VARIED RPM DRILL BIT STEERING

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ABSTRACT
A method of steering a drill bit while drilling a wellbore can include periodically increasing a rotational speed of the drill bit while drilling the wellbore, with the rotational speed being increased when an axis of the drill bit is oriented in a desired azimuthal direction relative to a drill string axis. A directional drilling system can include a drill string having a bend interconnected therein, a drill bit, and a controller which selectively increases a rotational speed of the drill bit when an axis of the drill bit is oriented in a desired azimuthal direction relative to an axis of the drill string above the bend. Another method of steering a drill bit while drilling a wellbore can include interconnecting a brake in a drill string, and periodically decreasing a braking force of the brake as the drill bit is rotated.
VARIED RPM DRILL BIT STEERING
CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit under 35 USC §119 of the filing date of International Application Serial No. PCT/US09/28498, filed Mar. 24, 2010, and PCT/US09/69609, filed Dec. 28, 2009. The entire disclosures of these prior applications are incorporated herein by this reference.

BACKGROUND

The present disclosure relates generally to equipment utilized and operations performed in conjunction with a subterranean well and, in an embodiment described herein, more particularly provides for drill bit steering by varying a rotational speed of the drill bit.

It is frequently desirable to drill a wellbore in a selected direction, for example, to steer toward a hydrocarbon reservoir, or to steer away from a fault or a water zone (although in some circumstances, such as geothermal and conformance operations, it may be desirable to steer toward a fault or water zone). Therefore, it will be appreciated that improvements are needed in the art of steering a drill bit to thereby drill a wellbore in a desired direction.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic view of a directional drilling system and associated method which may embody principles of the present disclosure.

FIG. 2 is a schematic depiction of relative relationships of axes of a drill string in the system and method of FIG. 1.

FIG. 3 is a schematic depiction of an azimuthal direction of a drill bit axis relative to a drill string axis.

FIGS. 4-7 are schematic cross-sectional views of various configurations of an impact tool which may be used in the system and method of FIG. 1.

FIG. 8 is a schematic cross-sectional view of a brake which may be used in the system and method of FIG. 1.

DETAIL ED DESCRIPTION

Representatively illustrated in FIG. 1 is a directional drilling system 10 and associated method which can embody principles of the present disclosure. It should be clearly understood, however, that the principles of this disclosure are not limited at all to the specific details of the system 10 and method described herein. Instead, the system 10 and method are provided as merely one example of how the principles of this disclosure can be effectively used for steering a drill bit, and for thereby drilling a wellbore in a desired direction (including inclination).

As depicted in FIG. 1, a wellbore 12 is being drilled with a generally tubular drill string 14. A drill bit 16 is connected at a lower end of the drill string 14. Rotation of the drill string 14 (e.g., by a drilling rig at or near the earth’s surface) can be used to rotate the drill bit 16, whereby the drill bit cuts into the earth to drill the wellbore 12.

A mud motor 18 is also preferably interconnected as part of the drill string 14. The mud motor 18 is of the type well known to those skilled in the art, which rotates the drill bit 16 in response to flow of drilling fluid through the drill string 14. Thus, the mud motor 18 can be used to rotate the drill bit 16, even if the drill string 14 above the mud motor is not rotated.

Mud motors are also known as positive displacement motors, Moineau-type motors and progressive cavity motors. Typically, such motors include a helical rotor which rotates within, and sealingly engages, a multi-lobed stator.

A bend 20 is also interconnected in the drill string 14. Although not perceptible in FIG. 1, the bend 20 provides a small (e.g., approximately 1.5 degree) deviation in a longitudinal axis of the drill string 14. The bend 20 is of the type well known to those skilled in the art, and is typically used for directional drilling when a mud motor (such as the mud motor 18) rotates a drill bit (such as the drill bit 16).

