

SYSTEMS AND METHODS FOR MONITORING SUBSEA WELLHEAD SYSTEMS

TECHNICAL FIELD

[0001] Embodiments of the subject matter disclosed herein generally relate to oil and gas wells, and, more specifically, to a wellhead monitoring system used to monitor wellheads utilized in oil and gas wells.

BACKGROUND

[0002] Certain oil and gas drilling sites may include control systems that may be provided to monitor the operational and environmental conditions of the oil and gas site. Generally, the control systems and/or other monitoring systems may be located at an above-sea or above-ground drilling rig, while the oil and gas well itself may be located deeply below the sea or deeply underground. Thus, the operators or other personnel at the drilling rig may not have access to real-time data regarding the operational and environmental conditions of the oil and gas wells below sea or below ground. Instead, the operators may have to rely upon an indirect interpolation of data derived from accelerometers placed on, for example, wellhead equipment at the oil and gas well. Such data may not indicate accurate real-time operational and environmental conditions of the wellhead equipment or other equipment utilized at the oil and gas well. It may be useful to provide systems to improve the monitoring of wellhead equipment at oil and gas wells.

SUMMARY OF THE INVENTION

[0003] In accordance with a first embodiment, a system includes a wellhead monitoring system. The wellhead monitoring system includes a processor configured to receive from a sensor a detection of one or more operating parameters associated with a wellhead disposed within a subsea environment. The sensor is coupled to the wellhead, and is configured to detect the one or more operating parameters within the subsea environment. The processor is configured to store the detection of the one or more operating parameters, and to generate an output based at least in part on the detection of the one or more operating parameters. The output includes an indication of an operational fatigue or an operational health of the wellhead.

[0004] In accordance with a second embodiment, a non-transitory computer-readable medium having computer executable code stored thereon includes instructions to cause a processor of a wellhead monitoring system to receive from a sensor a detection of one or more operating parameters associated with a wellhead disposed within a subsea environment. The sensor is coupled to the wellhead and is configured to detect the one or more operating parameters within the subsea environment. The code includes instructions to cause the processor to store the detection of the one or more operating parameters, and to cause the processor to generate an output based at least in part on the detection of the one or more operating parameters. The output includes an indication of an operational fatigue or an operational health of the wellhead.

[0005] In accordance with a third embodiment, a wellhead sensor and monitoring system includes a plurality of subsea sensors each coupled to a subsea wellhead and configured to detect one or more operating parameters associated with the subsea wellhead while disposed within a subsea environment and a subsea wellhead monitoring system coupled to each of the plurality of subsea sensors. The subsea wellhead monitoring system is configured to receive the detection of the one or more operating

parameters, store the detection of the one or more operating parameters, and to generate an output based at least in part on the detection of the one or more operating parameters. The output includes an indication of an operational fatigue or an operational health of the subsea wellhead.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate one or more embodiments and, together with the description, explain these embodiments. In the drawings:

[0007] FIG. 1 is an embodiment of a subsea oil and well system including a wellhead, a sensor, and a wellhead monitoring system, in accordance with the present embodiments;

[0008] FIG. 2 is a detailed embodiment of the wellhead, the sensor, and the wellhead monitoring system of FIG. 1, in accordance with the present embodiments; and

[0009] FIG. 3 is a flow diagram illustrating an embodiment of a process useful in providing improved monitoring of wellhead equipment at oil and gas wells, in accordance with the present embodiments.

DETAILED DESCRIPTION

[0010] The foregoing aspects, features, and advantages of the present embodiments will be further appreciated when considered with reference to the following description of preferred embodiments and accompanying drawings, wherein the reference numerals represent like elements. In describing the preferred embodiments of the technology illustrated in the appended drawings, specific terminology will be used for the sake of clarity. However, the technology is not intended to be limited to the specific

terms used, and it is to be understood that each specific term includes equivalents that operate in a similar manner to accomplish a similar purpose.

[0011] One or more specific embodiments of the invention will be described below. In an effort to provide a concise description of these embodiments, all features of an actual implementation may not be described in the specification. It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which may vary from one implementation to another. Moreover, it should be appreciated that such a development effort might be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure.

