

APPARATUS AND METHODS FOR REAL TIME COMMUNICATION IN DRILL STRINGS

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Application No. 61/371563, filed on August 6, 2010, which is incorporated herein by reference in its entirety.

BACKGROUND INFORMATION

Field of the Disclosure

[0001] This disclosure relates generally to drill bits that include sensors for providing measurements and communication of measured and/or processed data to components in a drilling assembly attached to the drill bit.

Brief Description Of The Related Art

[0002] Oil wells (wellbores) are usually drilled with a drill string that includes a tubular member having a drilling assembly (also referred to as the bottomhole assembly or “BHA”) with a drill bit attached to the bottom end thereof. The drill bit is rotated to disintegrate the earth formations to drill the wellbore. The BHA includes devices and sensors for providing information about a variety of parameters relating to the drilling operations, behavior of the BHA and formation surrounding the wellbore being drilled (formation parameters). A variety of sensors, such as pressure sensors, inclinometers, sensor gamma ray sensors, etc. are embedded in the drill bit for providing information about various drilling and formation parameters. The data from the bit sensors is often stored in memory devices in the drill bit, which data is retrieved after tripping the drill bit out of the wellbore for further processing and use. It is desirable to transmit the bit sensor data and/or processed data from a circuit in the drill bit to the BHA and/or to the surface while drilling the wellbore, i.e., in real-time because the drill bit does not generally have adequate space for housing electronic circuitry to process large amounts of data. The BHA normally includes processors that can process copious amounts of sensor data and therefore it is economical to process the drill bit data in the BHA. Also, the drill bit is subjected to greater vibrations and thrust forces than certain parts of the BHA, where it is more desirable to locate the processors.

[0003] The disclosure provides an apparatus and methods for real-time communication of data and power between the drill bit and another device, such as a BHA, connected to the drill bit.

SUMMARY

[0004] An apparatus made according to one embodiment includes a drill bit that has a cavity at an end thereof and a communication device placed in the cavity, wherein the communication device includes a first section and a second section, wherein an outer dimension of the second section is greater than an outer dimension of the first section, and wherein the second section includes a conduit configured to allow passage of a conductor from the drill bit to a location outside the drill bit so as to provide a direct connection of the conductor from the drill bit to an element outside the drill bit.

[0005] Examples of certain features of the apparatus 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 hereinafter that will form the subject of the claims appended hereto.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] For detailed understanding of the present disclosure, references should be made to the following detailed description, taken in conjunction with the accompanying drawings in which like elements have generally been designated with like numerals and wherein:

FIG. 1 is a schematic diagram of a drilling system that includes a BHA with a drill bit attached thereto and a communication apparatus between the drill bit and the BHA;

FIG. 2 is an isometric view of an exemplary drill bit showing placement of sensors in the drill bit and corresponding communication links to a neck of the drill bit;

FIG. 3 is an isometric line diagram of a shank of the drill bit of FIG. 2 showing placement of electronic circuit in a neck portion of the shank for processing drill bit sensor signals;

FIG. 4 is an isometric view of a communication link configured to house electronic circuitry and provide a passage for direct data and power connection between the drill bit and BHA;

FIG. 5 is a line diagram showing the communication link of FIG. 4 placed between a drill bit and another tool, such as a BHA, connected to the drill bit, according to one embodiment of the disclosure; and

FIG. 6 shows an auto-retractable device that may be utilized in the communication device for connecting conductors between the drill bit and another device, such as the BHA.

FIG. 7 is a line diagram showing the communication link of FIG. 4 placed between adjoining drill pipe sections to provide real time data and power communication between such pipe sections; and

FIG. 8 is a line diagram of a drill string that includes a data communication link at each pipe connection configured to provide real-time communication between a BHA and the surface.

DESCRIPTION OF THE DISCLOSURE

[0007] The present disclosure relates to real-time communication in a drill pipe. One embodiment of the drill pipe includes a number of serially connected tubulars with a communication device placed between the connecting ends of the tubulars, wherein the communication device provides a direct data communication link between the adjoining tubulars.

[0008] FIG. 1 is a schematic diagram of an exemplary drilling system 100 that may utilize drill bits and data communication devices disclosed herein for use in drilling wellbores. FIG. 1 shows a wellbore 110 that includes an upper section 111 with a casing 112 installed therein and a lower section 114 that is being drilled with a drill string 118. The drill string 118 includes a tubular member 116 that carries a drilling assembly 130 (also referred to as the bottomhole assembly or “BHA”) at its bottom end. The tubular member 116 may be made by joining drill pipe sections or it may be a coiled-tubing. A drill bit 150 is attached to the bottom end of the BHA 130 for disintegrating the rock formation to drill the wellbore 110 of a selected diameter in the formation 119. Not shown are devices such as thrusters, stabilizers, centralizers, and devices such as steering units for steering the drilling assembly 130 in a desired direction. The terms wellbore and borehole are used herein as synonyms.

