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(54) Apparatus and methods for well cementing

(57) An apparatus for performing managed pressure cementing operations includes at least one pressure sensor (101) attached to a tubular body, a downhole telemetry system (102), a surface telemetry system (103) and a managed pressure drilling interface (104). Downhole pressure data may be transmitted from the downhole telemetry system to the surface telemetry system by mud pulse telemetry. Pressure sensors may be installed on the outside of a tubular body, on the inside a tubular body or both.

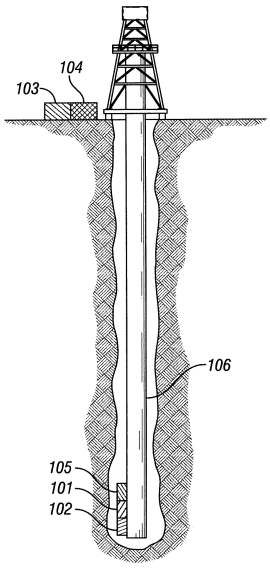

FIG. 1

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Description

BACKGROUND

[0001] The statements in this section merely provide background information related to the present disclosure and may not constitute prior art.

[0002] The present disclosure broadly relates to systems and methods for controlling annular fluid pressures in a subterranean well during cementing operations.

[0003] Managed pressure drilling (MPD) is a general oilfield term that refers to techniques for achieving improved control of annular fluid pressures. During conventional drilling, the bottomhole pressure (BHP) may vary widely due to friction-pressure changes and the concentration of cuttings in the drilling fluid. MPD minimizes BHP fluctuations by intervening at different points, including varying the backpressure applied to the annulus, changing the hydrostatic pressure of the fluid column and adjusting the mud pump rate.

[0004] MPD techniques allow operators to drill through formations in which the pore-and fracture pressures are very close, or in deviated sections in which, to maintain wellbore stability, annular pressures may be very close to fracture pressures. Additionally, MPD may be used to drill underbalanced or "at balance." Other benefits of the MPD technique may include increased rate of penetration (ROP) and earlier kick detection.

[0005] MPD is often complemented by a technique called pressure-while-drilling (PWD). PWD comprises attaching a tool to the bottomhole assembly (BHA) that is capable of measuring annular fluid pressure and transmitting the data to the surface using available telemetry. This reduces uncertainties related to BHP values, which are normally estimated or simulated from surface-pressure data, pump rates, wellbore-fluid density and rheological properties.

[0006] Cementing operations have been performed under the MPD regime, using the same principles and equipment, but the associated challenges are such that MPD may be used as a last resort. Since there are more fluids in the wellbore during cementing, with different properties, it is more difficult to predict downhole pressures based on surface measurements. Additionally, there are very few methods to measure downhole pressures during cementing operations.

SUMMARY

[0007] The present disclosure reveals apparatuses and methods by which downhole pressures may be controlled during cementing operations.

[0008] In an aspect, embodiments relate to apparatuses. One embodiment comprises at least one pressure sensor that is attached to a tubular body, a downhole telemetry system capable of transmitting data to a surface location and receiving data from the surface location, a surface telemetry system capable of receiving data from the downhole telemetry system and transmitting data to the downhole telemetry system, and a managed pressure drilling interface capable of receiving data from the surface telemetry system and transmitting data to the surface telemetry system.

[0009] In a further aspect, embodiments relate to methods for cementing a subterranean well having a borehole. At least one pressure sensor is attached to a tubular body, and the tubular body is lowered into the borehole. A downhole telemetry system is installed in the wellbore that is capable of transmitting data to a surface location and receiving data from the surface location. A surface telemetry system is installed that is capable of receiving data from the downhole telemetry system and transmitting data to the downhole telemetry system. A managed pressure drilling system is installed that is capable of receiving data from the surface telemetry system and transmitting data to the surface telemetry system. A pumpable and settable sealant is prepared and then placed into the well.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Figure 1 shows a diagram of the disclosed apparatus.