[0012] When introducing elements of various embodiments of the invention, the articles "a," "an," "the," and "said" are intended to mean that there are one or more of the elements. The terms "comprising," "including," and "having" are intended to be inclusive and mean that there may be additional elements other than the listed elements.

[0013] With the foregoing in mind, it may be useful to describe an embodiment of a subsea oil and well system, such as an example subsea oil and well system 10 illustrated in FIG. 1. In certain embodiments, the gas subsea oil and well system 10 may include a number of oil and gas drilling rigs 14, 16, and 18 that may be constructed within a large body of water 12 (e.g., ocean, sea, gulf). For example, in certain embodiments, the oil and gas drilling rigs 14, 16, and 18 may include one or more platforms situated within the large body of water 12 (e.g., ocean, sea, gulf) to support drilling of oil, gas, and/or other natural resources that may be within a subsea environment 22 or underneath the floor of the body of water 12. In certain embodiments, each of the drilling rigs 14,

16, and 18 may include a central control system 20 (e.g., human machine interface [HMI] or similar system) that may allow oil and gas drilling personnel (e.g., operators, engineers, technicians, and so forth) to monitor the operational and environmental conditions beneath the surface of the body of water 12.

[0014] In certain embodiments, as further depicted in FIG. 1, pipes 24 and 26 may extend from the drilling rigs 16 and 18 to wellheads 28 and 30, respectively. In certain embodiments, the wellheads 28 and 30 may each include valve or other mechanical device that may be used, for example, to seal, control and monitor one or more oil and gas wells within the subsea environment 22. For example, in certain embodiments, the wellheads 28 and 30 may be provided to prevent a blowout (e.g., uncontrolled release of crude oil and/or natural gas from the wells).

[0015] In certain embodiments, as depicted in FIG. 1 and as will be further appreciated with respect to FIG. 2, each of the wellheads 28 and 30 may include sensors 32 that may be coupled to each of the wellheads 28 and 30. For example, in certain embodiments, the sensors 32 may each include giant magneto-resistive (GMR) sensors, tunnel magneto-resistive (TMR) sensors, pressure sensors (e.g., to measure annulus pressure), temperature sensors (e.g., to measure annulus temperature), vibration sensors, level sensors (e.g., cement level and quality sensors detecting cement and fluid level and quality based on electromagnetic [EM] pulses, gamma ray detections, radio frequency identification [RFID], acoustics, fiber optics, and so forth), flow sensors, and/or any of various types of sensors that may be useful detecting or determining, for example, inclination (e.g., by accelerometers that may be coupled to the wellheads 30 and 32), cement level and quality, oil and/or gas levels, pressure, temperature, annulus pressure, annulus temperature, vibration, clearance (e.g., distance between stationary and rotating components), flow data, load data, and other operational and environmental data associated with the wellheads 30 and 32 and the oil and gas wells. Specifically, in

some embodiments, the aforementioned data captured or detected by the sensors 32 provided to a wellhead monitoring system 34 for processing and storage (e.g., temporary and/or long-term storage).

[0016] For example, as illustrated, the wellhead monitoring system 34 may include a processor 36 and a memory 38, and, in one embodiment, may include battery-powered system useful in processing and storing data over any period of time (e.g., minutes, hours, days, weeks, months, years) while remaining positioned at the wellheads 30 and 32 within the subsea environment 22. The processor 36 may include a general processor, an application-specific integrated chip (ASIC), a microcontroller unit (MCU), system-on-chip (SoC), or other processor that may be used to process operational and environmental data (e.g., inclination (e.g., by accelerometers that may be coupled to the wellheads 30 and 32), cement level, pressure, temperature, annulus pressure, annulus temperature, vibration, clearance, flow data, load data, and so forth) associated with the wellheads 30 and 32 and/or the oil and gas wells.

[0017] In certain embodiments, the processor 36 may be used to generate an indication of the remaining fatigue life, peak loads, and other operational and/or environmental conditions of the wellheads 28 and 30 based on the sensed operational data measured directly by the sensors 32. For example, as will be described in further detail with respect to FIG. 2, the processor 36 of the wellhead monitoring system 34 may receive data from the sensors 32 directly attached at a number predetermined wellhead 28, 30 locations, well locations, high stress locations on the conductors 24, 26 and casing below the wellheads 28, 30.

