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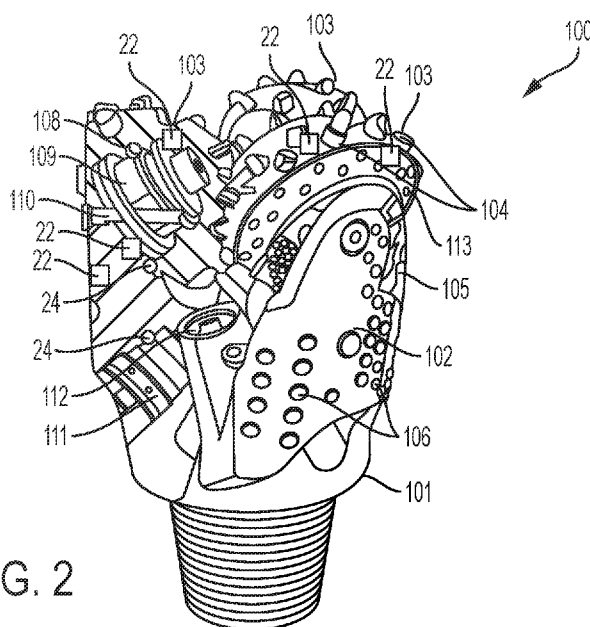


FIG. 2

(57) Abstract: Drill bit configured to operate within a wellbore of a hydrocarbon-bearing rock formations the drill bit including at least one leg (102), at least one roller cone (103) rotatably mounted on the drill bit body. The roller cone includes a plurality of cutting elements (104) for abrading or crushing rock. The drill bit includes at least one bearing (108) mounted between a surface of the drill bit body and the at least one roller cone (103) to facilitate rotation of the at least one roller cone. The drill bit system includes a lubrication system to reduce friction between moving parts of the drill bit. The drill bit system includes at least one wear sensor (22) associated with the drill bit to sense physical wear on the drill bit.

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- *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

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DRILL BIT SYSTEM

RELATED APPLICATIONS

[0001] This Application claims benefit of U.S. Provisional Patent Application Serial No. 62/671,586, filed May 15, 2018, entitled “DRILL BIT SYSTEM,” the disclosure of which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

[0002] This specification describes a drill bit system having one or more sensors.

BACKGROUND

[0003] In the oil and gas industry it is often necessary to create holes in the Earth’s surface or subsurface. Various drilling methods may be used to create a borehole or wellbore, which are selected as appropriate based on, for example, type of soil, required depth, cost or penetration rate required. Example drilling methods include auger drilling, percussion rotary air blast drilling (RAB), air core drilling, cable tool drilling, reverse circulation (RC) drilling, diamond core drilling, direct push rig drilling, or hydraulic rotary drilling.

SUMMARY

[0004] An example drill bit is configured to operate within a wellbore of a hydrocarbon-bearing rock formation. The drill bit includes a drill bit body, which includes at least one leg that is connectable to a drill string to connect the drill bit to a drilling rig. The drilling rig is configured to move the drill bit uphole or downhole, and to rotate the drill bit. The drill bit includes at least one roller cone connected to the drill bit body. The at least one roller cone includes a plurality of cutting elements for abrading or crushing rock. The at least one roller cone is rotatably mounted on the drill bit body. The drill bit includes at least one bearing mounted between a surface of the drill bit body and the at least one roller cone to facilitate rotation of the at least one roller cone. The drill bit system may include one or more of the following features, either alone or in combination.

[0005] The drill bit system may include a lubrication system to reduce friction between moving parts of the drill bit, for example between the at least one roller cone and the at least one

bearing. The lubrication system may include a lubrication reservoir. The drill bit system may include at least one lubrication sensor to sense a presence of lubricant in the lubricant reservoir.

[0006] The drill bit system may include at least one wear sensor associated with the drill bit to sense physical wear on the drill bit. The at least one wear sensor may be an erosion sensor to sense a reduction of drill bit material or a fluid sensor to sense a presence of wellbore fluid at a drill bit surface. The at least one wear sensor may be mounted in, or on, the at least one leg of the drill bit to monitor the wear of the leg of the drill bit. The at least one wear sensor may be mounted in, or on, at least one of the plurality of cutting elements of the at least one roller cone, or on a gauge protector of the at least one roller cone, to monitor the wear of the roller cone.

[0007] The drill bit system may include two or more sensors to sense wear of the drill bit. The sensors may be mounted in the drill bit at different distances from a surface of the drill bit to detect different levels of wear.

[0008] The drill bit system may include at least one processor in communication with the at least one wear sensor to provide sensing data to the at least one processor. The at least one processor is configured to process the sensing data to display the data on a user interface.

[0009] The at least one sensor may be connected to an intermediary device, and the intermediary device may be connected to the primary processor. The sensor, intermediary device, and processor may be connected through one or more electrical connections. The electrical connections may be or include wireless connections.

[0010] An example drill bit may include a drill bit body that is connectable to a drill string, the drill bit body including at least one blade. The at least one blade may include cutting elements for abrading or crushing rock. The drill bit may include at least one wear sensor associated with the drill bit to sense physical wear on the drill bit. An example drill bit may include both one or more roller cones and one or more blades.

[0011] Any two or more of the features described in this specification, including in this summary section, may be combined to form implementations not specifically described in this specification.

DESCRIPTION OF THE DRAWINGS

[0012] FIGS. 1A and 1B are block diagrams of versions of an example drill bit system including a sensor.

