A system, method and apparatus for controlling a downhole operation is disclosed. A tool is operated to perform the downhole operation at a selected downhole location using a first value of an operation parameter of the tool. A magnetostrictive position sensor is used to determine a relative position along a section of a wellbore related to the operation being performed using the first value of the operation parameter. The determined relative position is compared to a selected threshold. The operation parameter is altered to a second value based on the comparison of the relative position to the selected threshold.
Generate an outgoing ultrasonic pulse along MS rod extending along work string or wellbore at a reference location.

Move the tool or equipment and the corresponding transducer.

Generate an outgoing ultrasonic pulse along MS rod extending along work string or wellbore at unknown position.

Receive reflected ultrasonic pulses from the ends of MS rod.

Determine the time of flight for the signals at the reference position.

Determine the time of flight for the signals received at the unknown position.

Receive reflected ultrasonic pulses from the ends of MS rod.

Compare time of flight for reference position to unknown position to determine position.

Alter a value of an operation parameter when the at least one position meets a selected criterion with respect to the selected threshold value.

Figure 3
500

Generate an outgoing ultrasonic pulse along MS rod extending along work string or wellbore at a reference location.

502

Receive reflected ultrasonic pulses from the ends of MS rod.

504

Determine the time of flight for the signals at the reference position.

506

Move the tool or equipment and the corresponding MS rod.

508

Generate an outgoing ultrasonic pulse along MS rod extending along work string or wellbore at unknown position.

510

Receive reflected ultrasonic pulses from the ends of MS rod.

512

Determine the time of flight for the signals received at the unknown position.

514

Compare time of flight for reference position to unknown position to determine position.

516

Alter a value of an operation parameter when the at least one position meets a selected criterion with respect to the selected threshold value.

518

Figure 5
Generate an outgoing ultrasonic pulse along MS rod extending along work string or wellbore with pin at a reference location.

Receive reflected ultrasonic pulses from the pin location of the MS rod.

Determine the time of flight for the signals at the reference position.

Move the tool or equipment and the corresponding pin.

Generate an outgoing ultrasonic pulse along MS rod extending along work string or wellbore with pin at unknown position.

Receive reflected ultrasonic pulses from the pin location of the MS rod.

Determine the time of flight for the signals received at the unknown position.

Compare time of flight for reference position to unknown position to determine position.

Alter a value of an operation parameter when the at least one position meets a selected criterion with respect to the selected threshold value.
Generate an outgoing ultrasonic pulse along MS rod extending along work string or wellbore with transducer at a reference location.

Receive reflected ultrasonic pulses from the pin location of the MS rod.

Determine the time of flight for the signals at the reference position.

Move the tool or equipment and the corresponding transducer.

Generate an outgoing ultrasonic pulse along MS rod extending along work string or wellbore with transducer at unknown position.

Receive reflected ultrasonic pulses from the pin location of the MS rod.

Determine the time of flight for the signals received at the unknown position.

Compare time of flight for reference position to unknown position to determine position.

Alter a value of an operation parameter when the at least one position meets a selected criterion with respect to the selected threshold value.

Figure 9
MAGNETOSTRICTIVE APPARATUS AND METHOD FOR DETERMINING POSITION OF A TOOL IN A WELBORE

BACKGROUND

[0001] Field of the Disclosure

[0002] The present invention is related to a method of controlling downhole operations and, in particular, a method of measuring positions used in control of equipment used in a wellbore.

[0003] Background of the Art

[0004] Various downhole operations, such as drilling, production, fracturing operations, etc., require monitoring and controlling position of equipment. In such applications, linear position sensors, which measure absolute distance along a motion axis, may be used. In order to control the position of downhole tools, such as hydraulic actuated equipment, an operator will monitor a position of the equipment. However, most current position sensing technologies, including Hall Effect position sensors, potentiometers, and linear variable differential transformer (LVDT) sensors, may not adequately cope with severe vibrations, high pressure, and high temperature. Current position sensing technologies may consequently age prematurely, often leading to insufficient performance for monitoring these various downhole tools and operations.

SUMMARY OF THE DISCLOSURE

[0005] In one aspect, the present disclosure provides an apparatus for use in a wellbore, the apparatus including: a movable tool; and a sensor associated with the tool, wherein the sensor includes: a transducer; at least one reflection element spaced from the transducer, wherein the transducer transmits at least one signal to the at least one reflection element and receives the at least one signal reflected from the at least one reflection element; and a sensor controller configured to determine a position of the tool utilizing the reflected at least one signal.