[0018] In certain embodiments, the processor 36 of the wellhead monitoring system 34 may then store the data collected by the sensors 32 to the memory 38 of the wellhead monitoring system 34 for retrieval after some period of time (e.g., using the memory 38 of the wellhead monitoring system 34 to

store hours, days, weeks, months, or years of sensor 32 data, all while the sensors 32 and wellhead monitoring system 34 remain within the subsea environment 22). In another embodiment, in addition to storing the sensor 32 data to the memory 38 for later retrieval, the processor 36 of the wellhead monitoring system 34 may transmit the received sensor 32 data to, for example, the central control system 20 located at one or more of the oil and gas rigs 14, 16, or 18. In this way, the present techniques may provide personnel (e.g., operators, engineers, technicians) at the oil and gas rigs 14, 16, or 18 with useful information pertaining to wellheads 28 and 30 such as remaining fatigue life and peak loads measured directly by the sensors 32 during, for example, drilling and production operations.

[0019] Turning now to FIG. 2, which illustrates a detailed embodiment of the wellhead monitoring system 34 and, for example, the wellhead 28. It should be appreciated that the wellhead 28 is illustrated in FIG. 2 merely for the purpose of illustration. In actual implementation, the wellhead 28 may be one of any number of wellheads that may be operational within the subsea environment 22. Furthermore, the wellhead 28 may include any number of sensors 32. For example, as depicted in FIG. 2, in one or more embodiments, the wellhead 28 may include one or more packs of sensors 32 that may be disposed, for example, around the casing 44 of the wellhead 28 to measure cement level and quality, oil and/or gas levels, pressure, temperature, annulus pressure, annulus temperature, vibration, clearance (e.g., distance between stationary and rotating components), flow data, load data, and other operational and environmental data associated with the wellheads 30 and 32 and the oil and gas wells.

[0020] Indeed, as further depicted in FIG. 2, the one or more packs of sensors 32 may be disposed along high stress locations of the wellhead(s) 28, 30 such as the high pressure housing 38, the low pressure housing 40, the casing 44, the conductor pipe(s) 24, 26, and the connector 46. It should be appreciated that certain portions (e.g., the high pressure housing 38, the low pressure housing 40, the casing 44) of the wellhead(s) 28, 30 may, in some embodiments, be pre-magnetized in a place in which

the sensor 32 is to be placed are to be located to avoid any possibility of direct bonding to the metal to the portions of the wellhead(s) 28, 30. Furthermore, in one embodiment, the sensors 32 may be placed in a protective enclosure and disposed onto the wellhead(s) 28, 30 before the wellhead(s) 28, 30 are submerged into the subsea environment 22 to protect the sensors 32 from adverse environmental conditions in and/or about the oil and gas wells.

[0021] As previously noted, the processor 36 of the wellhead monitoring system 34 may then store the data collected by the sensors 32 to the memory 38 of the wellhead monitoring system 34 for retrieval after some period of time. In certain embodiments, based on the data detected by the sensors 32 and stored via the wellhead monitoring system 34, the processor 36 of the wellhead monitoring system 34, or, in another embodiment, the central control system 20 may be used to generate and predict an operational fatigue life or an operational health (e.g., remaining operational life or operational health before either maintenance or replacement of one or more components of the wellheads 28, 30) of the high pressure housing 38, the low pressure housing 40, the casing 44, the conductor pipe(s) 24, 26, and the connector 46, and, by extension, the wellhead(s) 28, 30.