- [0013] FIG. 2 is a partially cut-away, perspective view of an example tri-cone drill bit.
- [0014] FIG. 3A is a perspective view of an example drill bit having fixed cutters.
- [0015] FIG. 3B is a top view an example drill bit having fixed cutters.
- [0016] FIG. 4A is a perspective view of an example hybrid drill bit having both fixed cutters and rolling cutters.
- [0017] FIG. 4B is a top view of an example hybrid drill bit having both fixed cutters and rolling cutters.
- [0018] FIG. 5 is a block diagram of an example sensor configuration for a drill bit.
- [0019] Like reference numerals in the figures indicate like elements.

DETAILED DESCRIPTION

[0020] This disclosure describes examples of a drill bit system that includes real-time feedback for use in monitoring or determining the condition of cutting structures of a drill bit, life expectancy of the drill bit, or a combination of these factors and other measured or determined factors relating to the drill bit. The system may include one or more sensors that may be attached to, or embedded in, the drill bit system to perform the monitoring. In the context of a drill bit system, real-time feedback may not mean that example actions, such as communication, are simultaneous, immediate, or comport with any temporal requirements, but rather that the example actions may occur on a continuous basis or track each other in time, taking into account delays associated with processing, data transmission, hardware, and the like.

[0021] Oil or gas drilling may occur under harsh conditions, such as high temperatures and pressures down-hole. In this regard, down-hole may refer to the interior of a wellbore or hole of a well. The useful life of a drill bit thus may be limited by, and dependent on, down-hole conditions. Down-hole conditions may change as depth or distance in the hole increases, which may pose challenges for accurate estimation of drill bit life, among other things. The example systems described in this specification enable monitoring, including real-time monitoring, of one or more conditions of a drill bit while the drill bit is downhole. Examples of such conditions include, but are not limited to, drill bit gauge diameter, drill bit cutting structure wear, or drill bit body wear. The example systems described in this specification may also enabling monitoring, including real-time monitoring, of bearing, lubrication, or compensation systems associated with a drill bit downhole. The example systems may improve control of some types of drill bits, such

as rotary drill bits having a fixed cutting structure, a roller cone cutting structure, or other appropriate types of cutting structures.

[0022] An example drilling rig system may include a drill string, which may include a drill pipe and a bottom hole assembly. In some implementations, a drilling rig includes a drill bit, a drill pipe, a drill collar, drilling fluid, rotating equipment, a hoisting apparatus, and a prime mover. The drill pipe may include a hollow steel conduit having threaded ends, called tool joints, to which one or more tools may be connected. The drill pipe may be used to connect rig surface equipment, such as motors or pumps, to the bottom-hole assembly and the drill bit. This connection may be made to raise, to lower, to rotate, or otherwise to move the bottom-hole assembly, the drill bit, or both the bottom-hole assembly and the drill bit. An example bottom-hole assembly may include the drill bit system and may include special equipment, such as a drilling fluid motor, directional drilling and measuring equipment, measurements-while-drilling tools, logging-while-drilling tools, or other appropriate devices.

[0023] An example drill bit system 10 is shown in FIG. 1A. As described, drill bit system 10 may be associated with, or integrated into, a drilling rig system. Drill bit system 10 may include one or more sensors 20 (referred to subsequently as “sensor 20”) that are associated with a drill bit 30. For example, sensor 20 may be mounted on, or integrated into, drill bit 30. In some implementations, sensor 20 may be connected to one or more processing devices, examples of which are described in this specification. In the example of Fig. 1A, sensor 20 is connected, electrically, to example primary processor 40 via connection 41. Primary processor 40 is configured – programmed, for example – to receive, and to process, one or more data inputs, such as signals or signal data from sensor 20. Primary processor 40 is also configured – programmed, for example – to generate graphical data by processing the data inputs received. The graphical data may be used to render a graphical display on a user interface, examples of which are described in this specification. The graphical display may contain readings of the sensors or information that is based on those readings. In some implementations, the readings represented on the graphical display may include information relating to the temperature, size, or wear of a drill bit. In some implementations, sensor 20 may be connected to an intermediary device 50 via connection 42. Intermediary device 50 may be connected to primary processor 40 via connection 43. In some implementations, intermediary device 50 is, or includes, one or more processing devices, such as secondary processor 51. Secondary processor 51 is configured –

programmed, for example – to receive and to process one or more data inputs, such as signals or signal data from sensor 20. The resulting processed signal data may be transmitted to primary processor 40 or other appropriate processing devices for processing as described previously.

[0024] Connections 41, 42, and 43 may be electrical connections that are wired, wireless, or a combination of wired and wireless. In some implementations, one or more of connections 42 or 43 are cable or wire connections. In some implementations, one or more of the connections are wireless connections. In some implementations, connection 42 is a wire or cable connection and connection 43 is a wireless connection. In some implementations, connection 42 is a wireless connection and connection 43 is a wire or cable connection as shown, for example, in FIG. 1B. In some implementations, sensor 20 includes, or is connected to, a wireless transmitter 29. Wireless transmitter 29 is configured to transmit a signal to wireless receiver 59. Wireless receiver 59 may be connected to, or part of, intermediary device 50.

[0025] In some implementations, primary processor 40 is part of a measurement-while-drilling (MWD) or logging-while-drilling (LWD) device. In some implementations, intermediary device 50 is, includes, or is part of, an MWD device. An example MWD device includes tools to measure one or more downhole conditions, such as temperature or pressure. An example LWD device includes tools to make a record (log) of geologic formations. An MWD tool or LWD device may be included in a single device in a steering tool of a drill string, or in a device at the end of a drilling apparatus or the bottom hole assembly. In some implementations, such as in cases where an MWD device is used, data may be transmitted to a computing system at a surface of the well, or to primary processor 40 through connection 43. The data may be transmitted in pulses through a mud column formed by drilling mud in the borehole or using electromagnetic telemetry. Pulses through the mud column that communicate data or other information are referred to as mud pulses.