[0006] In another aspect, the present disclosure provides a method of determining a position in a wellbore, the method including: placing a moving tool in the wellbore; providing a sensor associated with the tool, wherein the sensor includes a transducer and at least one reflection element; transmitting at least one signal to the at least one reflection element via the transducer; receiving the at least one signal from the at least one reflection element via the transducer; and determining a position of the tool utilizing the reflected at least one signal.

[0007] In another aspect, the present disclosure provides a system for controlling a downhole operation, the system including: a moveable tool configured to perform the operation according to an operation parameter of the tool; a sensor associated with the tool, wherein the sensor includes: a transducer; at least one reflection element spaced from the transducer, wherein the transducer transmits at least one signal to the at least one reflection element and receives the at least one signal reflected from the at least one reflection element; and a sensor controller configured to determine a position of the tool utilizing the reflected at least one signal; and a controller configured to compare the position to a selected threshold; and after the operation parameter based on the comparison of the position to the selected threshold.

[0008] In yet another aspect, the present disclosure provides a system for use in a wellbore, the system including: a moveable tool; and an acoustic sensor coupled to the tool configured to determine the position of the tool in the wellbore.

[0009] Examples of certain features of the apparatus and method disclosed herein are summarized rather broadly in order that the detailed description thereof that follows may be better understood. There are, of course, additional features of the apparatus and method disclosed hereafter that will form the subject of the claims appended hereto.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The disclosure herein is best understood with reference to the accompanying figures in which like numerals have generally been assigned to like elements and in which:

[0011] FIG. 1 shows a downhole system that includes a position measurement system for controlling operation of the downhole system in an exemplary embodiment of the disclosure;

[0012] FIG. 2 shows an exemplary position sensor of the downhole system suitable for use in controlling downhole operations in an exemplary embodiment of the present disclosure;

[0013] FIG. 3 shows a flowchart illustrating a method of controlling operations downhole using position measurement using the exemplary position sensor of FIG. 2;

[0014] FIG. 4 shows another embodiment of a position sensor of the downhole system suitable for use in controlling downhole operations in another embodiment of the present disclosure;

[0015] FIG. 5 shows a flowchart illustrating a method of controlling operations downhole using position measurement using the embodiment of the position sensor of FIG. 4;

[0016] FIG. 6 shows another embodiment of a position sensor of the downhole system suitable for use in controlling downhole operations in another embodiment of the present disclosure;

[0017] FIG. 7 shows a flowchart illustrating a method of controlling operations downhole using position measurement using the embodiment of the position sensor of FIG. 6;

[0018] FIG. 8 shows another embodiment of a position sensor of the downhole system suitable for use in controlling downhole operations in another embodiment of the present disclosure; and

[0019] FIG. 9 shows a flowchart illustrating a method of controlling operations downhole using position measurement using the embodiment of the position sensor of FIG. 8.

DESCRIPTION OF THE EMBODIMENTS

[0020] FIG. 1 shows a downhole system 100 that includes a position measurement system for controlling operation of the downhole system 100 in an exemplary embodiment of the disclosure. The downhole system 100 includes a work string 102 disposed in a wellbore 132 formed in a formation 130. The work string 102 extends in the wellbore 132 from a surface location 104 to a downhole location 106. The work string 102 may include a drill string, a production string, a fracturing system including a multi-stage fracturing system, a perforation string, etc. A tool 108 for performing a downhole operation is conveyed to a selected depth of the wellbore by the work string 102. The tool 108 may be or contain a linear actuator, hydraulically actuated equipment, or may be another position sensitive downhole tool, for example. Further, the tool 108 may be a valve, sleeve, or other flow control
device, or a pneumatic cylinder control and may further be located in any suitable location. The tool 108 may be coupled to a control unit 110 via cable 136. Control unit 110 controls the tool 108 to perform various operations, such as drilling, fracturing or acid stimulation, perforation, production, etc. In various embodiments, the control unit 110 may be at a surface location 104 or at a suitable location in the work string 102. The control unit 110 includes a processor 112, a memory location or memory storage device 114 for storing data obtained from the downhole operation of the tool or values of operational parameters of the tool 108, and one or more programs 116 stored in the memory storage device 114. When accessed by the processor 112, the one or more programs 116 enable the processor 110 to perform the methods disclosed herein for controlling operation of the tool 108 using downhole position measurements. Position measurements may be displayed at display or monitor 140. The data may be stored downhole or may be sent to the surface without being stored downhole. Processing may occur downhole, upon the tool 108 at the surface location 104 or at both such locations. Thus, the methods disclosed herein may be performed in a closed-loop downhole system, in situ, and in real-time, or alternatively on the surface.