DETAILED DESCRIPTION

[0011] The present disclosure will be described in terms of treatment of vertical wells, but is equally applicable to wells of any orientation. The disclosure will be described for hydrocarbon-production wells, but it is to be understood that the disclosed methods can be used for wells for the production of other fluids, such as water or carbon dioxide, or, for example, for injection or storage wells. It should also be understood that throughout this specification, when a concentration or amount range is described as being useful, or suitable, or the like, it is intended that any concentration or amount within the range, including the end points, is to be considered as having been stated. Furthermore, each numerical value should be read once as modified by the term "about" (unless already expressly so modified) and then read again as not to be so modified unless otherwise stated in context. For example, "a range of from 1 to 10" is to be read as indicating each possible number along the continuum between about 1 and about 10. In other words, when a certain range is expressed, even if a few specific data points are explicitly identified or referred to within the range, or even when no data points are referred to within the range, it is to be understood that the Applicants appreciate and understand that any data points within the range are to be considered to have been specified, and that the Applicants have possession of the entire range points within the range.

[0012] In this disclosure, the tubular body may be any string of tubulars that may be run into the wellbore and at least partially cemented in place. Examples include

casing, liner, solid expandable tubular, production tubing, coiled tubing and drill pipe.

[0013] In an aspect, embodiments relate to apparatuses. One embodiment comprises at least one pressure sensor that is attached to a tubular body, a downhole telemetry system capable of transmitting data to a surface location and receiving data from the surface location, a surface telemetry system capable of receiving data from the downhole telemetry system and transmitting data to the downhole telemetry system, and a managed pressure drilling interface capable of receiving data from the surface telemetry system and transmitting data to the surface telemetry system.

[0014] In a further aspect, embodiments relate to methods for cementing a subterranean well having a borehole and a downhole pressure. At least one pressure sensor is attached to a tubular body, and the tubular body is lowered into the borehole. A downhole telemetry system is installed in the wellbore that is capable of transmitting data to a surface location and receiving data from the surface location. A surface telemetry system is installed that is capable of receiving data from the downhole telemetry system and transmitting data to the downhole telemetry system. A managed pressure drilling system is installed that is capable of receiving data from the surface telemetry system and transmitting data to the surface telemetry system. A pumpable and settable sealant is prepared and then placed into the well.

[0015] The viscosity of the sealant during placement may be lower than 1000 cP at a shear rate of 100 s^{-1}. The sealant composition may comprise inorganic materials including portland cement, calcium aluminate cement, fly ash, blast furnace slag, lime/silica blends, zeolites, magnesium oxychloride, geopolymers or chemically bonded phosphate ceramics or combinations thereof. The sealant composition may comprise organic materials including epoxy resins, furan resins, polyester resins or vinyl ester resins or combinations thereof.

[0016] For both aspects, a first component of the apparatus (shown in Fig. 1) is a pressure sensor 101 that is attached to the tubular body at a certain depth, prior to running in the borehole. The sensor may measure the downhole pressure along the outside of the tubular body (i.e., in the annular region between the tubular body and the borehole wall). Pressure measurements may be performed anytime during the period that the sensor spends in the well, including the following operations: running the tubular body, pre-job circulation, cement placement, post-job circulation, tubular expansion, waiting-on-cement (WOC) time and static periods in between. The pressure sensor may be attached to a memory device 105 that allows pressure measurements to be recorded even when data transmission is not possible (e.g., when mud pulse telemetry is the communication mechanism and the fluid is not being circulated).

[0017] The depth to which the sensor 101 is run may be selected according to adjacent geological parameters, tubular body properties, operational factors or other considerations. Multiple sensors may be placed along the tubular body string to allow measurements at several depths.

[0018] For both aspects, a second component of the apparatus is a downhole telemetry system 102 that transfers measured data to the surface. Annular mud pulse telemetry may be employed to send the data. The technique performs the required encoding and manages other aspects of communication with the surface. It is also capable of responding to commands from surface components, known as downlinking. Downlinked commands may be related to flow control and settings of the signal processing unit. Annular mud pulse telemetry may be complemented or replaced, if environmental and operating conditions permit, by other forms of telemetry including tubular mud pulse, guided electromagnetic waves and wired pipe. The downhole telemetry system may further comprise a signal processing unit that may perform functions including filtering, averaging and compressing data.

[0019] For both aspects, a memory device **105** may be integrated into the downhole telemetry system. The device may be used for buffering, may serve as the operational memory for the signal processing unit and may perform continuous data recording. The memory device may be deployed such that memory device itself, or the recorded content, may be retrieved-even after the rest of the downhole components are cemented in place. The retrieval may be performed by ordinary well intervention techniques.