[0026] In some implementations, drill bit 30 and intermediary device 50 include a power supply or energy storage mechanism, such as a battery or a generator, to power electrical components of drill bit 30 or intermediary device 50. In some implementations, sensor 20, or electrical systems connected to sensor 20, are powered by a source attached to, or integrated into, drill bit 30. In some implementations, sensor 20, or electrical systems connected to sensor 20, are powered by a power source attached to, or integrated into, intermediary device 50.

[0027] Sensor 20 may be, or include, a wear sensor 22. In some implementations, a wear sensor 22 may be, or include, an erosion sensor. In some implementations, an erosion sensor may include a metal probe element having a certain thickness. As the metal probe element is subjected to wear, the thickness of the metal probe element decreases. This produces a corresponding change in electrical properties, such as resistance, of the metal probe element. A change in an electrical property may be detected, for example, by monitoring a voltage or current applied to the metal probe element. This change in the electrical property is indicative of the amount of wear detected by the sensor. Other types of wear sensors may be used, as appropriate.

[0028] Wear sensor 22 may be, or include, a fluid sensor. In some implementations, a fluid sensor may be, or include, a water sensor. An example fluid sensor is configured to measure a difference in conductivity between two electrodes. A predefined difference in conductivity may be indicative of the presence of fluid or the lack of at least a predefined amount of fluid in a region measured. A fluid sensor can be placed in or on a drill bit such that the electrodes are exposed to wellbore fluid only after a certain amount of material has worn off the drill bit, thereby indicating a certain level of wear. In some implementations, a fluid sensor may be or include a temperature probe. Other types of fluid sensors may be used, as appropriate.

[0029] Sensor 20 may be, or include, a lubricant or oil level sensors 24 which may be configured to collect data that is usable for to monitor the condition of one or more bearings in the drill bit. An oil level sensor may be, or include, a mechanical sensor, such as a sensor that registers movement of a float against a switch. An oil level sensor may be, or include, a mechanical sensor, such as a pneumatic sensor that uses compression of a column of air against a diaphragm to actuate a switch. An oil level sensor may be, or include, an ultrasonic sensor, such as a sensor for registering a change in acoustic properties in reflected sound waves. An oil level sensor may be, or include, a conductive sensor that uses conductive properties of the oil or other material to perform point-level detection.

[0030] Drill bit system 10 may include one or more sensors 20 that may be associated with including, but not limited to, attached to, connected to, placed on, or embedded in, a drill bit 30 or components attached to the drill bit. The configurations of the sensors vis-à-vis the drill bit may be based on the type or configuration of drill bit used. For example, one or more sensors 20 may be used to send feedback to a surface computing system, which may be indicative of one or more of: changes in the drill bit body, changes in the drill bit cutting structure, changes in the

drill bit bearing, changes in drill bit lubrication, or changes in drill bit compensation systems. This information may be used by a drilling engineer or other appropriate party to avoid, or to ameliorate, drilling issues due to problems such as, but not limited to, drill bit failure or the drill bit tripping-out of the wellbore prematurely.

[0031] In some examples, drill bit 30 may be, or include, one of three basic drill bit types commonly used in the oil and gas industry, which are distinguished by their primary cutting mechanisms. One or more sensors 20 may be placed on, or integrated into, a drill bit in a variety of configurations, depending on type of drill bit. One example type of drill bit includes rolling cutter bits that fracture, abrade, or crush rock with protrusions – or teeth – extending from conical rolling cutter elements. In some implementations, one, two, three, or more rolling cutter elements may be used in a drill bit. During operation, rolling cutter elements roll across the face of a borehole as the bit is rotated, thus abrading or crushing material. Another example type of drill bit includes fixed cutter bits, which may include a set of edges or blades having hard cutting elements. As the drill bit is rotated, material is crushed or removed by scraping or grinding of blades against rock. In some implementations, these blades may be made of, or include, natural or synthetic diamond. Other types of drill bits that may be used in the drill bit system may include hybrid bits that include both rolling cutter elements and blades.

[0032] Drill bit 30 may be, or include, a drill bit having three rolling cutter elements, such as example tri-cone drill bit 100 shown in FIG. 2. Example tri-cone drill bit 100 includes a bit body 101, which may be made from a metal alloy, such as steel or a similar material. In this example, bit body 101 includes one or more – for example three – legs 102. A leg 102 may include a hard-face coating 105, which may be tungsten carbide for example, applied to the exterior surface of a leg. In an example, the coating may be applied on an erosion-prone portion of the leg, such as the leading edge of the leg or the semi-circular tip of shirt-tail 106. In this example, each leg 102 may be connected to a roller cone 103 that is rotatably mounted on the corresponding leg. A roller cone 103 may be made from a metal alloy, such as steel or a similar material. In some implementations, a roller cone 103 may include gauge protectors 113, which may be, or include, hardened inserts placed along or near the greatest circumference of a roller cone to enhance wear resistance. In some implementations, gauge protectors 113 may be made of, or include, tungsten carbide or diamond-enhanced materials. A roller cone 103 may include one or more cutting elements 104 attached to, or protruding from, a cone 103. Cutting elements

104 may include teeth or any other similar structures, such as inserts. In some implementations, cutting elements 104 may be made from a metal alloy, such as steel or a similar material, and may include additional material, such as diamond or a similar material.

