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Declarations under Rule 4.17:

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

[Continued on next page]

(54) Title: STRAIN SENSING CABLE

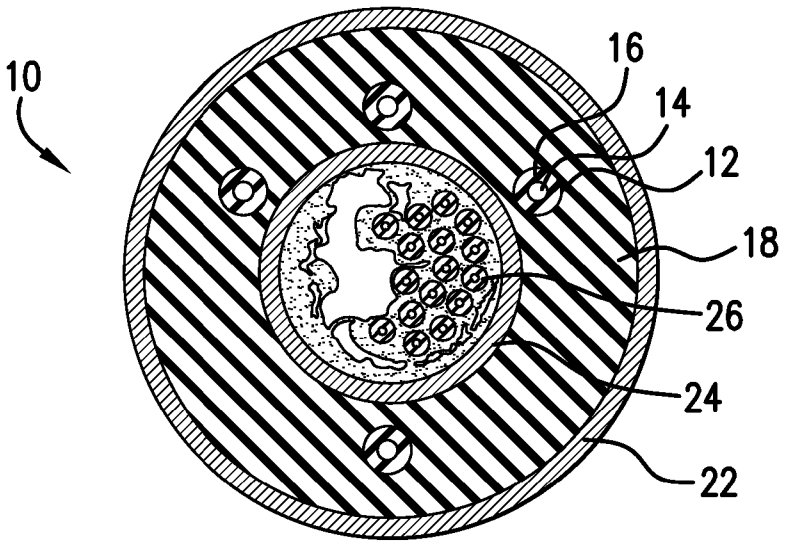

FIG. 1

(57) Abstract: A strain sensing cable including one or more strain sensing elements and a strain transfer medium extruded directly onto the one or more strain sensing elements disposed within the strain transfer medium. The strain transfer medium is operatively arranged to transfer strain experienced by the cable to the one or more strain sensing elements. A method of making a strain sensing cable is also included.

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— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

Published:

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

STRAIN SENSING CABLE

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Application No. 13/705301, filed on December 5, 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 often disposed with a tubular string or other downhole component and used for enabling a variety of downhole conditions and parameters, such as temperature, vibration, sound, pressure, strain, etc. to be sensed and/or monitored. In order to increase efficiency and reduce costs in installation, use, and manufacture, the industry always well receives advances in sensing technology and alternate styles of sensing and monitoring cables.

SUMMARY

[0003] A strain sensing cable including one or more strain sensing elements; and a strain transfer medium extruded directly onto the one or more strain sensing elements disposed within the strain transfer medium, the strain transfer medium operatively arranged to transfer strain experienced by the cable to the one or more strain sensing elements.

[0004] A method of making a strain sensing cable including positioning one or more strain sensing elements with respect to a strain transfer medium; and extruding the strain transfer medium through a die directly onto the one or more strain sensing elements with the one or more strain sensing elements disposed in the strain transfer medium.

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 cross-sectional view of a cable according to one embodiment disclosed herein; and

[0007] Figure 2 schematically illustrates an extrusion process for forming a cable according to one embodiment disclosed herein.

DETAILED DESCRIPTION

[0008] 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.

[0009] Referring now to Figure 1, a cross-section of a cable 10 is shown, having at least one strain sensing element 12, with the strain sensing elements 12 in turn having features that enable strain to be sensed, such as fiber Bragg gratings. In the illustrated embodiment, the elements 12 are each formed with a fiber optic core 14 surrounded by a protective sheath, cladding, or coating 16. The fiber optic core 14 may have any desired construction, e.g., that of a typical waveguide having a higher refractive index core surrounded by a lower refractive index material (e.g., glass), which are then covered by the coating 16 for additional mechanical protection. The fiber optic cores 14 are each arranged, for example, with the aforementioned fiber Bragg gratings or some other feature that enables the elements 12 to sense one or more parameters, particularly strain. In one embodiment, the fiber Bragg gratings or other sensing features enable distributed strain sensing along the length of the elements 12. In one embodiment, the cable 10 includes at least three sensing elements 12 in order to enable triangulation of the sensed strain, thereby enhancing the accuracy and performance of the cable 10. The coating 16 could comprise one more layers of suitable protective materials such as polyimide, polyether ether ketone (PEEK), polyvinyl chloride (PVC), etc., which are typically applied in liquid form cured onto the fiber cores 14.

[0010] The sensing elements 12 are particularly arranged for sensing strain experienced by the cable 10 which is representative of the strain in a component with which the cable 10 is arranged. In one embodiment the component for which strain is sensed by the cable 10 is a tubular string or other downhole component. The cable 10 could be mounted or affixed in any desired way, with some suitable examples provided by United States Patent Publication No. 2008/0271926 (Coronado et al.), which Publication is hereby incorporated by reference in its entirety.