The work string 102 further, in non-limiting embodiment, includes at least one position sensor 120 for obtaining measurements of position of the tool 108. Multiple position sensors 120 may be included to obtain measurements of position of the tool 108. The position sensor 120 includes a magnetostrictive transducer 122 and a magnetostrictive sensing rod 124. The position sensor 120 may be coupled to a pulser 126 via cable 138. The pulser 126 may be coupled to send position data to control unit 110 to allow for closed loop operation of the tool 108. The pulser 126 may send signals to activate the position sensor 120 and receive from the position sensor 120 measurements suitable for determining a position relative to the magnetostriuctive sensing rod 124. The position measurements may be obtained for an actuated portion of tool 108 relative to stationary portion of tool 108, wellbore 132, relative to work string 102 or any other suitable reference point, in various embodiments. Details of the position sensor 120 are discussed below with respect to FIGS. 2-9.

FIG. 2 shows an exemplary position sensor 220 suitable for use in controlling downhole operations in an exemplary embodiments of the present disclosure. The position sensor 220 includes a magnetostrictive sensing rod 224 and a magnetostrictive transducer (MST) 222 coupled to the magnetostriuctive sensing rod 224. The magnetostriuctive sensing rod 224 may extend along a section of the work string (102, FIG. 1) and/or tool 108 (FIG. 1). The position sensor 220 may be suitable for determining a position along the magnetostriuctive sensing rod 224 via an ultrasonic pulse sent longitudinally along the magnetostriuctive sensing rod 224. In an exemplary embodiment, a diameter of the magnetostriuctive sensing rod 224 may be less than about 1 millimeter (mm) and the length of the magnetostriective sensing rod 224 may be varied according to the range to be measured. The magnetostriective sensing rod may be made of a material from Group IVB (such as Titanium), Group VIII (such as Rhenium), or Group VIIIb (such as Fe, Ni, Rhodium) in the periodic table of the elements or alloys, such as Vicalloy, stainless steel, nickel alloy and thoriated tungsten. Such materials may allow for desired operation and durability even in high temperature environments reaching up to 500 degrees Celsius. Sensing rod 224 may be fixed to portions 109 stationary relative to MST 222 to provide a reference for the position measurements. Sensing rod 224 need not be straight, and may be deformed to complex surfaces to measure positions at locations that are not co-linear. Sensing rod 224 may be formed to any suitable size.

The MST 222 includes a coil 204 contained within a housing 210. Housing 210 may be fixed to the moving portion of tool 108 to track the position thereof, relative to sensing rod 224. MST 222 may be coupled to magnetostriective rod 224 to allow translation of MST 222 without any direct contact with magnetostriective rod 224, allowing for less wear for both MST 222 and magnetostriective rod 224. Moving portion of tool 108 may move in direction 211, resulting in the movement of MST 222. A magnet 206 may be used along with signals in the coil 204 to excite and detect ultrasonic pulses in the magnetostriective sensing rod 224. The coil 204 and optional magnet 206 serve to transform current into an ultrasonic pulse and vice-versa. A portion 224a of the magnetostriective sensing rod 224 extends into the housing and portion 224b further extends through the hollow center of coil 204 without any contact with MST 222. In an exemplary embodiment, coil 204 may be wrapped around a spool with a hollow center, wherein portion 224a passes therethrough. Accordingly, the MST 222 can move freely along the sensing rod 224.

The magnet 206 is positioned outside coil 204 adjacent to a first side of the coil. As used herein, the “inside” or “interior” of the coil refers to the generally cylindrical volume between the turns of the coil and centered on axis 228, while the “outside” or “exterior” of the coil refers to the remaining volume which generally surrounds the coil and excludes the cylindrical interior volume.

The coil 204 is coupled to the pulser 226 via a connector or cable 138, which may be a coaxial connector, for example. Pulser 226 may be located downhole or at any remote location. The pulser 226 may provide power and/or electrical signals to the coil 204. The signal may, for example, be a pulse, a square wave, or any other suitable waveform with any suitable frequency. An electrical signal sent from the pulser 226 generates a changing magnetic field, causing magnetostriception at the portion 224a of the magnetostriective sensing rod 224 within the housing 210. The magnetostriective generates an outgoing ultrasonic pulse that propagates from the portion 224a along the magnetostriective sensing rod 224 in both directions away from the coil 204 towards each end of the magnetostriective sensing rod 224b and 224c.

As the outgoing ultrasonic pulse propagates along the magnetostriective sensing rod 224, each end of the sensing rod 224b, 224c acts as a reflection element that reflects the outgoing ultrasonic pulse back towards the MST 222. The reflected ultrasonic pulses that are received at the MST 224 produces an electrical signal in the coil 204 which is sent to the pulser 226.