[0009] Drill string 118 is shown conveyed into the wellbore 110 from a rig 180 at the surface 167. The exemplary rig 180 shown in FIG. 1 is a land rig for ease of explanation. The apparatus and methods disclosed herein may also be utilized with rigs used for drilling offshore wellbores. A rotary table 169 or a top drive (not shown) coupled to the drill string 118 at the surface may be utilized to rotate the drill string 118 and thus the drilling assembly 130 and the drill bit 150 to drill the wellbore 110. A drilling motor 155 (also referred to as “mud motor”) may also be provided to rotate the drill bit. A control unit (or controller) 170 in the BHA 130 may be configured to receive and process data from the sensors 160 in the drill bit 150 and sensors 175 in the drilling assembly 130 and to control selected operations of the various devices and sensors in the drilling assembly 130. The controller 170 may include a processor

172, such as a microprocessor, a data storage device 174 and programs 176 for use by the processor 170 to process the data from the sensors 160 and 175. Also, a controller 190, which may be a computer-based system, may be placed at the surface 167 for receiving and processing data transmitted by the sensors in the drill bit and sensors 175 in the drilling assembly 130 and for controlling selected operations of the various devices and sensors in the drilling assembly 130. The surface controller 190, in one embodiment, may include a processor 192, a data storage device (or a computer-readable medium) 194 for storing data and computer programs 196. The data storage devices 174 and 194 may be any suitable devices, including, but not limited to, a read-only memory (ROM), a random-access memory (RAM), a flash memory, a magnetic tape, a hard disc and an optical disk. To drill a wellbore, a drilling fluid from a source 179 is pumped under pressure into the tubular member 116. A telemetry unit 188 in the BHA provides two-way communication between the BHA and the surface controller 190. During drilling, the drilling fluid discharges at the bottom of the drill bit 150 and returns to the surface via the annular space (also referred as the “annulus”) between the drill string 118 and the inside wall of the wellbore 110.

[0010] Still referring to FIG. 1, drill bits, such as drill bit 150, commonly include a threaded pin connection at its top end that is connected to a box end at the bottom of the BHA 130. The box end includes internal threads that complement the threads on the drill bit pin connection. Mating the box end with the pin end provides a fixed connection between the BHA and the drill bit 150. Such a connection is not conducive to providing a direct path for conductors from the drill bit 150 to the BHA 130. Therefore, electrical communication between the drill bit 150 and the data bus in the BHA 130 are either not provided or in some cases, electrical coupling rings are used at the box end and at a neck portion of the pin connection, which coupling rings come in contact with each other when the box end mates with the pin end, thereby providing an electrical path between the drill bit 150 and the BHA 130. In the configuration shown in FIG. 1, a direct data and power connection between the drill bit 150 and the BHA 130 is provided via a communication link 154. In another aspect, the communication link 154 may be placed at each connection between drill pipe sections that make the drilling tubular 116 to provide real-time communication throughout the drilling tubular 116 and thus between the drill bit and the surface equipment, such controller 190. The direct real time data communication between the drill bit and the BHA is described in reference to FIGS. 4-6. and along the drilling tubular in reference to FIGS. 4-8.

[0011] FIG. 2 shows a perspective view of an exemplary drill bit 150. The drill bit 150 shown is a PDC (polycrystalline diamond compact) drill bit for the purposes of explaining the

concepts described herein. However, any other type of drill bit may be utilized for the purpose of this disclosure. The drill bit 150 is shown to include a drill bit body 212 comprising a crown 212a and a shank 212b. The crown 212a includes a number of blade profiles (or profiles) 214a, 214b, . . . 214n. A number of cutters are placed along each profile. For example, profile 214n is shown to contain cutters 216a-216m. All profiles are shown to terminate at the bottom 215 of the drill bit 150. Each cutter has a cutting surface or cutting element, such as element 216a' of cutter 216a, that engages the rock formation when the drill bit 150 is rotated during drilling of the wellbore. The drill bit 150 includes a neck or pin connection 212c having external threads 212d. The BHA connects to the pin section 212c via a box section having internal threads compliant with the threads 212d. One or more sensors, such as sensors 240a, 240b, 240c, placed in the drill bit body generate measurement signals that may be processed by circuits in the drill bit 150 and transmitted to the BHA 130 or transmitted to the BHA by the direct communication link 154 (FIG. 1) as described in more detail in reference to FIGS. 3-6.

