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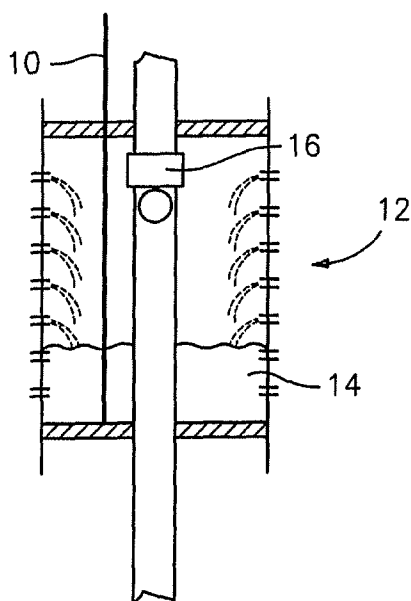


FIG. 1

(57) Abstract: An optical sensing member within the annulus zone of a well is disclosed, which sensing member determines the level of debris in the well. When debris accumulates within the annulus zone, said sensing member returns a signal indicative of the level of such debris within the zone. The optical sensing member may include an optical fiber and/or any known optical sensors configured to determine strain, pressure, shape, force, and/or temperature.

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OPTICAL SENSOR FOR MEASURING DOWNHOLE INGRESS OF DEBRIS

BACKGROUND

[0001] Optical Fibers have become the communication medium of choice for long distance communication due to their excellent light transmission characteristics over long distances and the ability to fabricate such fibers in lengths of many kilometers. The transmitted light can also power sensors, thus obviating the need for lengthy electrical wires. This is particularly important in the petroleum and gas industry, where strings of electronic sensors are used in wells to monitor downhole conditions.

[0002] As a result, in the petroleum and gas industry, passive fiber optic sensors are used to obtain various downhole measurements, such as, pressure, strain, shape or temperature. A string of optical fibers within a fiber optic system may be used to communicate information from wells being drilled, as well as from completed wells. For example, a series of weakly reflecting fiber Bragg gratings (FBGs) may be written into a length of optical fiber, such as by photoetching. As is known in the art, the distribution of light wavelengths reflected from an FBG is influenced by the temperature and strain of the device to which the FBG is attached. An optical signal is sent down the fiber, which is reflected back to a receiver and analyzed to characterize the length of optical fiber. Using this information, downhole measurements may be obtained.

[0003] Due to the depth of typical oil and gas wells, one or more of the optical sensors are typically spliced into a length of optical transmission fiber that extends from the surface to the desired depths. As such, it is desirable to take measurements at various depths of the well.

[0004] One problem in the downhole art concerns the accumulation of sand and other debris in the annulus of a zone in a well during operations. For some applications, it is important to determine the level of such sand and other debris with optical sensors, which heretofore has not been disclosed in the art.

SUMMARY OF THE INVENTION

[0005] The above described and other problems are overcome by the present optical well monitoring system, which comprises an optical sensing member within the annulus zone of a well to determine the level of debris in the well. When debris accumulates within the annulus zone, said sensing member returns a signal indicative of the level of such debris within the zone. The optical sensing member may include an optical fiber and/or any known optical sensors configured to determine strain, pressure, shape, force, and/or temperature.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] In the accompanying drawings, which form a part of the specification and are to be read in conjunction therewith and in which like reference numerals are used to indicate like parts in the various views:

[0007] FIG. 1 is a schematic representation of an exemplary injection well with sand debris detected by an optical cable;

[0008] FIG. 2 is a schematic representation of an exemplary injection well with a sensing cable attached to a movable sliding sleeve valve; and

[0009] FIG. 3 is schematic representation of an exemplary well with a sensing cable configured as a coil or spring which may be compressed by a weight of debris.

DETAILED DESCRIPTION

[0010] As illustrated in the accompanying drawings as discussed in detail below, the present disclosure relates to an optical position sensor for measuring the accumulation of debris in the annulus of a downhole well due to operation of tools or oilfield equipment such as packers, fishing tools, perforation gun, logging tools, sliding sleeves, inflatable packers, *etc.*. The present optical sensor can determine a level of such debris by providing various types of sensors, e.g., strain, shape, temperature, etc.

[0011] The present optical sensor may utilize known optical sensors, including but not limited to FBGs, extrinsic Fabry-Perot interferometers (EFPI), intrinsic Fabry-Perot interferometers (IFPI), Mach-Zehnder interferometers, Sagnac interferometers, Michelson type sensors, backscatter, *etc.*, and known sensing techniques including but not limited to optical frequency domain reflectometry (OFDR), optical time domain reflectometry (OTDR), optical coherence domain reflectometry (OCDR) and spectral interrogation. In some exemplary embodiments, sensors can be distributed throughout the optical fiber such that they are distinct or spatially separated from each other, such as distributed discrete sensors (DDxS), which include distributed discrete temperature sensors (DDTS), distributed discrete strain sensors (DDSS) or distributed discrete pressure sensors (DDPS). Alternatively, the sensors can be distributed throughout the optical fiber and are continuous, *i.e.*, not spatially separated from each other, such as distributed temperature sensors (DTS) or distributed strain sensors (DSS).