As the position of the MST 222 changes relative to magnetostriective sensing rod 224 the distance from each end 224b, 224c changes accordingly. The velocity of sound for the signal propagating through the magnetostriective sensing rod 224 is known or determined through calibration procedures wherein time of flight of the signal is compared against a known distance. As noted above, the choice of the material for the magnetostriective rod affects the propagation of the acoustic wave through the sensing rod 224. In addition to having the desired acoustic velocity characteristics, the mate-
rial preferably has strong magnetostrictive characteristics, resistance to corrosion from materials which will be in contact with the magnetostrictive rod, and appropriate mechanical characteristics, such as hardness, strength, thermal expansion coefficient, etc. Thus, determining the travel time between generating a pulse at a first location (e.g., at coil 204) and receiving its reflection from the second or end locations (e.g., at each end 224b, 224c) may be used to determine a position of MST 222. A shorter distance reduces the travel time for the ultrasonic pulse between the first location and the second location. Therefore, the position may be determined by determining a travel time between generating the outgoing ultrasonic pulse and receiving a reflection from the ends of the sensing of the generated pulse (i.e., the travel time for the ultrasonic pulse between the first location and the second location), and comparing the determined time to a time interval for an ultrasonic pulse between the first location and the second location at a known reference position. While an acoustic signal is received from both ends of the magnetostrictive sensing rod 224b, 224c, in certain embodiments, only a single signal is needed to identify the position as described. In certain embodiments, signals received from both ends 224b, 224c may be used for error checking or other redundancy purposes. The position measurement derived may have an accuracy of 10 microns.

[0028] The pulser 226 may therefore obtain position measurements by generating an ultrasonic pulse along the magnetostrictive sensing rod 224. The position measurements may be used to determine the relative position of tool 108. The position measurements may be related to a downhole operation such as operation of the downhole tool 108. The control unit 110 may therefore process the position measurements and control an operation of tool 108 using the processed position measurements. Alternatively, the control unit 110 may store the position measurements at the memory storage device 114 for calculations at a later time.

[0029] In various embodiments, the control unit 110 may monitor the position of the tool 108 at the selected downhole location using the position sensor 220 described herein. In various embodiments, position limits may be set for controlling the use of the tool. The control unit 110 or processor may then compare at least one of the position measurements against a selected threshold and alter an operation parameter of the tool 108 or a downhole operation when the comparison meets a selected criterion. For example, the processor may determine that the position is greater than the selected threshold or that the position is less than the selected threshold and control the tool corresponding to results of the comparison. In one embodiment, when a downhole operation generates position changes above the selected threshold, an operation parameter of the tool may be altered from a first value to a second value in order to maintain the position changes below the selected threshold. In some cases, the tool 108 may be turned off or the downhole operation interrupted when the position changes above the selected threshold.

[0030] FIG. 3 shows a flowchart illustrating a method of controlling operations downhole using position measurement obtained using the position sensor 220 disclosed herein. In block 302, an outgoing ultrasonic pulse is generated by MST 222 along the magnetostrictive sensing rod with the MST 222 at a known reference position. The magnetostrictive sensing rod extends along the well string 102 or a depth interval in the wellbore 132. In block 304, reflected ultrasonic pulses are received at the pulser 226 from the reflective elements or ends of the magnetostrictive rod 224. In block 306, the received reflected ultrasonic pulses are used to determine the time of flight for the ultrasonic signals emitted at the reference position of the MST 222. In block 308, the equipment to be tracked is moved to an unknown location with MST 222 affixed thereto. In block 310 an outgoing ultrasonic pulse is generated by MST 222 along the magnetostrictive sensing rod. In block 312, reflected ultrasonic pulses are received at the pulser 226 from the reflective elements. In block 314, the received reflected ultrasonic pulses are used to determine the time of flight for the ultrasonic signals. In block 316, the time of flight for the reference position may be compared to the time of flight for the unknown position to determine the unknown position. Further processing may be performed by the pulser 226. In block 318, a value of an operational parameter of the tool of a downhole operation is altered when the at least one position meets a selected criterion with respect to the selected threshold value. A position measurement meeting the selected criterion may include the position measurement being greater than the selected threshold value or being less than the selected threshold value, in various embodiments.