[0022] In certain embodiments, as further illustrated by FIG. 2, the processor 36 of the wellhead monitoring system 34 may transmit the received sensor 32 data to, for example, the central control system 20 located at one or more of the oil and gas rigs 14, 16, or 18 via a wired communication connection (e.g., ultrasonic communication channel or other acoustic communication channel). In another embodiment, as further illustrated by FIG. 2, the processor 36 of the wellhead monitoring system 34 may transmit the received sensor 32 data to, for example, the central control system 14 located at one or more of the oil and gas rigs 14, 16, or 18 via a wired communication connection to a remotely operated underwater vehicle (ROV) system 48. For example, by communicating the sensor 32 data to the central control system 14 located at one or more of the oil and gas rigs 14,

16, or 18 may allow for immediate verification of the loading and fatigue or health conditioning of the wellhead(s) 28, 30.

[0023] In one embodiment, the ROV system 48 may be coupled between the central control system 20 and the wellhead monitoring system 34 via an ROV umbilical cable useful in transferring information within the subsea environment 22 without being compromised due to the subsea environmental conditions. In another embodiment, the ROV system 48 may be coupled to the central control system 20 via the ROV umbilical cable and coupled to the wellhead monitoring system 34 via a wireless communication connection (e.g., via optical communication transmission or via an inductively coupled hot stab). In this way, the present techniques may provide personnel (e.g., operators, engineers, technicians) at the oil and gas rigs 14, 16, or 18 with useful information pertaining to wellheads 28 and 30 such as remaining fatigue life or operational health and peak loads measured directly by the sensors 32 during, for example, drilling and production operations.

[0024] Turning now to FIG. 3, a flow diagram is presented, illustrating an embodiment of a process 50 useful in providing improved monitoring of wellhead equipment at oil and gas wells, by using, for example, the wellhead monitoring system 34 depicted in FIGS. 1 and 2. The process 50 may include code or instructions stored in a non-transitory computer-readable medium (e.g., the memory 46) and executed, for example, by the processor 36 included in the wellhead monitoring system 34. The process 50 may begin with the wellhead monitoring system 34 receiving (block 52) system operating parameters associated with the subsea wellhead(s) 28, 30. For example, as discussed above with respect to FIGS. 1 and 2, the wellhead monitoring system 34 may receive one or more indications of the operating parameters (e.g., cement level and quality, oil and/or gas levels, pressure, temperature, annulus pressure, annulus temperature, vibration, clearance, flow data, load data, and so forth) of the wellhead(s) 28, 30 detected via the sensors 32.

[0025] The process 50 may then continue with the wellhead monitoring system 34 collecting and storing (block 54) the system operating parameters at the wellhead(s) 28, 30. For example, as noted above with respect to FIG. 2, the wellhead monitoring system 34 may store the data collected by the sensors 32 to the memory 38 of the wellhead monitoring system 34 for retrieval after some period of time (e.g., using the memory 38 of the wellhead monitoring system 34 to store hours, days, weeks, months, or years of sensor 32 data, all while the sensors 32 and wellhead monitoring system 34 remain within the subsea environment 22). The process 50 may then continue with the wellhead monitoring system 34 transmitting (block 56) the system operating parameters to the above-sea central control system 20 located, for example, at one or more of the oil and gas rigs 14, 16, or 18.

[0026] The process 50 may then conclude with the wellhead monitoring system 34, or, in another embodiment, the central control system 20 determining (block 58) an operational fatigue or an operational health of the wellhead(s) 28, 30. For example, as noted above with respect to FIG. 2, the wellhead monitoring system 34 and/or the central control system 20 may be used to generate an indication of the remaining operational fatigue life, peak loads, and other operational and/or environmental conditions of the wellheads 28, 30 based on the sensed operational data measured directly by the sensors 32. In this way, the present techniques may provide personnel (e.g., operators, engineers, technicians) at the oil and gas rigs 14, 16, or 18 with useful information pertaining to wellheads 28 and 30 such as remaining fatigue life or operational health and peak loads measured directly by the sensors 32 during, for example, drilling and production operations.

[0027] This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other

examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal language of the claims.

[0028] Although the features and elements of the present exemplary embodiments are described in the embodiments in particular combinations, each feature or element may be used alone without the other features and elements of the embodiments or in various combinations with or without other features and elements disclosed herein.