[0012] Additionally, the present optical sensor can also utilize optical fibers without sensors, *i.e.*, using Rayleigh backscattering as described in U.S. Patent No. 6,545,760, or Brillouin back scattering as disclosed in U.S. Patent No. 5,515,192, to ascertain the location of the tools. The present optical position sensor can also utilize the Raman effect for sensing changes temperature on the optical fiber by measuring the changed wavelength of emitted light as describes in U.S. Patent No. 5,765,948. These references are incorporated by reference in their entireties.

[0013] Referring to FIG. 1 and in accordance to one exemplary embodiment, at least one optical sensing cable 10 is disposed in wellbore 12. An unlimited number sensing cables 10 can be deployed depending on the particular application or need. Position sensors 10 are connected to a surface instrumentation unit (SIU) (not shown). Suitable optical cables include single mode fibers, multimode fibers, polarization maintaining fibers, plastic fibers and coreless fibers.

[0014] In the illustrated exemplary embodiment, sand or other debris 14 accumulates within the annulus of the well after injection is halted by closing the sliding sleeve valve 16. The optical sensing cable 10 is positioned such that the cable may

determine a level of debris within the well, e.g., to determine whether to perform some trigger action. In an exemplary embodiment, a temperature change is introduced into water within the well, and the difference in heat transfer in the water versus areas including debris are measured to give an indication of the level or uppermost position of such debris within the well. In another exemplary embodiment, the strain induced by the force of the accumulated debris, or the change in shape of the fiber, is determined to give an indication of the level or uppermost position of such debris within the well. The optical sensing cable 10 may be loose or, as in the exemplary embodiment illustrated by FIG. 2, be at least partially coiled.

[0015] Referring again to FIG. 2, optical sensor 10 can also be attached to a movable part, such as a sliding sleeve valve 16, and extended into an area where debris may collect. As the part moves, the motion induces strains on the cable. As is known in the art, the applied force stresses the sensor cable and when interrogated by an optical signal, the applied stress alters the signal returned to SIU. Accordingly, the level or uppermost position of debris within the well may be detected.

[0016] Referring still to FIG. 2, additionally or in the alternative, masses 20, such as catch basins, may be attached to the cable in one or more positions to cause debris weight to pull on the sensing cable, and the strains in the cable can be interpreted to indicate the debris level.

[0017] FIG. 3 illustrates another exemplary configuration, wherein a coil of sensing cable or spring of sensing cable (sensing cable on a spring) 22 is provided at an area of interest. Such coil or spring 22 may be placed to compress according to the weight of debris above may be measured.

[0018] FBGs, EFPI, an IFPI are some of the known optical sensors that react to stress/applied force or changes temperature and, thus, are exemplary sensors utilized herein. FBGs benefit from the ease in manufacturing of these gratings by photoetching. Other sensors such as silicon sensors that are optically sensitive to heat can be used. Any optical sensors that respond to stress/strain or temperature are suitable, including those

described above. DDxS sensors may be used, *e.g.*, DDTs, DDPS and/or DDSS sensors, as well as DTS or DSS type sensors.

[0019] In another exemplary embodiment, Rayleigh backscattering signals may be processed to ascertain a level of debris in the well (reference is made to the '760 patent previously incorporated above). Likewise, Brillouin backscattering and Raman effect can also be used.

[0020] The presently described invention advantageously provides accurate and reliable mechanisms for detecting unwanted accumulation of sand and other debris within a well bore, which left unchecked may cause operational problems.

[0021] While the present optical sensor is described in terms of exemplary embodiments, it is appreciated that numerous modifications and other embodiments may be devised by those skilled in the art. Therefore, it will be understood that the appended claims are intended to cover all such modifications and embodiments, which would come within the spirit and scope of the present invention.

[0022] What is claimed is:

CLAIMS:

1. An optical monitoring system comprising:

an optical fiber sensing member within the anullus of a well, the optical fiber sensing member configured to return a signal indicative of a level or amount of debris within the well.

2. An optical monitoring system in accordance with claim 1, wherein the optical fiber is configured to determine strain, pressure, shape, force, and/or temperature representative of a level or amount of debris within the well.

3. An optical monitoring system in accordance with claim 2, wherein the optical fiber is configured such that it extends through a portion of the well including debris as well as a portion of the well including water without significant amounts of debris, and wherein said well further comprises a mechanism for inducing a temperature change in the water such that the heat transfer in the debris and water mixture may be differentiated from the heat transfer in the water itself.