The bend 20 can be used for steering the drill bit 16 in the system 10 when the mud motor 18 rotates the drill bit (e.g., when the drill string 14 is not rotated from the surface). However, this disclosure also provides for steering the drill bit 16 when the drill string 14 is rotated, and the mud motor 18 is used for rotating the drill bit in response to flow of drilling fluid through the mud motor.

In one unique feature of the system 10, when the drill string 14 and the mud motor 18 are used for rotating the drill bit 16, the rotational speed of the drill bit (rotations per minute or “rpm”) can be varied, to thereby control a direction of drilling the wellbore 12. The timing of the rpm variations is controlled by a controller 24, which is in communication with a sensor assembly 26, and which can be remotely operable and communicated with (e.g., from the surface) via various forms of wired and wireless telemetry.

In another unique feature of the system 10, the rotational speed of the drill bit 16 can be varied by operation of a brake 17. The brake 17 selectively applies a braking force to a shaft of the mud motor 18, to thereby vary the rotational speed of the drill bit 16.

The brake 17 can deliver timed periodic variations of drill bit 16 rpm as described more fully below. The timing of application of the braking force is preferably controlled by the controller 24.

The sensor assembly 26 can be of the type well known to those skilled in the art as a measurement while drilling (MWD) system. Such MWD systems are capable of measuring a multitude of drilling parameters, and in this system 10 the sensor assembly 26 is beneficially capable of detecting an orientation of the drill string 14 and, in conjunction with a sensor 19 of the mud motor 18, an azimuthal direction of the drill bit 16 relative to the longitudinal axis of the drill string above the bend 20 can be readily determined.

Interconnected in the drill string 14 above the mud motor 18 is an optional impact tool 22. The impact tool 22 can deliver timed periodic impacts to the drill bit 16 as described more fully below, although use of the impact tool is not necessary in keeping with the principles of this disclosure. The timing of the impacts is controlled by the controller 24, and can also be remotely operable (e.g., from the surface) via various forms of wired and wireless telemetry.

Referring additionally now to FIG. 2, a schematic depiction of the longitudinal axis 28 of the drill string 14 is representatively illustrated. The bend 20 in the drill string 14 is exaggerated in FIG. 2 for illustrative purposes.

The longitudinal axis 28 of the drill string 14 above the bend 20 is designated as 28a, the longitudinal axis of the drill string at the bend is designated as 28b, and the longitudinal axis of the drill string below the bend is designated as 28c in FIG. 2. Note that the longitudinal axis 28c of the drill string 14 below the bend 20 coincides with the longitudinal axis of the drill bit 16.
It will be appreciated that the axis 28c of the drill bit 16 deviates from the longitudinal axis 28a of the drill string 14 above the bend 20 by an angle A. This angle A may be relatively small, but when compounded over distances of, for example, a hundred meters or more, can produce a much larger change in direction of the wellbore 12 and thereby steer drill bit 16.

Note that, although the axis 28a is depicted in FIG. 2 as being vertical, the axis 28a is described herein as being "above" the bend 20, and the axis 28c is described herein as being "below" the bend, it is not necessary in keeping with the principles of this disclosure for the axis 28a to be vertical, since the axis 28a could be generally horizontal, deviated, inclined relative to vertical, etc. The terms "above," "below" and similar directional terms are used for convenience to refer to positions relative to proximal and distal ends of the drill string 14. For example, the axis 28a is "above" the bend 20, in that it is nearer the proximal end of the drill string 14 (e.g., closer to the surface), and the axis 28c is "below" the bend, in that it is nearer the distal end (in this case, the bottom end) of the drill string (e.g., farther from the surface).

The impact tool 22 can be used to deliver an impact (represented by arrows 30 in FIG. 2) directed along the longitudinal axis 28 of the drill string 14. Due to the bend 20 in the drill string 14, the impact 30 can be directed both along the axis 28a of the drill string 14 above the bend 20, and along the axis 28c of the drill string and drill bit 16 below the bend. This arrangement provides advantages to the system 10 in some embodiments as described more fully below.