CLAIMS

1. A system, comprising:

a wellhead monitoring system, comprising:

a processor configured to:

receive from a sensor pack a detection of one or more operating parameters associated with a wellhead disposed within a subsea environment, wherein the sensor pack includes sensors disposed around and coupled to a casing of the wellhead, and configured to detect the one or more operating parameters within the subsea environment;

store the detection of the one or more operating parameters; and

generate an output based at least in part on the detection of the one or more operating parameters, wherein the output comprises an indication of an operational fatigue or an operational health of the wellhead.
2. The system of claim 1, wherein the processor is configured to receive the detection of the one or more operating parameters within the subsea environment.
3. The system of claim 1, wherein the processor is configured to receive a detection of a cement level parameter, a cement quality parameter, a fluid level parameter, a pressure parameter, temperature parameter, a vibration parameter, a clearance parameter, a flow parameter, a load parameter, or any combination thereof, as the detection of the one or more operating parameters.

4. The system of claim 1, wherein the processor is configured to receive a detection of an annulus pressure of the wellhead and an annular temperature of the wellhead as the detection of the one or more operating parameters.
5. The system of claim 1, wherein the sensors comprise a giant magneto-resistive (GMR) sensor.
6. The system of claim 1, wherein the sensors comprise a tunnel magneto-resistive (TMR) sensor.
7. The system of claim 1, wherein the processor is configured to generate the output during a drilling operation of the wellhead.
8. The system of claim 1, wherein the processor is configured to generate the output during a production operation of the wellhead.
9. The system of claim 1, wherein the processor is configured to store the detection of the one or more operating parameters at the wellhead within the subsea environment.
10. The system of claim 1, wherein the processor is configured to transmit the stored detection of the one or more operating parameters to a central control system at an above-sea location.
11. A non-transitory computer-readable medium having computer executable code stored thereon, the code comprising instructions to:
 - cause a processor of a wellhead monitoring system to receive from a sensor pack a detection of one or more operating parameters associated with a wellhead disposed within a subsea environment, wherein the sensor pack includes sensors disposed around and coupled

to a casing of the wellhead, and configured to detect the one or more operating parameters within the subsea environment;

cause the processor to store the detection of the one or more operating parameters; and

cause the processor to generate an output based at least in part on the detection of the one or more operating parameters, wherein the output comprises an indication of an operational fatigue or an operational health of the wellhead.

12. The non-transitory computer-readable medium of claim 11, wherein the code comprises instructions to cause the processor to generate the output during a drilling operation of the wellhead.
13. The non-transitory computer-readable medium of claim 11, wherein the code comprises instructions to cause the processor to generate the output during a production operation of the wellhead.
14. The non-transitory computer-readable medium of claim 11, wherein the code comprises instructions to cause the processor to store the detection of the one or more operating parameters at the wellhead within the subsea environment.
15. The non-transitory computer-readable medium of claim 11, wherein the code comprises instructions to cause the processor to transmit the stored detection of the one or more operating parameters to a central control system at an above-sea location.
16. The non-transitory computer-readable medium of claim 15, wherein the code comprises instructions to cause the central control system to generate an output comprising an indication of the operational fatigue or the operational health of the wellhead.

17. A wellhead sensor and monitoring system, comprising:

a pack of subsea sensors each coupled to a casing of a subsea wellhead and configured to detect one or more operating parameters associated with the subsea wellhead while disposed within a subsea environment; and

a subsea wellhead monitoring system coupled to each sensor of the pack of subsea sensors, wherein the subsea wellhead monitoring system is configured to:

receive the detection of the one or more operating parameters;

store the detection of the one or more operating parameters; and

generate an output based at least in part on the detection of the one or more operating parameters, wherein the output comprises an indication of an operational fatigue or an operational health of the subsea wellhead.

18. The wellhead sensor and monitoring system of claim 17, wherein the pack of subsea sensors comprises a plurality of giant magneto-resistive (GMR) sensors.

19. The wellhead sensor and monitoring system of claim 17, wherein the pack of subsea sensors comprises a plurality of tunnel magneto-resistive (TMR) sensors.

20. The wellhead sensor and monitoring system of claim 17, wherein the pack of subsea sensors are configured to be disposed along a high pressure housing, a low pressure housing, a connector, or a combination thereof, of the subsea wellhead.