[0031] FIG. 4 shows an alternative position sensor 420 suitable for use in controlling downhole operations in an exemplary embodiment of the present disclosure. The position sensor 420 includes a magnetostrictive sensing rod 424 and a magnetostrictive transducer (MST) 422 coupled to the magnetostrictive sensing rod 424. Compared to the previously contemplated position sensor 220, sensing rod 424 may be fixed to the moving portion of tool 108 to track the position of tool 108 relative to fixed MST 422 to provide a reference for the position measurements. Moving portion of tool 108 may move in direction 411, causing magnetostrictive rod 424 to move in the direction 411 of tool 108. Accordingly, the ends of magnetostrictive rod 424b, 424c serve as reflection elements that may be used to determine a relative position. The magnetostrictive sensing rod 424 may extend along a section of the work string (102, FIG. 1) and/or tool (108, FIG. 1). The position sensor 420 may be suitable for determining a position along the magnetostrictive sensing rod 424 via an ultrasonic pulse sent longitudinally along the magnetostrictive sensing rod 424. Sensing rod 424 need not be straight, and may be conformed to complex surfaces to measure positions at locations that are not coaxial.

[0032] The MST 422 includes a coil 404 contained within a housing 410. Housing 410 may be fixed to stationary portion 109, yet allow movement relative to sensing rod 424 without contact. A magnet 406 may be used along with signals in the coil 404 to excite and detect ultrasonic pulses in the magnetostrictive sensing rod 424. The coil 404 and optional magnet 406 serve to transform current into an ultrasonic pulse and vice-versa. A portion 424a of the magnetostrictive sensing rod 424 extends into the housing and portion 424a further extends through the hollow center of coil 404 without any contact with MST 422. In an exemplary embodiment, coil 404 may be wrapped around a spool with a hollow center, wherein portion 424a passes therethrough. Accordingly, the MST 422 can move freely along the sensing rod 424.

[0033] FIG. 5 shows a flowchart illustrating a method of controlling operations downhole using position measurement obtained using the position sensor 420 disclosed herein. In block 502, an outgoing ultrasonic pulse is generated by MST 422 along the magnetostrictive sensing rod with the sensing rod at a known reference position. The magnetostrictive sensing rod extends along the well string 102 or a depth interval.
in the wellbore 132. In block 504, reflected ultrasonic pulses are received at the pulser 426 from the reflective elements or ends of the magnetostrictive rod 424. In block 506, the received reflected ultrasonic pulses are used to determine the time of flight for the ultrasonic signals at the reference position of the rod 424. In block 508, the equipment to be tracked and the corresponding rod 424 move to an unknown position. In block 510 an outgoing ultrasonic pulse is generated along the magnetostrictive sensing rod 424 by MST 422. In block 512, reflected ultrasonic pulses are received from the reflective elements or the ends of rod 424 at the pulser 426. In block 514, the reflected ultrasonic pulses are used to determine the time of flight for the ultrasonic signals. In block 516, the time of flight for the reference position may be compared to the time of flight for the unknown position to determine the unknown position. In block 518, a value of an operational parameter of the tool of a downhole operation is altered when the at least one position meets a selected criterion with respect to the selected threshold value. A position measurement meeting the selected criterion may include the position measurement being greater than the selected threshold value or being less than the selected threshold value, in various embodiments.

[0034] FIG. 6 shows an exemplary position sensor 620 suitable for use in controlling downhole operations in an exemplary embodiment of the present disclosure. The position sensor 620 includes a magnetostrictive sensing rod 624 and a magnetostrictive transducer (MST) 622 in a fixed relationship. Position sensor 620 further includes a probe pin 640 slidably coupled to sensing rod 624. The magnetostrictive sensing rod 624 may extend along a section of the work string (102, FIG. 1) and/or tool (108, FIG. 1). The position sensor 620 may be suitable for determining a location of the probe pin 640 along the magnetostrictive sensing rod 624 via an ultrasonic pulse sent longitudinally along the magnetostrictive sensing rod 624. Position sensor 620 may be used in applications where the moving transducer of position sensor 220 or the moving rod of position sensor 420 may not be desired. Sensing rod 624 may be affixed to stationary portion 109 to provide a reference for the position measurements. Sensing rod 624 need not be straight, and may be conformed to complex surfaces to measure positions at locations that are not coaxial.

[0035] The MST 622 includes a coil 604 contained within a housing 610. Housing 610 may be fixed to stationary portion 109 along with sensing rod 424. A magnet 606 may be used along with signals in the coil 604 to excite and detect ultrasonic pulses in the magnetostrictive sensing rod 624. The coil 604 and optional magnet 606 serve to transform current into an ultrasonic pulse and vice-versa. A portion 624a of the magnetostrictive sensing rod 624 extends into the housing and portion 624a further extends through the hollow center of coil 604 without any contact with MST 622. In an exemplary embodiment, coil 604 may be wrapped around a spool with a hollow center, wherein portion 624a passes therethrough.