Referring additionally now to FIG. 3, a schematic view of the relationship between the azimuthal direction of the drill bit 16 (represented by arrow 32 in FIG. 3) and the drill string axis 28a is representatively illustrated. That is, FIG. 3 presents a view downward along the axis 28a and, due to the angle A by which the drill bit axis 28c deviates from the drill string axis 28a, the drill bit 16 has an azimuthal direction 32 relative to the drill string axis 28a.

As the drill string 14 rotates, the azimuthal direction 32 of the drill bit axis 28c relative to the drill string axis 28a also rotates (as indicated by arrow 34 in FIG. 3). In one unique aspect of the system 10, the brake 17 causes the drill bit 16 rpm to increase when the azimuthal direction 32 of the drill bit axis 28c relative to the drill string axis 28a is in a desired direction (or at least within a selected range of the desired direction, for example, within a window of 10 degrees to either side of the desired direction). Viewed from another perspective, the brake 17 causes the drill bit 16 rpm to decrease when the azimuthal direction 32 of the drill bit axis 28c relative to the drill string axis 28a is not in the desired direction.

In an optional feature of the system 10, the impact tool 22 delivers the impact 30 to the drill bit 16 when (and preferably only when) the azimuthal direction 32 of the drill bit axis 28c relative to the drill string axis 28a is in a desired direction. The impact tool 22 may be used to deliver the impact 30 in conjunction with the drill bit 16 speed variations, or the impact tool may be used separately from the variations in drill bit speed (i.e., so that the two techniques are not simultaneously used to steer the drill bit 16).

For example, if it is desired to steer the drill bit 16 in an azimuthal direction of 30 degrees relative to the drill bit axis 28c, then the impact 30 would be delivered to the drill bit 16 when the drill bit axis 28c is oriented in an azimuthal direction 32 of 30 degrees relative to the drill string axis 28a (as depicted in FIG. 3). Since the azimuthal direction 32 of the drill bit axis 28c rotates about the drill string axis 28a (as represented by arrow 34 in FIG. 3) as the drill string 14 rotates, the azimuthal direction of the drill bit axis will coincide with the desired azimuthal direction once for every rotation of the drill string 14.

Preferably, the brake 17 increases the rpm of the drill bit 16 once for each rotation of the drill string 14 (when the azimuthal direction 32 of the drill bit axis 28c is oriented toward the desired direction), but the increased rpm could be provided every other rotation, every third rotation, multiple times per rotation, or at other times, in keeping with the principles of this disclosure.

The controller 24 controls the timing of the increased rpm, based on the detection of the orientation of the drill bit axis 28c relative to the drill string axis 28a as sensed by the sensor assembly 26 and the mud motor sensor 19, and preferably based on commands, data, instructions, etc. communicated with a remote location (such as the surface) via telemetry. Any form of telemetry may be used, for example, wired or wireless telemetry. Wireless telemetry may include acoustic, electromagnetic, pressure pulse (positive and/or negative), pipe manipulation, etc. Wired telemetry may be via conductors internal to, external to, or in a wall of the drill string 14, etc.

The controller 24 may be used to activate or deactivate the brake 17 (e.g., to cause the brake to begin or cease delivering the variations in drill bit 16 rpm), to change the frequency of the rpm variations (e.g., the number of rpm variations per rotation of the drill string 14), to change the desired azimuthal direction for steering the drill bit, to change the amplitude of rpm variation, etc. Any parameter related to the performance of the rpm variation may be controlled using the controller 24, in keeping with the principles of this disclosure. The controller 24, or any portion of it, may be located downhole or at a remote location (such as the earth's surface, a sea floor location, a floating rig, etc.), and the controller can be part of a more comprehensive control system.

As the bend 20 below the mud motor 18 rotates through the hole it will create a rotating contact pressure on the inner wall of the wellbore 12, due to the bend. Thus, by including the bend 20, some of the force (such as, due to the weight of the drill string 14) applied to the drill bit 16 is directed laterally, instead of only in an axial direction. When the rpm of the drill bit 16 is varied at any given azimuthal orientation of the bend 20, it will facilitate either more or less cutting into the earth at that orientation, thereby providing for steering in a desired direction.

