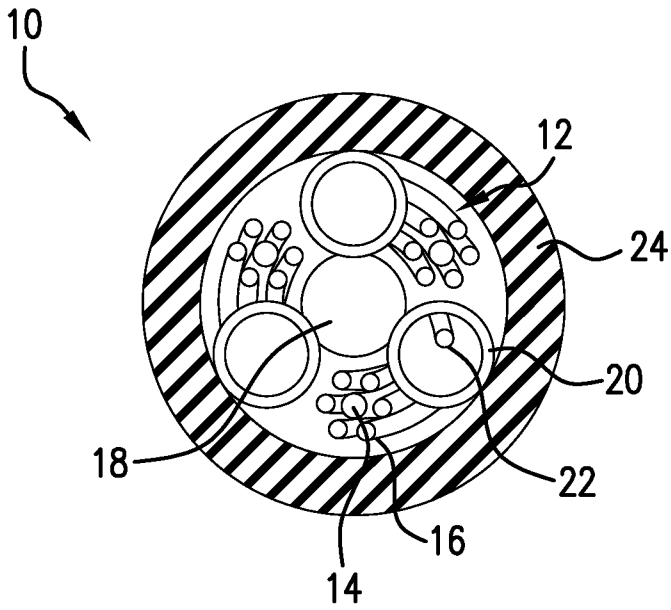

FIG. 2

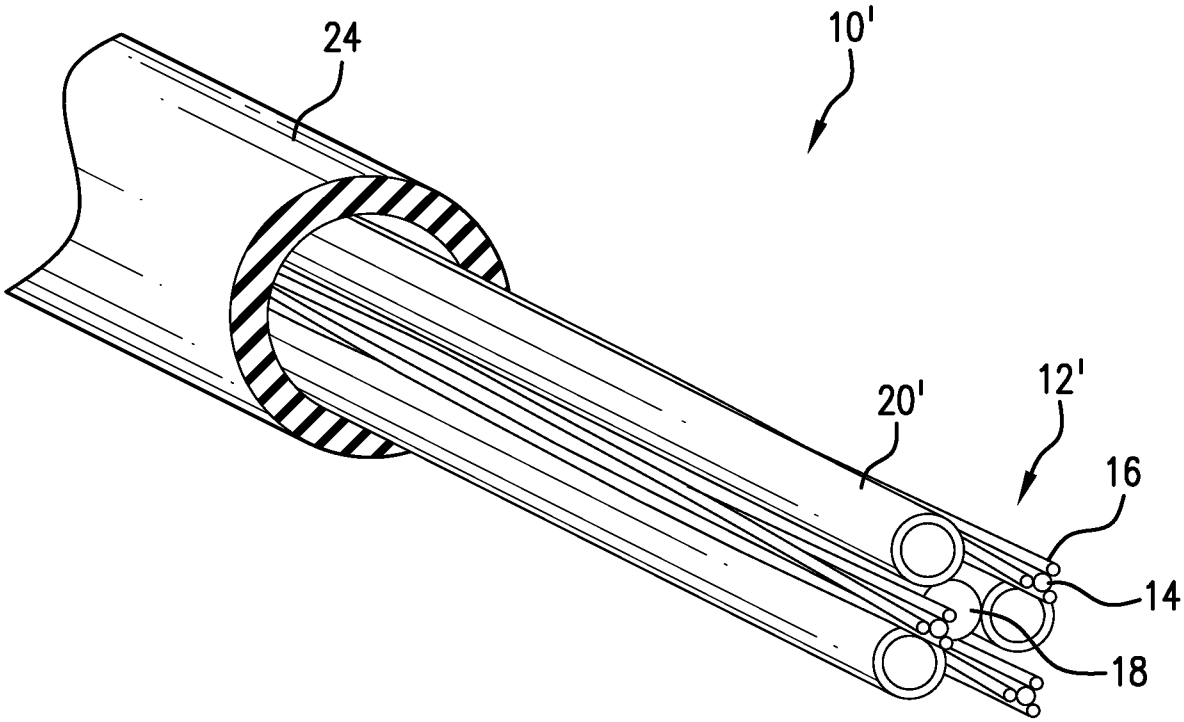

FIG.3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/038216

A. CLASSIFICATION OF SUBJECT MATTER

H01B 11/22(2006.01)i

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)
H01B 11/22; G01L 1/24; G02B 5/14; G02B 5/172; G02B 6/00; G02B 6/44

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: sensing cable, strain, fiber

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2012-044947 A1 (AFL TELECOMMUNICATIONS LLC.) 05 April 2012 See abstract, paragraphs [0064]-[0073], claims 18-19,28 and figure 2B.	1-4,7-14,16,18-21
Y		5-6,15,17
Y	US 2012-0082422 A1 (DAVIDE SARCHI et al.) 05 April 2012 See abstract, paragraphs [0067],[0071],[0078]-[0081],[0095],[0098], [0129]-[0132] and figures 1a-1b,3.	5-6
Y	US 2004-0258373 A1 (JON STEINAR ANDREASSEN) 23 December 2004 See abstract, paragraphs [0038]-[0047], claim 1 and figure 1.	15,17
A	US 2011-0058778 A1 (BRIAN HERBST) 10 March 2011 See abstract, paragraphs [0022]-[0027], claims 1-2,6 and figures 2A-2B.	1-21
A	US 2009-0034903 A1 (BRIAN GERALD HERBST) 05 February 2009 See abstract, paragraphs [0027]-[0032], claims 1,13-14 and figures 1-2.	1-21
A	US 4488040 A (DONALD H. ROWE) 11 December 1984 See abstract, column 2, lines 19-50, claim 1 and figures 2-3.	1-21

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

☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of citation or other special reason (as specified)
"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
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
23 August 2013 (23.08.2013)	**23 August 2013 (23.08.2013)**

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/US2013/038216

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