[0012] FIG. 3 shows a transparent perspective view of the shank 212b and the pin section 212c of the drill bit 150 shown in FIG. 2. The shank 212b includes a bore 310 therethrough for supplying drilling fluid 313 to the crown 212a (FIG. 2) of the drill bit 150. The upper end 312 of the neck section 212c includes a recess section 318 for housing therein the communication link 154 (FIG. 1) and electronics 250 for processing signals from the various sensors 240a, 240b, 240c (collectively sensors 240) in the drill bit 150. Threads 319 on the neck section 312 connect the drill bit 150 to the drilling assembly 130 (FIG. 1) as described before. Power to and measurement signals from the sensors 240 may be communicated between the recess 318 via conductors (electrical, fiber optic, etc.) 242 placed in a bore 332 in the shank 212b between the sensors 240 and the bottom 318a of the recess 318.

[0013] FIG. 4 is a perspective view of an exemplary communication device or a communication link 400 configured to provide direct communication link between two connecting members, including, but not limited to, drill bit 150 and BHA 130 (FIG. 1) and adjacent drill pipe sections. The communication link 400 shown is configured as a double spool that includes a lower section 402 and an upper section 404. In one aspect, the lower and upper sections 402, 404 may be mirror images of each other, as shown in FIG. 4. The section 402 is shown to include a lower recess or first recess section 412a, a middle recess or second recess section 412b and an upper recess or third recess section 412c. Similarly, the upper section 404 includes a lower recess section 414a, a middle recess section 414b and an upper recess section 414c. In the embodiment shown, the middle recess sections 412b and 414b abut against each other and may be made of the same or different dimensions. In one aspect, the outer dimension

or diameter 422b of the middle recess section 412b is greater than the outer diameter 422a of the lower recess section 412a, while the outer diameter 424b of the middle recess section 414b is greater than the outer diameter 424a of the lower recess section 414a. The middle recess sections 412b and 414b, in one embodiment, are configured to contain electrical circuits and processors configured to process signals generated by the sensors 240 in the drill bit 150 (FIG. 2 and 3). The recess sections 412a, 412c, 414a and 414c are configured to contain separate seals, such as o-rings configured to fluidly seal the communication link 400 at one end from a first member, such as the drill bit 150, and at the second end from a connecting member, such as a box end at the end of the BHA 130 (FIG. 1). One or more bores, such as bore 420, may be formed from a flange surface 434b of the middle recess section 412b to a flange surface 444b of the middle recess section 414b. The bores 420 are of a size suitable to run conductors, such as electrical conductors and optical fibers therethrough. The location of the bores 420, in one configuration, is outside the diameters 422a and 424a so that conductors can be run directly from below the lower recess section 412a to the bore 420 and then from the bore 420 to a location above the lower recess 414a, as described in more detail in reference to FIG. 5.

[0014] FIG. 5 shows an assembly 500, wherein a pin section 502 of a drill bit 510 is coupled to a box end 562 of a tool 560, with one section 402 of a communication link 400 placed within the pin section 502 of the drill bit 510 and the other section 404 placed within the box end 562 of the tool 560 to provide a direct communication link between the drill bit 510 and the tool 560. A communication link or device, including, but not limited to device 400, placed between adjoining members configured to provide a direct communication link between the adjoining members may be referred to as a “communication sub” or “sub.” The adjoining members may be any suitable members, including, but not limited to, two tubular members, such as drill pipe sections, a drill bit and a BHA, a BHA and a tubular, and two downhole tools.

[0015] In the configuration shown in FIG. 5, the pin section 502 is shown to include a recess 512 having a lower or smaller recess 512a of diameter d1 and an upper or larger recess 512b of diameter d2. The box end 562 includes the same recess structure as the pin section 502. As shown, the box end 562 includes a recess 572 having a lower or smaller recess 572a of diameter d1 and an upper or larger recess 572b of diameter d2. To form the assembly 500, a sealing member 514a is placed in the recess 412a and a sealing member 514c is placed in the recess 412c of the communication link 400. The lower section 402 of the communication link 400 is then placed inside the recess 512a so that the seal 514a seals the recess 412a against the wall 516a of the recess 512a and the seal 514c seals the recess 412c against the inside wall 516b of the recess 512b. This ensures that the lower section 402 of the communication sub 400

is secured airtight in the pin connection. In an embodiment, a bottom facet 435 of section 402 has an anti-rotational feature that would keep the communication link 400 from rotating when the box end 562 of tool 560 screwed onto pin section 502. An exemplary anti-rotational feature may be alternating surface heights of the bottom facet 435, and/or non-rounded (e.g., elliptical, hex, rectangular) geometry of the bottom facet 435. In the example, the spool section 402 with the anti-rotational feature is connected to the bit first, the box end of the tool is then connected to the pin of the bit, and concurrently connected or mated with the spool.