[0011] In order to enable the sensing elements 12 to accurately sense strain, the elements 12 are disposed in a strain transfer medium 18. More specifically, as shown schematically in Figure 2, the medium 18 is extruded directly onto the sensing elements 12 or, alternatively stated, the sensing elements 12 are positioned directly within the medium 18, during extrusion of the medium 18 through a die 20. The medium 18 could be forced through the die 20 in any suitable manner, such as by a ram, press, hydraulic pressure, etc. The extrusion process could place the medium 18 into its final shape for use in the cable 10 or a preliminary shape that is further processed to form the cable 10. The medium 18 could be

any suitable material that is able to be extruded directly onto the sensing elements 12, such as a plastic, polymer, elastomer, or combination thereof. In one embodiment, the medium 18 is a thermoplastic polyester elastomer commercially available from DuPont under the trade name Hytrel®. It has been found by the current inventors that extruding the medium 18 directly onto and/or with the sensing elements 12 results in a cable that is not only quickly and efficiently manufacturable, but also has improved strain sensing capabilities with respect to prior cables.

[0012] In order to generally protect the cable 10 during installation and use, a cover, jacket, sheath, outer cover, or cladding 22 is provided. The cladding 22 can be any suitable material that provides protection to the sensing elements 12 and the medium 18, such as crush or compression, abrasion, and chemical reactivity resistance. In one embodiment, the cladding 22 is made from a stainless steel tube having radial dimensions larger than the medium 18, which is drawn down to tightly encase the medium 18. Of course, the cladding 22 could be assembled according to other methods, such as wrapping or bending a sheet about the medium 18, etc., or from other materials.

[0013] In the illustrated embodiment, the cable 10 also includes a tube or other structural member 24. The member 24 in the illustrated embodiment is hollow in order to house one or more additional fibers or elements 26. Of course, the member 24 could be arranged with a solid cross-section and/or be arranged for some other purpose such as to provide desired rigidity, ductility, resiliency, or other properties to the cable 10. As shown in Figure 2, the member 24 can be directly extruded with the medium 18. The elements 26 can be added to the member 24 after the extrusion of the medium 18 thereon. In one embodiment, the additional elements 26 are arranged with the member 24 according to known Fiber In Metal Tube (FIMT) techniques. By placing the additional elements 26 inside of the member 24, the elements 26 can be further protected from harsh environments, being crushed or bent, etc. Placement in the member 24 also isolates the elements 26 from the medium 18 such that the elements 26 are not subjected to the strain experienced by the cable 10. In this way, the elements 26 can be arranged for sensing parameters other than strain, such as temperature, acoustics, etc. It is also to be appreciated that while the elements 26 could be sensing elements such as fiber optic strands, other signal, sensing, and/or electrical power conductors could be included.

[0014] 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 strain sensing cable comprising:

one or more strain sensing elements; and

a strain transfer medium extruded directly onto the one or more strain sensing elements disposed within the strain transfer medium, the strain transfer medium operatively arranged to transfer strain experienced by the cable to the one or more strain sensing elements.

2. The cable of claim 1, wherein the one or more strain sensing elements comprises one or more optic fibers.

3. The cable of claim 2, wherein the one or more optic fibers each comprise a fiber optic core coated by a protective sheath.

4. The cable of claim 2, wherein the one or more optic fibers include fiber Bragg gratings for enabling the one or more optic fibers to sense strain.

5. The cable of claim 1, wherein each of the one or more strain sensing elements is arranged to provide distributed strain sensing over a length thereof.

6. The cable of claim 1, wherein the one or more strain sensing elements includes at least three strain sensing elements for enabling triangulation.

7. The cable of claim 1, wherein the strain transfer medium is a polymer, elastomer, plastic, or a combination including at least one of the foregoing.

8. The cable of claim 1, wherein the strain transfer medium is a thermoplastic polyester elastomer.

9. The cable of claim 1, further comprising a structural member disposed in the strain transfer medium.

10. The cable of claim 1, wherein the structural member is hollow and contains one or more other sensing elements therein.

11. The cable of claim 10, wherein the one or more other elements are operatively arranged to sense parameters other than strain and the structural member isolates the one or more other elements from strain experienced by the cable.

12. The cable of claim 1, further comprising a cladding surrounding the strain transfer medium.

13. A method of making a strain sensing cable comprising:

positioning one or more strain sensing elements with respect to a strain transfer medium; and

extruding the strain transfer medium through a die directly onto the one or more strain sensing elements with the one or more strain sensing elements disposed in the strain transfer medium.

14. The method of claim 13, further comprising encasing the strain transfer medium with an outer cladding.

15. The method of claim 14, wherein encasing the strain transfer medium includes drawing the outer protective jacket to tightly encase the strain transfer medium.