[0036] The sliding pin 640 is affixed to the moving portion of tool 108. Moving portion of tool 108 may move in direction 611 causing pin 640 to move in the same direction 611. The sliding pin 640 is in contact with sensing rod 624 at all times. The contact of the sliding pin 640 with sensing rod 624 causes elastic deformation of the cross section of sensing rod 624. In conjunction with MST 622, ultrasonic pulses are disturbed and reflected at the position of sliding pin 640 due to the change of cross section of the sensing rod 624. In this embodiment, sliding pin 640 may be considered a reflection element to allow a relative position to be determined. This reflection is received and processed by pulser 626 in a similar manner as described with respect to position sensor 220.

[0037] FIG. 7 shows a flowchart illustrating a method of controlling operations downhole using position measurement obtained using the position sensor 620 disclosed herein. In block 702, an outgoing ultrasonic pulse is generated by MST 622 along the magnetostrictive sensing rod 624 with the sliding pin 640 at a known reference position. The magnetostrictive sensing rod extends along the work string 102 or a depth interval in the wellbore 132. In block 704, reflected ultrasonic pulses are received at the pulser 626 from the reflective element or the portion of magnetostrictive rod 624 at the reference location where the sliding pin 640 is resident. Sliding pin 640 locally elastically deforms magnetostrictive rod 624 causing a reflection to propagate at the location of sliding pin 640. In block 706, the received reflected ultrasonic pulses are used to determine the time of flight for the ultrasonic signals at the reference position of the sliding pin 640. In block 708, the equipment to be tracked and corresponding sliding pin 640 are moved to an unknown location. In block 710 an outgoing ultrasonic pulse is generated by MST 622 along the magnetostrictive sensing rod. In block 612, reflected ultrasonic pulses from the portion of the magnetostrictive rod 624 at the position where the reflective element or sliding pin 640 is resident are received at the pulser 626. In block 714, the reflected ultrasonic pulses are used to determine the time of flight for the ultrasonic signals. In block 716, the time of flight for the reference position may be compared to the time of flight for the unknown position to determine the unknown position. In block 718, a value of an operational parameter of the tool of a downhole operation is altered when the at least one position meets a selected criterion with respect to the selected threshold value. A position measurement meeting the selected criterion may include the position measurement being greater than the selected threshold value or being less than the selected threshold value, in various embodiments.

[0038] FIG. 8 shows an alternative position sensor 820 suitable for use in controlling downhole operations in an exemplary embodiment of the present disclosure. The position sensor 820 includes a magnetostrictive sensing rod 824 and a magnetostrictive transducer (MST) 822 in a fixed relationship. Position sensor 820 further includes a probe pin 840 slidingly coupled to sensing rod 824. Compared to the previously contemplated position sensor 620, magnetostrictive sensing rod 824 and MST 822 may be fixed to the moving portion of tool 108 to track to the position of the tool 108 relative to fixed probe pin 840 to provide a reference for the position measurements. Moving portion of tool 108 may move in direction 811 of tool 108 relative to fixed portion 109 wherein probe pin 840 is fixed.

[0039] The magnetostrictive sensing rod 824 may extend along a section of the work string (102, FIG. 1) and/or tool (108, FIG. 1). The position sensor 820 may be suitable for determining a position of the magnetostrictive sensing rod 824 and MST 822 via an ultrasonic pulse sent longitudinally along the magnetostrictive sensing rod 824. Sensing rod 824 may be affixed to tool 108. Sensing rod 824 need not be straight, and may be conformed to complex surfaces to measure positions at locations that are not coaxial.

[0040] The MST 822 includes a coil 804 contained within a housing 810. Housing 810 may be fixed to tool 108 along with sensing rod 824. Moving portion of tool 108 may move in
direction 811 causing MST 822 and sensing rod 824 to move in the same direction 811. A magnet 806 may be used along with signals in the coil 804 to excite and detect ultrasonic pulses in the magnetostrictive sensing rod 824. The coil 804 and optional magnet 806 serve to transform current into an ultrasonic pulse and vice-versa. A portion 824a of the magnetostrictive sensing rod 824 extends into the housing and portion 824a further extends through the hollow center of coil 804 without any contact with MST 822. In an exemplary embodiment, coil 804 may be wrapped around a spool with a hollow center, wherein portion 824a passes therethrough.

The sliding pin 840 is affixed to the fixed portion 109. The sliding pin 840 is in contact with sensing rod 824 at all times. The contact of the sliding pin 840 with sensing rod 824 causes elastic deformation of the cross section of sensing rod 824. In conjunction with MST 822, ultrasonic pulses are disturbed and reflected at the position of sliding pin 840 due to the change of cross section of the sensing rod 824. In this embodiment, sliding pin 840 may be considered a reflection element to allow a relative position to be determined. This reflection is received and processed by pulser 826 in a similar manner as described with respect to position sensor 220.