[0033] A roller cone, such as roller cone 103, may be rotatably mounted on an appropriate part of a bit body. For example, the roller cone may be mounted on protrusion 107 or any other appropriate location, such as leg 102. An assembly that includes roller cone 103 and bit body 101 may include bearings, such as ball bearings, roller bearings or bushings. One or more bearings of appropriate type may be included, for example ball bearing 108 or bushing 109. In some implementations, a ball bearing 108 may be held in place via ball retaining pin 110. A rotary drill bit 100 may include a lubrication system to reduce friction between moving parts of the drill bit. In some implementations, a ball bearing 108 may be lubricated and connected to a lubricant reservoir 111, for example by a tube or channel (not shown). In some implementations, a bit body 101 includes a jet nozzle 112, through which drilling fluid may be released, for example to lubricate or to cool roller cones 103.

[0034] In some implementations, rotary drill bit 100 may include one or more wear sensors 22. In some implementations, wear sensor 22 is placed in, on, or near, a leg 102, a bearing, for example bushing 109, or a roller cone 103, or at any other appropriate location.

[0035] In some implementations, rotary drill bit 100 may include one or more lubricant or oil level sensors 24. In some implementations, lubricant sensor 24 is placed in, on, or near, lubricant reservoir 111. In some implementations, lubricant sensor 24 is placed in, on, or near, an interface between an assembly comprising bit body 101. For example lubricant sensor 24 may be placed on protrusion 107, on roller cone 103, or at any other appropriate location.

[0036] Drill bit 30 may be, or include, a drill bit that includes fixed cutters, such as fixed cutter bit 200 shown in FIG. 3A and FIG. 3B. In some implementations, a fixed cutter bit includes one or more blades 201. In some implementations, a fixed cutter bit includes only fixed cutters, such as one or more blades 201. Each blade 201 may include a top region 202 and a side region 203. In some implementations, top region 202 may include one or more cutting elements 204 attached to, or protruding from, blade 201. Cutting elements may include teeth or any other appropriate structure, such as inserts, to cut through rock and other material. In some implementations, cutting elements 204 may be made from a metal alloy, such as steel or a similar material, and may include additional material, such as diamond or a similar material.

[0037] In some implementations, fixed cutter bit 200 may include one or more wear sensors 22. In some implementations, wear sensor 22 is placed in, on, or near, a top region 202 or a side region 203 of a blade 201, or at any other appropriate location.

[0038] Drill bit 30 may be, or include, a drill bit that includes fixed cutters and rolling cutter elements, such as hybrid bit 300 shown in FIG. 4A and FIG. 4B. In some implementations, a fixed cutter bit includes one or more blades 301. Each blade may include a top region 302 and a side region 303. In some implementations, top region 302 may include one or more cutting elements 304 attached to, or protruding from, blade 301. In some implementations, bit body 301 includes one or more legs, such as three legs 305. Each leg 305 may be connected to a roller cone 306 rotatably mounted on the corresponding leg. A roller cone 306 may be made from a metal alloy, such as steel or a similar material. A roller cone 306 may include one or more cutting elements 307 attached to, or protruding from, a roller cone 306. Cutting elements 304, 307 may include teeth or other appropriate structure, such as inserts. In some implementations, cutting elements 304, 307 may be made from a metal alloy, such as steel or a similar material, and may include additional material, such as diamond or a similar material.

[0039] In some implementations, hybrid bit 300 may include one or more wear sensors 22. In some implementations, wear sensor 22 is placed in, on, or near, a top region 302 or a side region 303 of a blade 301, or at any other appropriate location.

[0040] In some implementations, sensors embedded in a drill bit 30 may be used to assess a reduction in the outside diameter of drill bit 30. In some implementations, one, two, three, or more sensors may be positioned inside the body of drill bit 30 at different distances from an outside surface of drill bit 30, as shown in FIG. 5 for an example cylindrical portion of an example drill bit 630. In FIG. 5, circle 601 indicates a dimension of an intact example drill bit 630 at full gauge. Circle 602 indicates a dimension of drill bit 630 that has been worn, through use, by 1/16 inch under full gauge. For example, following wear, drill bit 630 may have a circumference that is full gauge minus 1/16 inch. When drill bit 630 worn to 1/16 inch under full gauge, sensor 622 is exposed to material in the wellbore, such as wellbore fluid or debris, which may cause sensor 622 to send a signal to primary processor 40, to secondary processor 50, to a surface-located computing system, or to some combination of primary processor 40, secondary processor 50, or the surface-located computing system.

[0041] Circle 603 indicates a dimension of drill bit 630 that has been worn, through use, by 2/16 inch under full gauge. For example, following wear, drill bit 630 may have a circumference that is full gauge minus 2/16 inch. When drill bit 630 worn to is 2/16 inch under full gauge, sensor 623 is exposed to material in the wellbore, such as wellbore fluid or debris, which may cause sensor 623 to send a signal to primary processor 40, to secondary processor 50, to a surface-located computing system, or to some combination of primary processor 40, secondary processor 50, or the surface-located computing system.

[0042] Circle 604 indicates a dimension of drill bit 630 that has been worn, through use, by 3/16 inch under full gauge. For example, following wear, drill bit 630 may have a circumference that is full gauge minus 3/16 inch. When drill bit 630 worn to is 3/16 inch under full gauge, sensor 624 is exposed to material in the wellbore, such as wellbore fluid or debris, which may cause sensor 624 to send a signal to primary processor 40, to secondary processor 50, to a surface-located computing system, or to some combination of primary processor 40, secondary processor 50, or the surface-located computing system.