16. The method of claim 13, further comprising positioning a structural member with respect to the strain transfer medium and extruding the strain transfer medium directly onto the structural member.

17. The method of claim 16, wherein the structural member is hollow, the method further comprising disposing one or more other sensing or conductive elements within the structural member.

18. The method of claim 13, wherein the strain sensing medium is a thermoplastic polyester elastomer.

19. The method of claim 13, wherein the one or more strain sensing elements are one or more optic fibers.

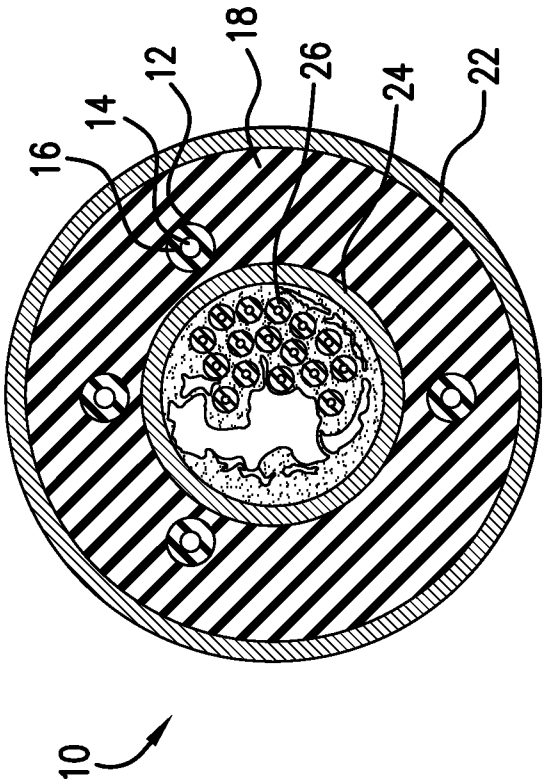

FIG.1

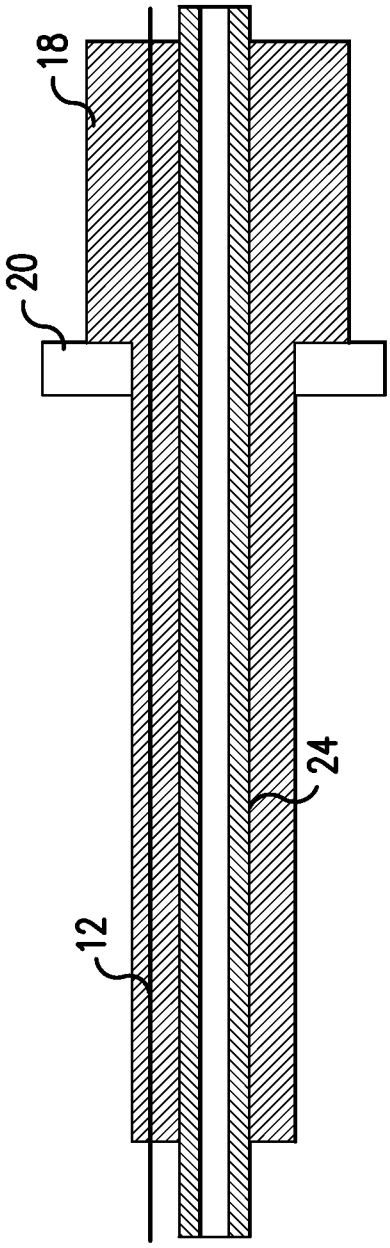

FIG.2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/068060

A. CLASSIFICATION OF SUBJECT MATTER

E21B 47/007(2012.01)i, E21B 47/01(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)
E21B 47/007; G01L 1/24; G01B 11/16; G01L 9/00; G01V 9/00; G02B 6/00; G02B 6/44; E21B 47/01

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: strain, sensor, transfer medium, optic fiber, and structural member

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2011-0311179 A1 (GREENAWAY, ROBERT) 22 December 2011 See abstract, paragraphs [0013]-[0019], claim 9 and figure 2.	1-3,5,7-8,12-15 ,18-19
Y		4,6
A		9-11,16-17
Y	US 2012-0143521 A1 (CHEN et al.) 07 June 2012 See abstract and paragraph [0024].	4
Y	US 2005-0234648 A1 (ECONOMIDES et al.) 20 October 2005 See abstract and paragraph [0092].	6
A	US 2009-0074348 A1 (XIA et al.) 19 March 2009 See paragraphs [0035]-[0055] and figures 1-8.	1-19
A	JP 2007-271513 A (OCC CORP.) 18 October 2007 See abstract and paragraphs [0001]-[0010].	1-19

☐ 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 another 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
29 January 2014 (29.01.2014)	**29 January 2014 (29.01.2014)**

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/US2013/068060

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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