FIG. 9 shows a flowchart illustrating a method of controlling operations downhole using position measurement obtained using the position sensor 820 disclosed herein. In block 902, an outgoing ultrasonic pulse is generated by MST 822 along the magnetostrictive sensing rod 824 with the MST 822 at a known reference position. The magnetostrictive sensing rod extends along the work string 102 or a depth interval in the wellbore 132. In block 904, reflected ultrasonic pulses are received at the pulser 826 from the reflector element or the portion of magnetostrictive rod 824 at the reference location where the sliding pin 840 is resident. Sliding pin 840 locally elastically deforms magnetostrictive rod 824 causing a reflection to propagate at the location of sliding pin 840. In block 906, the received reflected ultrasonic pulses are used to determine the time of flight for the ultrasonic signals at the reference position of the MST 822. In block 908, the equipment to be tracked and corresponding MST 822 are moved to an unknown location. In block 910 an outgoing ultrasonic pulse is generated by MST 822 along the magnetostrictive sensing rod. In block 912, reflected ultrasonic pulses from the portion of the magnetostrictive rod 824 at the position where the reflective element or sliding pin 840 is resident are received at the pulser 826. In block 914, the reflected ultrasonic pulses are used to determine the time of flight for the ultrasonic signals. In block 916, the time of flight for the reference position may be compared to the time of flight for the unknown position to determine the unknown position. In block 918, a value of an operational parameter of the tool of a downhole operation is altered when the at least one position meets a selected criterion with respect to the selected threshold value. A position measurement meeting the selected criterion may include the position measurement being greater than the selected threshold value or being less than the selected threshold value, in various embodiments.

Therefore in one aspect, the present disclosure provides an apparatus for use in a wellbore, the apparatus including: a moveable tool; and a sensor associated with the tool, wherein the sensor includes: a transducer; at least one reflection element spaced from the transducer, wherein the transducer transmits at least one signal to the at least one reflection element and receives the at least one signal reflected from the at least one reflection element; and a sensor controller configured to determine a position of the tool utilizing the reflected at least one signal. In various embodiments, the transducer may be coupled to the tool. Further, in various embodiments, the at least one reflection element may be coupled to the tool. In certain embodiments, the transducer may be a magnetostrictive device that transmits at least one acoustic signal to the at least one reflection element. A rod may be associated with the sensor. In certain embodiments, the at least one reflection element may be either: at least one end of the rod, a fixed pin coupled to the rod, or a sliding pin coupled to the rod. The operation in the wellbore includes at least one of: operation of a flow control device; operation of a hydraulic motor; operation of a sleeve; and operation of a linear actuator. The term transducer is used herein broadly to include a transmitter, receiver or both and wherein a common element or device may be utilized for both the transmission and reception of signals, such as acoustic waves, or separate elements or devices may be placed proximate to each other or placed spaced apart from each other as transmitters and receivers.

In another aspect, the present disclosure provides a method of determining a position in a wellbore, the method including: placing a moving tool in the wellbore; providing a sensor associated with the tool, wherein the sensor includes a transducer and at least one reflection element; transmitting at least one signal to the at least one reflection element via the transducer; receiving the at least one signal from the at least one reflection element via the transducer; and determining a position of the tool utilizing the reflected at least one signal. In various embodiments, the transducer may be coupled to the tool. Further, in various embodiments, the at least one reflection element may be coupled to the tool. In certain embodiments, the transducer may be a magnetostrictive device that transmits at least one acoustic signal to the at least one reflection element. A rod may be associated with the sensor. In certain embodiments, the at least one reflection element may be either: at least one end of the rod, a fixed pin coupled to the rod, or a sliding pin coupled to the rod. The operation in the wellbore includes at least one of: operation of a flow control device; operation of a hydraulic motor; operation of a sleeve; and operation of a linear actuator.

In another aspect, the present disclosure provides a system for controlling a downhole operation, the system including: a moveable tool configured to perform the operation according to an operation parameter of the tool; a sensor associated with the tool, wherein the sensor includes: a transducer; at least one reflection element spaced from the transducer, wherein the transducer transmits at least one signal to the at least one reflection element and receives the at least one signal reflected from the at least one reflection element; and a sensor controller configured to determine a position of the tool utilizing the reflected at least one signal; and a controller configured to: compare the position to a selected threshold; and alter the operation parameter based on the comparison of the position to the selected threshold. In various embodiments, the transducer may be coupled to the tool. Further, in various embodiments, the at least one reflection element may be coupled to the tool. In certain embodiments, the transducer may be a magnetostrictive device that transmits at least one acoustic signal to the at least one reflection element. A rod may be associated with the sensor and the at least one reflection element may be either: at least one end of the rod, a fixed pin coupled to the rod, or a sliding pin coupled to the rod. The operation in the wellbore includes at least one of: operation of
a flow control device; operation of a hydraulic motor; operation of a sleeve; and operation of a linear actuator.