When the impact tool 22 is used, preferably the impact tool delivers the impact 30 to the drill bit 16 once for each rotation of the drill string 14 (when the azimuthal direction 32 of the drill bit axis 28c is oriented toward the desired direction), but the impact could be delivered every other rotation, every third rotation, multiple times per rotation, or at other times, in keeping with the principles of this disclosure.

The controller 24 controls the timing of the impact 30, based on the detection of the orientation of the drill bit axis 28c relative to the drill string axis 28a as sensed by the sensor assembly 26, the sensor 19, and preferably based on commands, data, instructions, etc. received from a remote location (such as the surface) via telemetry.

The controller 24 may be used to activate or deactivate the impact tool 22 (e.g., to cause the impact tool to begin or cease delivering the impact 30 to the drill bit 16), to change
the frequency of the impact (e.g., the number of impacts per rotation of the drill string 14), to change the desired azimuthal direction for steering the drill bit, to change the impact force delivered, etc. Any parameter related to the delivery of the impact 30 by the impact tool 22 may be controlled using the controller 24, in keeping with the principles of this disclosure.

[0036] Referring additionally now to FIGS. 4-7, various configurations of the impact tool 22 are schematically and representatively illustrated. However, it should be clearly understood that these examples of configurations of the impact tool 22 are not to be taken as limiting the principles of this disclosure to the depicted examples. Instead, the examples depicted in FIGS. 4-7 are intended to demonstrate that a wide variety of impact tool configurations are possible in keeping with the principles of this disclosure.

[0037] In FIG. 4, the impact tool 22 is depicted in a configuration in which a valve or other flow restricting device 36 is used to periodically close off or restrict flow of the drilling fluid 38 through a passage extending longitudinally through the impact tool. When the flow of the drilling fluid 38 is restricted by the device 36, the momentum of the fluid is converted to a force transmitted as the impact 30 through an outer housing 42 of the impact tool 22.

[0038] The device 36 could be provided as a spool valve, rotary valve, poppet valve or any other type of valve. However, it is not necessary for flow of the fluid 38 to be entirely prevented in order for the impact 30 to be generated, since a sufficient change in momentum of the fluid through the passage 40 could result from substantially restricting (rather than entirely preventing) the flow of the fluid.

[0039] Operation of the device 36 (for example, the timing of the restriction to flow of the fluid 38 through the passage 40) is controlled by the controller 24, as described above. Lines 44 are depicted in FIG. 4 for connecting the device 36 to the controller 24, but it should be understood that the controller could control operation of the device mechanically, hydraulically, electrically, optically, or in any other manner, in keeping with the principles of this disclosure.

[0040] In FIG. 5, the impact tool 22 is depicted as including a valve 46, a piston 48, a mass 50, a biasing device 52 and a shoulder 54. When the impact 30 is to be delivered to the drill bit 16, the valve 46 is opened, thereby exposing the piston 48 to fluid pressure in the passage 40, and the piston displaces the mass 50 into contact with the shoulder 54. The timing of the opening of the valve 46 is controlled by the controller 24, as described above.

[0041] In FIG. 6, the impact tool 22 is depicted as including a solenoid 56 which is used to displace the mass 50 into contact with the shoulder 54 to thereby produce the impact 30. The timing of energizing the solenoid 56 is controlled by the controller 24, as described above.

[0042] In FIG. 7, the impact tool 22 is depicted as including a piezoelectric material 58 in the form of a stack of annular disks 60. When an electrical potential is applied across the piezoelectric material 58, the material distorts and thereby produces the impact 30. The timing of applying the electrical potential across the piezoelectric material 58 is controlled by the controller 24, as described above.