[0020] For both aspects, multiple downhole telemetry operations may be run on the same string. If annular mud pulse telemetry is used and the sensor is exposed to the annulus, the telemetry unit may be placed at the bottom of the tubular body with transducers connected to the unit.

[0021] Multiple sensors may or may not share the same telemetry. Sensors that measure parameters other than pressure are included in the present disclosure, for example temperature sensors, chemical sensors, acoustic sensors, strain gauges. electrical conductivity sensors and other devices known in the art. Such devices may allow operators to monitor the properties of downhole fluids.

[0022] For both aspects, a third component of the apparatus is a surface telemetry system **103.** The surface telemetry system receives data sent from the downhole telemetry system **102,** decodes it and sends it to a managed pressure drilling (MPD) interface **104.** If annular mud pulse telemetry is being employed, the equipment is installed in the well annulus. For optimal signal strength, the equipment may be placed upstream from MPD intervention points (e.g., chokes, subsea pumps, etc.). For other downhole telemetry systems, the appropriate sensors may be installed according to normal practice provided they do not interfere with MPD operations. The surface telemetry system may be able to send downlink commands to the downhole telemetry system and may communicate with more than one downhole telem-

etry sensor.

[0023] For both aspects, a fourth component of the apparatus is a managed pressure drilling (MPD) interface **104.** A first function of the MPD interface is to act as a physical connection between the surface telemetry system and the MPD system, supplying the measured downhole pressure to the MPD system. A second function is to perform further data processing prior to forwarding it to the MPD system. Such data processing may include filtering, averaging, error correction, extrapolation and interpolation.

[0024] A delay (dead time) may be introduced into a MPD control loop. If the dead-time compensation of the MPD system cannot be adjusted to match the dead time, a predictive compensation may be applied as part of the data processing. If well control and borehole stability information are provided to the MPD interface, the interface may be able to change the set point for the MPD system. Thus, compensations may be made for data transmission lags.

[0025] For both aspects, the downhole components of the apparatus may be run into the borehole together with the tubular body and cemented in place (with the possible exception of the memory unit). This deployment procedure may allow extending the application of the downhole components from the time the tubular body is run into the wellbore and throughout a period during which measured data can be retrieved.

[0026] For both aspects, downhole components of the apparatus may be battery powered. The battery life may be sufficient to supply power to the components during the period between installation and cementing in place.

[0027] For both aspects, sensors may be placed on the outside of the tubular body, on the inside of the tubular body or both.

[0028] Although various embodiments have been described with respect to enabling disclosures, it is to be understood that this document is not limited to the disclosed embodiments. Variations and modifications that would occur to one of skill in the art upon reading the specification are also within the scope of the disclosure, which is defined in the appended claims.

Claims

1. An apparatus, comprising:

(i) at least one pressure sensor that is attached to a tubular body;
(ii) a downhole telemetry system capable of transmitting data to a surface location and receiving data from the surface location;
(iii) a surface telemetry system capable of receiving data from the downhole telemetry system and transmitting data to the downhole telemetry system; and
(iv) a managed pressure drilling interface capable of receiving data from the surface telemetry system and transmitting data to the surface telemetry system.

2. The apparatus of claim 1, wherein the at least one pressure sensor is mounted on an outside surface of the tubular body, an inside surface of the tubular body or both.

3. The apparatus of claim 1 or 2, wherein the pressure sensor is attached to a memory device.

4. The apparatus of any one of claims 1-3, wherein annular mud pulse telemetry, tubular mud pulse, guided electromagnetic waves or wired pipe or a combination thereof are applied to allow communication between the downhole telemetry system and the surface telemetry system.

5. The apparatus of any one of claims 1-4, wherein the managed pressure drilling interface performs one or more functions selected from the group consisting of filtering, averaging, correcting, extrapolating and interpolating data.

6. The apparatus of any one of claims 1-5, wherein the at least one pressure sensor and the downhole telemetry system are battery powered.

7. A method for cementing a subterranean well having a borehole, comprising:

(i) attaching at least one pressure sensor to a tubular body and lowering the tubular body into the borehole;
(ii) installing a downhole telemetry system in the wellbore that is capable of transmitting data to a surface location and receiving data from the surface location;
(iii) installing a surface telemetry system capable of receiving data from the downhole telemetry system and transmitting data to the downhole telemetry system;
(iv) installing a managed pressure drilling interface capable of receiving data from the surface telemetry system and transmitting data to the surface telemetry system;
(v) preparing a pumpable and settable sealant; and
(vi) placing the sealant into the well.