[0016] Still referring to FIG. 5, before placing the communication link 400 in the pin section 502, conductors 522 (electrical wires, optical fibers, etc.) are run from the sensors 520 in the drill bit 510 to the cavity 512 in the pin section via a conduit or cavity 524 in the drill bit 510. A connector 526 may be used to connect the conductors 522 to a circuit 530 placed in or around the middle recess 412b of the section 402 of the communication link 400. Conductors 528 from the circuit 530 are run through the bore 420 in the communication link 400 so that conductors 528 are available for connection to the circuits 540 in the recess section 414b and/or the BHA 130 as described below. Once the conductors 522 have been run through the bore 420, the lower section 402 of the communication link 400 may be placed in cavity 512. The conductors 528 are then connected to the circuit 540. The conductors 541 from the circuit are then run through the bore or conduit 568 in the box section 562 to the BHA. Alternatively or in addition to conductors 522 from the drill bit 510 may be run to the BHA 130 via the bore 420 and bore 568. Such configurations provide direct connection of the conductors 522, 528 and 541 from the drill bit 510 to the BHA. The conductors 522, 528 and 541, as the case may be, can carry large amounts of data to a suitable circuit and processor in the BHA. Also, conductors can be run from the BHA 130 to the circuits 530, 540 and sensors 520 to provide power and to provide two-way communication with such elements. Direct communication between the drill bit 510 and the BHA 130 eliminates the need for batteries in the drill bit and the use of delicate electronic circuits, including microprocessors, because such elements can be placed in the BHA sections where more space is available and which sections may be less susceptible to vibrations compared to the drill bit. Once all the conductors have been run as desired, the box end 562 of the tool 560 is then screwed onto the pin section 502. Seals 572a and 572c respectively provide airtight connections between the box end 562 and the lower recess 414a and the upper recess 414c.

[0017] FIG. 6 shows an exemplary auto-retrievable device 600 that may be used to connect the conductors 541 from the communication link 400 to conductors that run to the BHA 130. In one aspect, the auto-retrievable device 600 includes a connector 602 that is

connected to the conductors 541. A conductor 604, connected to a storage spool 606 that includes a retraction device 608, is wound around the recess section 414b in a manner that when the box end 562 is screwed on to the pin section 502, the conductor 604 will be retracted into the spool 606. The conductors to and from the BHA 130 are connected to a connector 620.

[0018] FIG. 7 is a line diagram showing a communication link of FIG. 4 placed between the adjoining drill pipe sections to provide real time data and power communication between such pipe sections. FIG. 7 shows a first pipe section 710 that has a pin connection or pin end 712 at its upper end. The pin end 710 includes a cavity 714 and a passage 720 from the cavity 714 to a conduit 716 drilled in the pipe section 710. A second pipe section 740 includes a box section 742 that further includes a cavity 744 that complements the cavity 714 of pipe section 710. A passage 750 in the cavity provides access to a conduit 746 in the pipe section 740. In FIG. 7, the box end 742 of pipe section 740 is shown connected to the pin section 712 of the pipe section 710. A communication link 400 is placed in the cavities 714 and 744 as described in reference to FIG. 5. However, before connecting the pipe section 740 to the pipe section 710, conductors 718 running in the conduit 716 are coupled to a connector 728 and conductors 724 from the connector 728 are run through the bore 420 in the communication link 400. Also, conductors 724 are connected to a connector 752 in the cavity 744 of the box section 742. The conductors 748 running through the conduit 746 in the pipe section 740 are connected to the connector 752 to complete the direct connection between the conductors 718 in the pipe section 710 and conductors 748 in the pipe section 740. Additional pipe sections may be joined in the manner that pipe sections 710 and 740 are connected to make the drill string as described in reference to FIG. 8. Additionally, in some applications, it may be desirable to place sensors 760 and circuitry 762 for processing measurement signals from such sensors in either one or both pipe sections 710 and 740. In such cases the signals from the sensors 760 and/or the circuitry 762 may be transmitted to the surface or BHA via conductors 718 and 748.