4. An optical monitoring system in accordance with claim 2, wherein the optical fiber is attached to a movable part within the well, which movable part, in combination with accumulated debris within the well overlying part of said optical fiber, induces strain on the fiber, which strain is indicative of a level of debris within the well.

5. An optical monitoring system in accordance with claim 4, wherein said fiber is loosely coiled around the annulus of the well from a top portion to a bottom portion, which bottom portion is configured to accumulate said debris.

6. An optical monitoring system in accordance with claim 4, wherein said fiber further comprises at least one mass adhered to said fiber and configured to pull on said fiber by accumulation of debris.

7. An optical monitoring system in accordance with claim 2, wherein the optical fiber is attached to at least one mass, which when in contact with accumulated debris within the well overlying part of said mass, induces strain on the fiber, which strain is indicative of a level of debris within the well.

8. An optical monitoring system in accordance with claim 7, wherein said mass is configured as a debris catch basin.

9. An optical monitoring system in accordance with claim 2, wherein the optical fiber is coiled beneath a debris collecting zone, wherein accumulated debris within the well overlying said coiled optical fiber, bears down on and compresses said fiber, and wherein said fiber is configured to determine the weight of said debris in accordance with compression of the coiled fiber.

10. An optical monitoring system in accordance with claim 9, wherein the optical fiber is coiled along a spring.

11. A method for measuring downhole ingress of debris comprising:

disposing an optical fiber sensing member within the a well zone subject to accumulation of debris; and

interrogating said optical fiber sensing member to return a signal indicative of a level or amount of debris within the well.

12. A method for measuring downhole ingress of debris in accordance with claim 11, comprising interrogating said optical fiber to determine strain, pressure, shape, force, and/or temperature representative of a level or amount of debris within the well.

13. A method for measuring downhole ingress of debris in accordance with claim 12, wherein the optical fiber is configured such that it extends through a portion of the well including debris as well as a portion of the well including water without significant amounts of debris, and further comprising inducing a temperature change in the water such that the heat transfer in the debris and water mixture is differentiated from the heat transfer in the water itself during interrogation of said fiber.

14. A method for measuring downhole ingress of debris in accordance with claim 12, wherein the optical fiber is attached to a movable part within the well, and further comprising actuating said movable part, which movable part, in combination with accumulated debris within the well overlying part of said optical fiber, induces strain on the fiber, which strain is indicative of a level of debris within the well.

15. A method for measuring downhole ingress of debris in accordance with claim 12, wherein the optical fiber is coiled beneath a debris collecting zone, wherein accumulated debris within the well overlying said coiled optical fiber, bears down on and compresses said fiber, and further comprising interrogating said fiber to determine the weight of said debris in accordance with compression of the coiled fiber.

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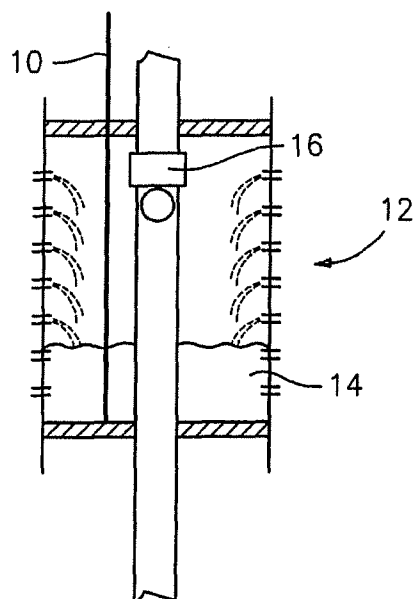


FIG. 1

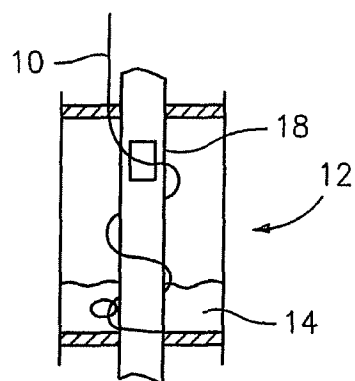


FIG. 2

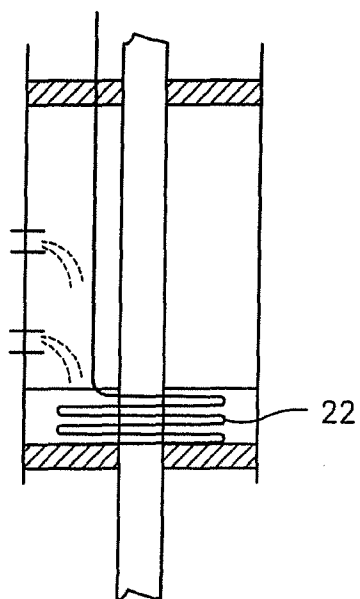


FIG. 3