8. The method of claim 7, further comprising:

(vii) using the downhole telemetry system to receive pressure data from the at least one pressure sensor;
(viii) using the downhole telemetry system to transmit the pressure data to the surface telem-

etry system;
(ix) using the surface telemetry system to transmit the pressure data to the managed pressure drilling interface;
(x) using the managed pressure drilling interface to analyze the pressure data; and
(xi) using the managed pressure drilling interface to issue commands for controlling the downhole pressure.

9. The method of claim 7 or 8, wherein techniques for controlling the downhole pressure comprise adjusting a circulation rate, adjusting wellbore fluid density or adjusting annular backpressure or a combination thereof.

10. The method of any one of claims 7-9, wherein the at least one pressure sensor is mounted on an outside surface of the tubular body, an inside surface of the tubular body or both.

11. The method of any one of claims 7-10, wherein the pressure sensor is attached to a memory device.

12. The method of any one of claims 7-11, wherein annular mud pulse telemetry, tubular mud pulse, guided electromagnetic waves or wired pipe or a combination thereof are applied to allow communication between the downhole telemetry system and the surface telemetry system.

13. The method of any one of claims 7-12, wherein the managed pressure drilling interface performs one or more functions selected from the group consisting of filtering, averaging, correcting, extrapolating and interpolating data.

14. The method of any one of claims 7-13, wherein the at least one pressure sensor and the downhole telemetry system are battery powered.

15. The method of any one of claims 7-14, wherein the at least one pressure sensor and the downhole telemetry system are cemented in place.

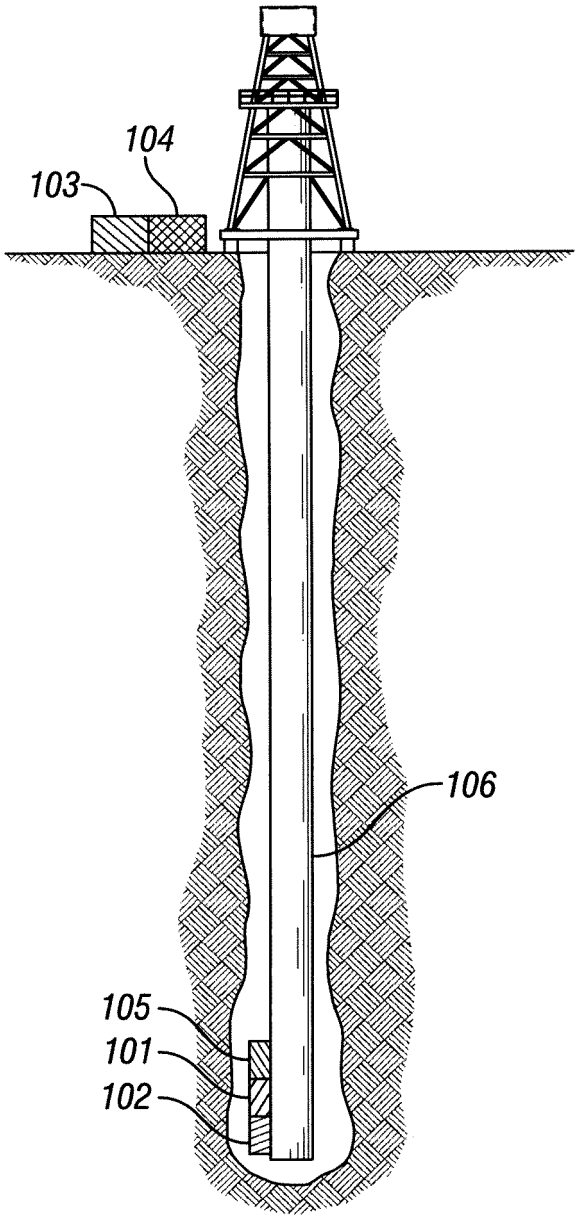

FIG. 1

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Application Number
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	19 January 2015	Hustedt, Bernhard

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X : particularly relevant if taken alone
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EUROPEAN SEARCH REPORT

Application Number
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