[0043] In some examples, an operator may determine a level of wear of drill bit 30 based on signals, or the timing of signals, from example sensors 622, 623, or 624. In some implementations, one or more example sensors 622, 623, or 624 may be fluid sensors, debris sensors, wear sensors, erosion sensors or a combination of fluid sensors, debris sensors, wear sensors, or erosion sensors. One or more of the sensors may be placed in, or on, a drill bit as appropriate, such as on or near areas of a drill bit that are particularly prone to wear. For example, wear sensors or fluid sensors may be attached to or embedded in a rotary drill bit as described in this specification.

[0044] Although the example drill bit system has been described previously in the context of an oil or gas well, the example drill bit system may be used with any appropriate type of well, including, but not limited to, water wells.

[0045] At least part of the drill bit system and its various modifications may be implemented, or controlled, at least in part, via a computer program product, such as a computer program tangibly embodied in one or more information carriers, such as in one or more tangible machine-readable storage media, for execution by, or to control the operation of, data processing apparatus, for example a programmable processor, a computer, or multiple computers.

[0046] A computer program may be written in any form of programming language, including compiled or interpreted languages, and it may be deployed in any form, including as a stand-alone program or as a module, component, subroutine, or other unit suitable for use in a computing environment. A computer program may be deployed to be executed on one computer or on multiple computers at one site or distributed across multiple sites and interconnected by a network.

[0047] Actions associated with implementing the systems may be performed by one or more programmable processors executing one or more computer programs to perform the functions of the calibration process. All or part of the systems may be implemented as special purpose logic circuitry, for example an field programmable gate array (FPGA) or an ASIC application-specific integrated circuit (ASIC), or both.

[0048] Processors suitable for the execution of a computer program include, by way of example, both general and special purpose microprocessors, and any one or more processors of any kind of digital computer. Generally, a processor will receive instructions and data from a read-only storage area or a random access storage area or both. Components of a computer (including a server) include one or more processors for executing instructions and one or more storage area devices for storing instructions and data. Generally, a computer will also include, or be operatively coupled to receive data from, or transfer data to, or both, one or more machine-readable storage media, such as mass storage devices for storing data, for example magnetic, magneto-optical disks, or optical disks. Non-transitory machine-readable storage media suitable for embodying computer program instructions and data include all forms of non-volatile storage area, including by way of example, semiconductor storage area devices, for example erasable programmable read-only memory (EPROM), electrically erasable programmable read-only memory (EEPROM), and flash storage area devices; magnetic disks, for example internal hard disks or removable disks; magneto-optical disks; and CD-ROM and DVD-ROM disks.

[0049] Each computing device, such as a surface-locating computing system, may include a hard drive for storing data and computer programs, and a processing device (for example a microprocessor) and memory (for example RAM) for executing computer programs. Each computing device may include an image capture device, such as a still camera or video camera. The image capture device may be built-in or simply accessible to the computing device.

[0050] Each computing device may include a graphics system, including a display screen. A display screen, such as a liquid crystal display (LCD) or a CRT (Cathode Ray Tube) displays, to a user, images that are generated by the graphics system of the computing device. As is well known, display on a computer display (for example a monitor) physically transforms the computer display. For example, if the computer display is LCD-based, the orientation of liquid crystals may be changed by the application of biasing voltages in a physical transformation that is visually apparent to the user. As another example, if the computer display is a CRT, the state of a fluorescent screen may be changed by the impact of electrons in a physical transformation that is also visually apparent. Each display screen may be touch-sensitive, allowing a user to enter information onto the display screen via a virtual keyboard. On some computing devices, such as a desktop or smartphone, a physical QWERTY keyboard or Arabic keyboard and scroll wheel may be provided for entering information onto the display screen. Each computing device, and computer programs executed on such a computing device, may also be configured to accept voice commands, and to perform functions in response to such commands. For example, the process described in this specification may be initiated at a client, to the extent possible, via voice commands.

[0051] Any “electrical connection” as used in this specification may imply a direct physical connection or a wired or wireless connection that includes or does not include intervening components but that nevertheless allows electrical signals to flow between connected components. Any “connection” involving electrical circuitry that allows signals to flow, unless stated otherwise, is an electrical connection and not necessarily a direct physical connection regardless of whether the word “electrical” is used to modify “connection”.

[0052] Physical connections or couplings between components described in this specification may be direct or through one or more intervening components.

[0053] Components of different implementations described in this specification may be combined to form other implementations not specifically set forth in this specification. Components may be left out of the systems, computer programs, databases, etc. described in this specification without adversely affecting their operation. Various separate components may be combined into one or more individual components to perform the functions described here.

What is claimed is:

1. A drill bit system comprising:
 - a drill bit comprising a drill bit body, the drill bit body comprising at least one leg that is connectable to a drill string;
 - at least one roller cone connected to the drill bit body, the at least one roller cone comprising cutting elements;
 - at least one bearing mounted between a surface of the drill bit body and the at least one roller cone;
 - a lubrication system to reduce friction between moving parts of the drill bit; and
 - at least one wear sensor associated with the drill bit to sense physical wear on the drill bit.
2. The drill bit system of claim 1, comprising at least one lubrication sensor to sense a presence of lubricant in a lubricant reservoir.
3. The drill bit system of claim 1, where the at least one wear sensor is an erosion sensor to sense a reduction of drill bit material.
4. The drill bit system of claim 1, where the at least one wear sensor is fluid sensor to sense a presence of wellbore fluid at a drill bit surface.
5. The drill bit system of claim 1, where the at least one wear sensor is mounted in, or on, the at least one leg of the drill bit.
6. The drill bit system of claim 1, where the at least one wear sensor is mounted in or on at least one of the plurality of cutting elements of the at least one roller cone.
7. The drill bit system of claim 1, where the at least one sensor is mounted in, or on, a gauge protector of the at least one roller cone.