[0019] FIG. 8 is a line diagram of a drill string 800 that includes serially connected pipe sections or tubulars 810a, 810b, 810c... 810n. To form the drill string 800, the first pipe section 810a is connected to the BHA. The next pipe section 810b is then connected to the pipe section 810a with the communication link, such as link 400, placed between the pin end 820a of pipe section 810a and the box end 830b of the pipe section 810b in the manner described in reference to FIG. 7. As the drilling progresses, additional pipe sections, such as pipe sections 810c ... 810n are connected in the manner described herein. Therefore, at all time, there is a direct connection between the serially connected pipe sections via conductors 850a, 850b, 850c, etc.

[0020] The foregoing description is directed to particular embodiments for the purpose of illustration and explanation. It will be apparent, however, to persons skilled in the art that many modifications and changes to the embodiments set forth above may be made without departing from the scope and spirit of the concepts and embodiments disclosed herein. It is intended that the following claims be interpreted to embrace all such modifications and changes.

CLAIMS

1. A drill string, comprising:
a first member having a first end and a second end;
a second member having a first end and a second end, the second member connected to the first member forming with a passage between the first end of the first tubular and the second end of the second tubular; and
a communication device in the passage between the first member and the second member, the communication device including a conduit configured to allow passage of a conductor from the first tubular to provide direct signal communication between the first member and the second member.
2. The drill string of claim 1, wherein the first end of the first member includes a first cavity, the second end of the second member includes a second cavity and the communication device is placed in the first cavity and the second cavity.
3. The drill string of claim 2, wherein the communication device includes a first section in the first cavity, a second section in the second cavity and a third section between the first section and the second section with an outer dimension greater than an outer dimension of the first section and the second section and wherein the conduit runs through the third section outside the first section and the second section.
4. The drill string of claim 3 further comprising a conductor passing through the conduit, a first connector connected to the conductor in the first cavity and a second connector connected to the conductor in the second cavity.
5. The drill string of claim 1 further comprising a first conductor in the first member and coupled to the first connector and a second conductor in the second member and coupled to the second connector so as to provide direct communication between the first member and the second member.
6. The drill string of claim 5, wherein the first conductor is placed in one of: (i) inside a wall of the first member and (ii) in a bore through the first member and the second conductor is placed in one of: (i) inside a wall of the second member; and (ii) a bore through the second member.
7. The drill string of claim 1, wherein the first member and the second member are connected as one of: a threaded connection; and a stabbed connection.
8. The drill string of claim 1, wherein the communication device comprises a double spool, with a first spool placed in the first end of the first member and a second spool placed in the second end of the second device.

9. The drill string of claim 1 wherein the communication device provides a pressure-tight first cavity in the first end of the first member and a second pressure tight cavity in the second end of the second member.

10. The drill string of claim 4 further comprising a retrievable device connected to the conductor passing through the conduit, wherein the retrievable device is configured to enable one of the first member and the second member to be screwed on to the other member.

11. The drill string of claim 1 further including a plurality of members connected in series with the first and second members, each connection between such plurality of members further including a communication device, such communication devices providing a communication link from a surface location to the drilling assembly.

12. A method of providing communication through a drill string, comprising:
connecting a first end of a first member to a second end of a second member to form a connection, the connection including a passage therethrough;
placing a communication device in the connection, the communication device including a conduit configured to allow passage of a conductor therethrough; and
passing a conductor through the conduit to provide a direct communication link between the first member and the second member.

13. The method of claim 12, wherein the first end of the first member includes a first cavity, the second end of the second member includes a second cavity and the communication device is placed in the first cavity and the second cavity.

14. The method of claim 13, wherein the communication device includes a first section in the first cavity, a second section in the second cavity and a third section between the first section and the second section with an outer dimension greater than an outer dimension of the first section and the second section and wherein the conduit runs through the third section outside the first section and the second section.

15. The method of claim 14 further comprising connecting a first connector to the conductor in the first cavity and a second connector connected to the conductor in the second cavity.

16. The method of claim 15 further comprising coupling the first connector to a conductor running in the first member and the second connector to a conductor running in the second member to provide end-to-end communication between the first member and the second member.

17. The drill string of claim 16, wherein the first conductor is in one of: (i) inside a wall of the first member and (ii) in a bore through the first member and the second conductor is

placed in one of: (i) inside a wall of the second member; and (ii) a bore through the second member.

18. The drill string of claim 12, wherein the first member and the second member are connected as one of: a threaded connection and a stabbed connection.

19. The method of claim 12, wherein the communication device comprises a double spool, with a first spool placed in the first end of the first member and a second spool placed in the second end of the second device.

20. The method of claim 12 wherein the communication device provides a pressure tight first cavity in the first end of the first member and a second pressure tight cavity in the second end of the second member.

21. The method of claim 15 further comprising connecting a device to the conductor passing through the conduit configured to enable the second member to the first member by rotation.