[0043] Referring additionally now to FIG. 8, a schematic cross-sectional view of one configuration of the brake 17 which may be used in the system 10 is representatively illustrated. In this view, it may be seen that a shaft 62 rotated by the mud motor 18 extends through the brake 17. The shaft 62 is connected to the drill bit 16 below, whereby the mud motor 18 rotates the drill bit via the shaft.

[0044] The brake 17 is used to apply a braking force to the shaft 62, thereby decreasing the drill bit 16 rpm, when the azimuthal direction 32 of the drill bit axis 28c relative to the drill string axis 28a does not coincide with the desired azimuthal direction. The braking force is released (or at least decreased), thereby increasing the drill bit 16 rpm, when the azimuthal direction 32 of the drill bit axis 28c relative to the drill string axis 28a does coincide with the desired direction (or at least when the azimuthal direction of the drill bit axis is within a selected range of the desired direction).

[0045] As depicted in FIG. 8, the brake 17 includes an electronic interface and power supply 64 which is connected to the controller 24. Lines 65 are shown in FIG. 8 for connecting the interface and power supply 64 to the controller 24, but it should be understood that the controller could control operation of the device mechanically, hydraulically, electrically, optically, or in any other manner, in keeping with the principles of this disclosure. Upon receiving an appropriate command from the controller 24, the interface and power supply 64 causes electrical power to be applied to a braking device 66, which in response applies a braking force to the shaft 62.

[0046] The braking device 66 could be any type of device which is capable of applying a variable braking force to the shaft 62. For example, the braking device 66 could comprise a magnetic brake which utilizes a magnetic field in conjunction with one or more permanent magnets 68 carried on the shaft 62 to apply the braking force. By varying the magnetic field output from the braking device 66, the braking force applied to the shaft 62 can be conveniently varied as desired.

[0047] Of course, other means of applying a braking force to the shaft 62 (or otherwise varying the rpm of the drill bit 16) may be used, in keeping with the principles of this disclosure. A rotational speed of the mud motor 18 could be varied by, for example, varying a flow rate of fluid through the motor, or varying fluid pressure applied to the motor. A variable braking force could be applied mechanically, hydraulically, magnetically (as described above), or in any other manner.

[0048] Although the brake 17, mud motor 18, bend 20, impact tool 22, controller 24 and sensor assembly 26 are separately described above, any of these elements could be combined with any of the other elements, as desired. For example, the mud motor 18 could be provided with the bend 20 as a single assembly, the impact tool 22 and controller 24 could be provided as a single assembly, the brake 17 could be incorporated into the mud motor or bend, the mud motor 18 can be provided with the sensor assembly 26 for detecting when the drill bit axis 28c is pointing in the desired azimuthal direction relative to the drill string axis 28a, etc.

[0049] It may now be fully appreciated that the above disclosure provides several advancements to the art of steering a drill bit and directional drilling of a wellbore. In particular, the drill bit 16 can be steered while the mud motor 18 rotates the drill bit, by increasing the rpm of the drill bit when an azimuthal direction 32 of its axis 28c is in a desired direction relative to an axis 28a of the drill string. The increase in rotational speed of the drill bit 16 when its axis 28c is oriented in the desired azimuthal direction 32 (or within a selected range of the desired direction) causes the wellbore 12 to be preferentially drilled in the desired direction. Furthermore, the impact tool 22 can be used to deliver the impact 30 to the drill bit 16 when its axis 28c is in the desired azimuthal
direction 32 relative to the drill string axis 28a, to thereby enhance the steering of the drill bit in the desired direction.

[0050] The above disclosure provides to the art a method of steering a drill bit 16 while drilling a wellbore 12. The method can include periodically increasing a rotational speed of the drill bit 16 while drilling the wellbore 12, with the rotational speed of the drill bit 16 being increased when an axis 28c of the drill bit 16 is oriented in a desired azimuthal direction 32 relative to an axis 28a of a drill string 14.

[0051] The rotational speed of the drill bit 16 may be decreased when the drill bit axis 28c is oriented away from the desired azimuthal direction 32.