8. The drill bit system of claim 1, wherein the at least one sensor comprises at least two sensors, where the at least two sensors comprise at least a first wear sensor and a second wear sensor to sense physical wear on the drill bit;

where the first wear sensor is mounted in the drill bit at a first distance from a surface of the drill bit, and the second wear sensor is mounted in the drill bit at a second distance from a surface of the drill bit, where the second distance is greater than the first distance.

9. The drill bit system of claim 8, where the at least two sensors comprise a third wear sensor to sense physical wear on the drill bit, where the third wear sensor is mounted in the drill bit at a third distance from a surface of the drill bit, where the third distance is greater than the second distance.

10. The drill bit system of claim 1, further comprising at least one processor, where the at least one wear sensor is in communication with the at least one processor to provide sensing data to the at least one processor, and where the at least one processor is configured to process the sensing data to display the data on a user interface.

11. The drill bit system of claim 1, where the at least one sensor is connected to an intermediary device through a first electrical connection, and the intermediary device is connected to the primary processor through a second electrical connection.

12. The drill bit system of claim 11, where the first electrical connection and the second electrical connection include wireless connections.

13. A drill bit system comprising:
a drill bit comprising a drill bit body that is connectable to a drill string, the drill bit body comprising at least one blade, the at least one blade comprising cutting elements; and
at least one wear sensor associated with the drill bit to sense physical wear on the drill bit.

14. A drill bit system comprising:

a drill bit comprising a drill bit body that is connectable to a drill string, the drill bit body comprising at least one blade, the at least one blade comprising cutting elements;

at least one roller cone connected to the drill bit body, the at least one roller cone comprising cutting elements;

at least one bearing between a surface of the drill bit body and the at least one roller cone;

a lubrication system to reduce friction between moving parts of the drill bit; and

at least one wear sensor mounted associated with the drill bit to sense physical wear on the drill bit.

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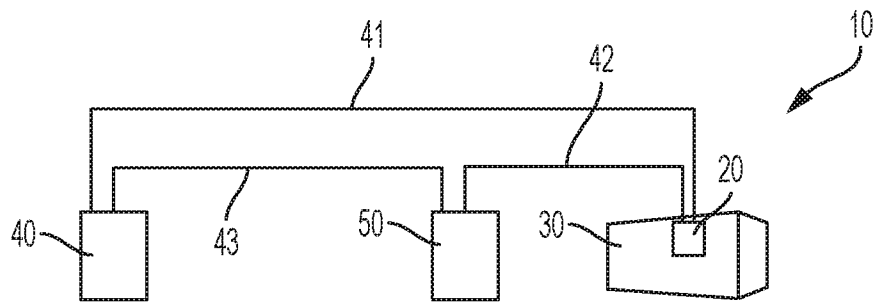