[0046] In yet another aspect, the present disclosure provides a system for use in a wellbore, the system including: a moveable tool; and an acoustic sensor coupled to the tool configured to determine the position of the tool in the wellbore.

[0047] While the foregoing disclosure is directed to the certain exemplary embodiments of the disclosure, various modifications will be apparent to those skilled in the art. It is intended that all variations within the scope and spirit of the appended claims be embraced by the foregoing disclosure.

What is claimed is:

1. An apparatus for use in a wellbore, comprising:
a moveable tool; and
a sensor associated with the tool, wherein the sensor includes:
a transducer;
at least one reflection element spaced from the transducer, wherein the transducer transmits at least one signal to the at least one reflection element and receives the at least one signal reflected from the at least one reflection element; and
a pulser configured to determine a position of the tool utilizing the reflected at least one signal.

2. The apparatus of claim 1, wherein the transducer is coupled to the tool.

3. The apparatus of claim 1, wherein the at least one reflection element is coupled to the tool.

4. The apparatus of claim 1, wherein the transducer is a magnetostriuctive device that transmits at least one acoustic signal to the at least one reflection element.

5. The apparatus of claim 1, wherein the sensor further includes a rod associated with the sensor.

6. The apparatus of claim 5, wherein the at least one reflection element is selected from a group comprising: at least one end of the rod, a fixed pin coupled to the rod and a fixed position, and a sliding pin coupled to the rod and the tool.

7. The apparatus of claim 1, wherein an operation in the wellbore includes at least one of: operation of a flow control device: operation of a hydraulic motor; operation of a sleeve; and operation of a linear actuator.

8. A method of determining a position in a wellbore, the method comprising:
placing a moving tool in the wellbore;
providing a sensor associated with the tool, wherein the sensor includes a transducer and at least one reflection element;
transmitting at least one signal to the at least one reflection element via the transducer;
receiving the at least one signal from the at least one reflection element via the transducer; and
determining a position of the tool utilizing the reflected at least one signal.

9. The method of claim 8, further comprising coupling the transducer to the tool.

10. The method of claim 8, further comprising coupling the at least one reflection element to the tool.

11. The method of claim 8, wherein the transducer is a magnetostriuctive device and the at least one signal is at least one acoustic signal.

12. The method of claim 8, further comprising associating a rod with the sensor.

13. The method of claim 12, wherein the at least one reflection element is selected from a group comprising: at least one end of the rod, a fixed pin coupled to the rod and a fixed position, and a sliding pin coupled to the rod and the tool.

14. The method of claim 8, wherein an operation in the wellbore includes at least one of: operation of a flow control device; operation of a hydraulic motor; operation of a sleeve; and operation of a linear actuator.

15. A system for controlling a downhole operation, comprising:
a moveable tool configured to perform the operation according to an operation parameter of the tool;
a sensor associated with the tool, wherein the sensor includes:
a transducer;
at least one reflection element spaced from the transducer, wherein the transducer transmits at least one signal to the at least one reflection element and receives the at least one signal reflected from the at least one reflection element; and
a pulser configured to determine a position of the tool utilizing the reflected at least one signal; and
a controller configured to:
compare the position to a selected threshold; and
alter the operation parameter based on the comparison of the position to the selected threshold.

16. The system of claim 15, wherein the transducer is coupled to the tool.

17. The system of claim 15, wherein the at least one reflection element is coupled to the tool.

18. The system of claim 15, wherein the transducer is a magnetostriuctive device that transmits at least one acoustic signal to the at least one reflection element.

19. The system of claim 15, wherein the sensor further includes a rod associated with the sensor and wherein the at least one reflection element is selected from a group comprising: at least one end of the rod, a fixed pin coupled to the rod and a fixed position, and a sliding pin coupled to the rod and the tool.

20. The system of claim 15, wherein the operation includes at least one of: operation of a flow control device; operation of a hydraulic motor; operation of a sleeve; and operation of a linear actuator.

21. A system for use in a wellbore, comprising:
a moveable tool; and
an acoustic sensor coupled to the tool configured to determine the position of the tool in the wellbore.

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