FIG. 1A

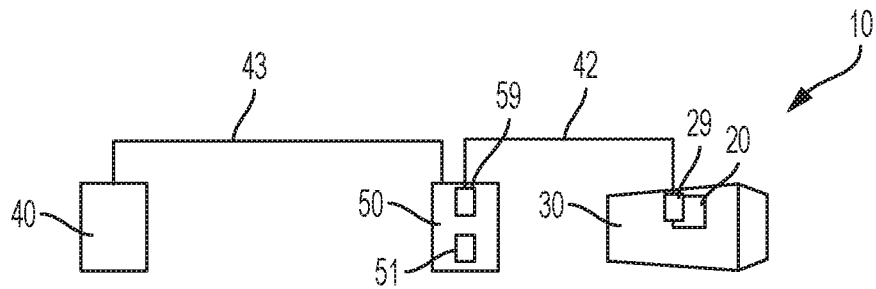


FIG. 1B

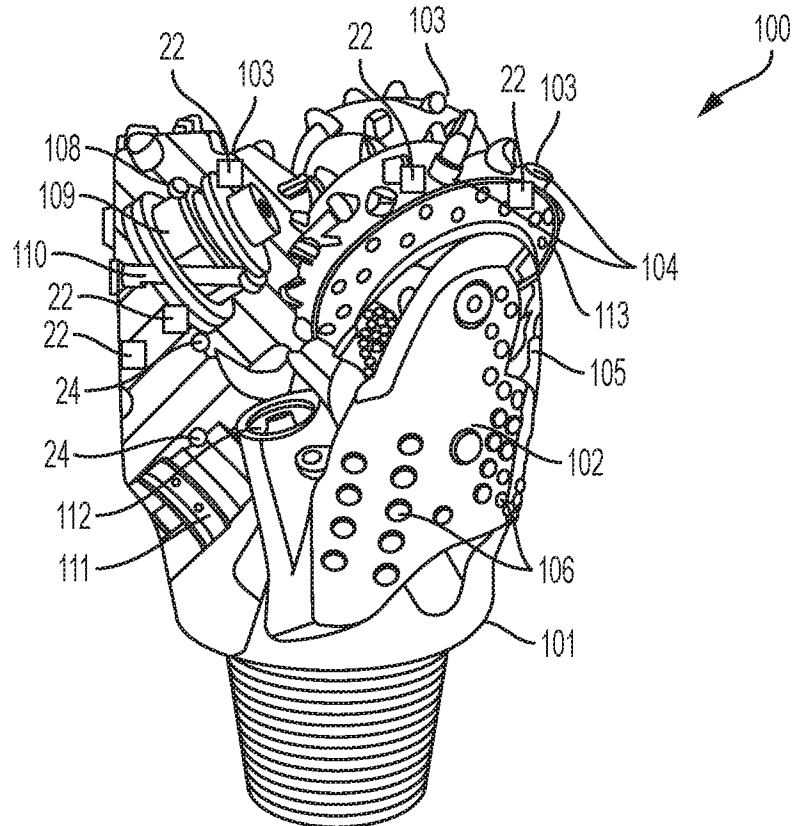


FIG. 2

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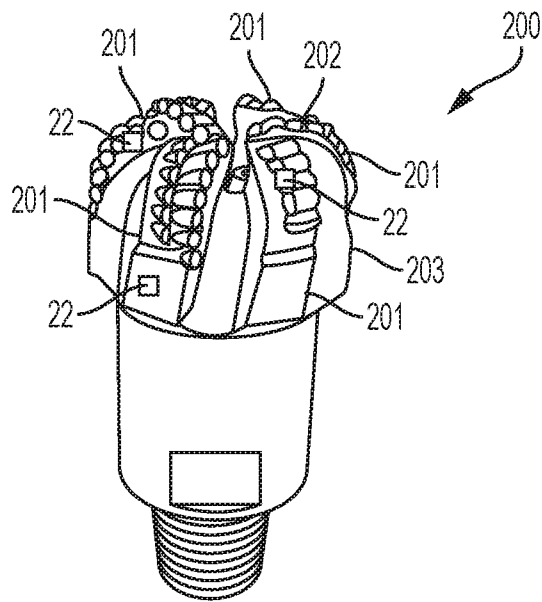


FIG. 3A

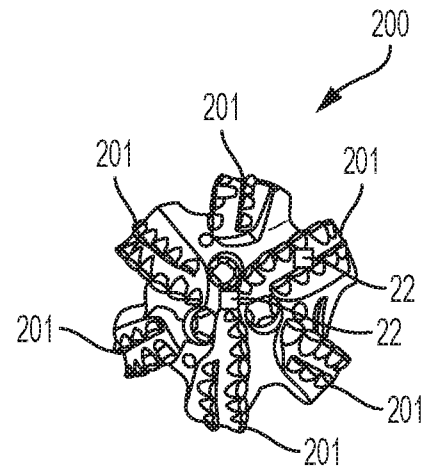


FIG. 3B

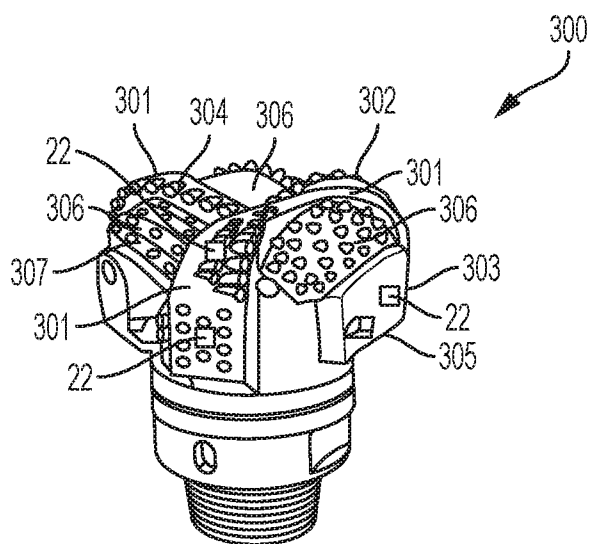


FIG. 4A

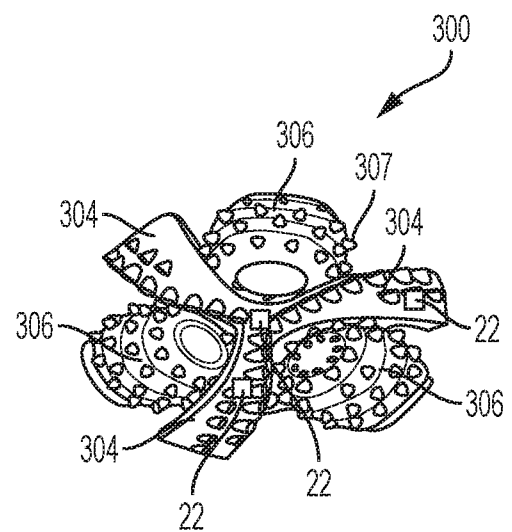


FIG. 4B

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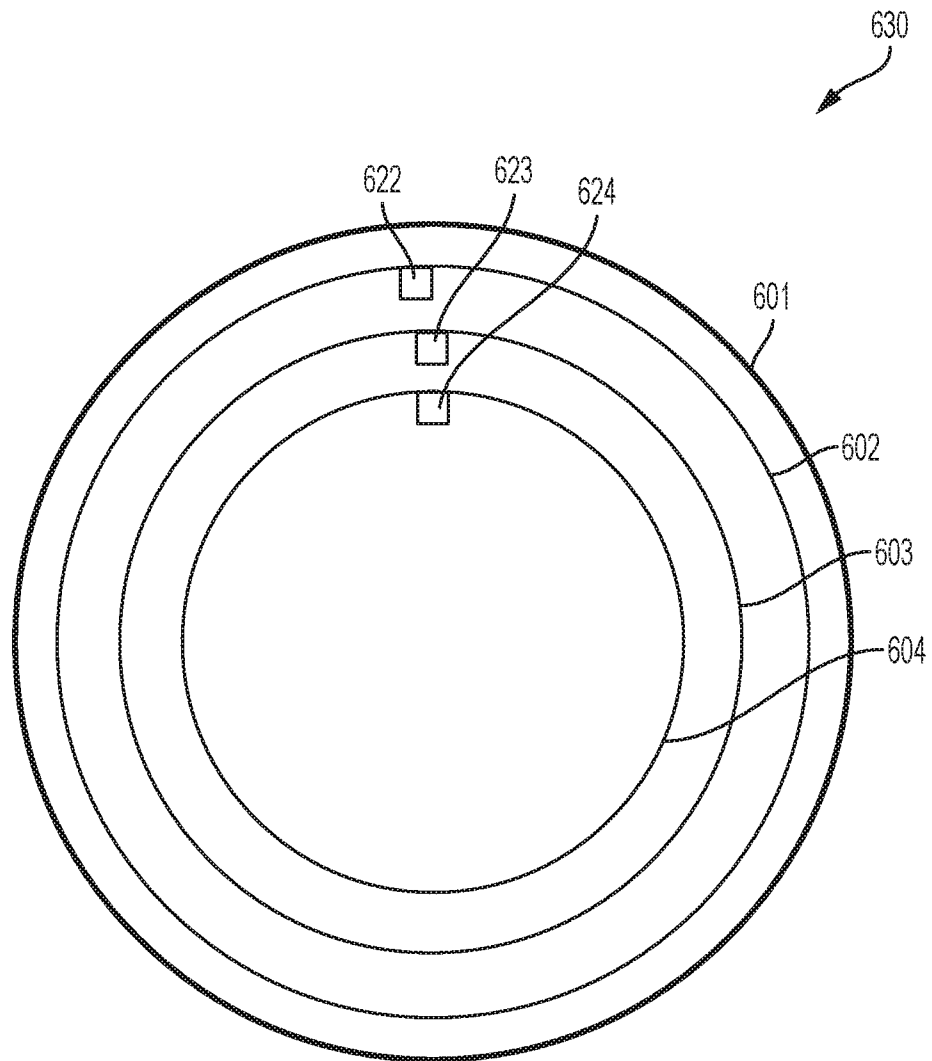


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2018/057416

A. CLASSIFICATION OF SUBJECT MATTER INV. E21B47/12 E21B10/14 E21B10/42 E21B10/55 E21B10/56 E21B12/02 E21B10/08 ADD. According to International Patent Classification (IPC) or to both national classification and IPC																	
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) E21B Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal, WPI Data																	
C. DOCUMENTS CONSIDERED TO BE RELEVANT <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 10%;">Category*</th> <th style="width: 70%;">Citation of document, with indication, where appropriate, of the relevant passages</th> <th style="width: 20%;">Relevant to claim No.</th> </tr> </thead> <tbody> <tr> <td style="text-align: center; vertical-align: top;">X</td> <td style="vertical-align: top;"> WO 2015/147786 A1 (HALLIBURTON ENERGY SERVICES INC [US]) 1 October 2015 (2015-10-01) paragraphs [0018], [0020]; claim 1; figures 1-8 ----- </td> <td style="text-align: center; vertical-align: top;">1-14</td> </tr> <tr> <td style="text-align: center; vertical-align: top;">X</td> <td style="vertical-align: top;"> US 9 464 487 B1 (ZURN WILLIAM HARRISON [US]) 11 October 2016 (2016-10-11) column 7, lines 1-6 ----- </td> <td style="text-align: center; vertical-align: top;">1-14</td> </tr> <tr> <td style="text-align: center; vertical-align: top;">X</td> <td style="vertical-align: top;"> US 2005/230149 A1 (BOUCHER MARCEL [US] ET AL) 20 October 2005 (2005-10-20) claims 1-4 ----- </td> <td style="text-align: center; vertical-align: top;">1-14</td> </tr> <tr> <td style="text-align: center; vertical-align: top;">X</td> <td style="vertical-align: top;"> GB 2 516 450 A (SCHLUMBERGER HOLDINGS [VG]) 28 January 2015 (2015-01-28) paragraphs [0039], [0042], [0059] ----- -/-- </td> <td style="text-align: center; vertical-align: top;">1-14</td> </tr> </tbody> </table>			Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.	X	WO 2015/147786 A1 (HALLIBURTON ENERGY SERVICES INC [US]) 1 October 2015 (2015-10-01) paragraphs [0018], [0020]; claim 1; figures 1-8 -----	1-14	X	US 9 464 487 B1 (ZURN WILLIAM HARRISON [US]) 11 October 2016 (2016-10-11) column 7, lines 1-6 -----	1-14	X	US 2005/230149 A1 (BOUCHER MARCEL [US] ET AL) 20 October 2005 (2005-10-20) claims 1-4 -----	1-14	X	GB 2 516 450 A (SCHLUMBERGER HOLDINGS [VG]) 28 January 2015 (2015-01-28) paragraphs [0039], [0042], [0059] ----- -/--	1-14
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X	GB 2 516 450 A (SCHLUMBERGER HOLDINGS [VG]) 28 January 2015 (2015-01-28) paragraphs [0039], [0042], [0059] ----- -/--	1-14															
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Date of the actual completion of the international search 24 January 2019	Date of mailing of the international search report 04/02/2019																
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Manolache, Iustin																

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International application No
PCT/IB2018/057416

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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