[0052] The drill bit axis 28c preferably rotates about the drill string axis 28a while the rotational speed of the drill bit 16 varies.

[0053] The rotational speed of the drill bit 16 may be increased only when the drill bit axis 28c is oriented in the desired azimuthal direction 32 relative to the drill string axis 28a, or when the drill bit axis 28c is oriented within a selected range of the desired azimuthal direction 32 relative to the drill string axis 28a.

[0054] The method can include periodically delivering an impact to the drill bit 16 as the drill bit is rotated. The impact may be delivered by an impact tool 22 interconnected in the drill string 14. The impact 30 is preferably delivered to the drill bit 16 when an axis 28c of the drill bit 16 is oriented in a desired azimuthal direction 32 relative to an axis 28a of the drill string 14.

[0055] The desired azimuthal direction 32 of the drill bit axis 28c can be changed from a remote location. Changing the desired azimuthal direction 32 may be performed in part by transmitting a command from the remote location via a telemetry signal.

[0056] Increasing the rotational speed of the drill bit 16 can be performed by decreasing a braking force.

[0057] Also described by the above disclosure is a directional drilling system 10 which can include a drill string 14 having a bend 20 interconnected therein, a drill bit 16, and a controller 24 which selectively increases a rotational speed of the drill bit 16 when an axis 28c of the drill bit 16 is oriented in a desired azimuthal direction 32 relative to an axis 28a of the drill string 14 above the bend 20.

[0058] The controller 24 may selectively decrease the rotational speed of the drill bit 16 when the axis 28c of the drill bit 16 is oriented away from the desired azimuthal direction 32. The controller 24 can selectively decrease the rotational speed of the drill bit 16 by selectively increasing a braking force applied to the drill string 14.

[0059] The controller 24 may selectively increase the rotational speed of the drill bit 16 when the axis 28c of the drill bit 16 is oriented within a selected range of the desired azimuthal direction 32. The controller 24 can selectively increase the rotational speed of the drill bit 16 by selectively decreasing a braking force applied to the drill string 14.

[0060] The system 10 can also include an impact tool 22 which delivers an impact 30 to the drill bit 16. The impact tool 22 may deliver the impact 30 to the drill bit 16 when the axis 28c of the drill bit is oriented in the desired azimuthal direction 32.

[0061] At least one sensor 19, 26 interconnected in the drill string 14 may sense the azimuthal direction of the axis 28c of the drill bit 16 relative to the axis 28a of the drill string 14 above the bend 20.

[0062] The desired azimuthal direction 32 may be changeable from a remote location. The desired azimuthal direction 32 may be changed in part by transmission of a command from the remote location to the controller 24 via a telemetry signal.

[0063] In another method of steering a drill bit 16 while drilling a wellbore 12, the method can include interconnecting a brake 17 in a drill string 14, and periodically decreasing a braking force of the brake 17 as the drill bit 16 is rotated.

[0064] The braking force may be decreased when an axis 28c of the drill bit 16 is oriented in a desired azimuthal direction 32 relative to an axis 28a of the drill string 14. The desired azimuthal direction may be changed from a remote location, in some examples, at least in part by transmitting a command from the remote location via a telemetry signal.

[0065] A rotational speed of the drill bit 16 can be increased as a result of decreasing the braking force. The rotational speed of the drill bit 16 may be increased while an axis 28c of the drill bit 16 is oriented in a desired azimuthal direction 32 relative to an axis 28a of the drill string 14, or at least while the axis 28c of the drill bit 16 is oriented within a selected range of the desired azimuthal direction 32.

[0066] The method can include periodically delivering an impact 30 to the drill bit 16 as the drill bit is rotated. The impact 30 may be delivered by an impact tool 22 interconnected in the drill string 14. The impact 30 is preferably delivered to the drill bit 16 when an axis 28c of the drill bit 16 is oriented in a desired azimuthal direction 32 relative to an axis 28a of the drill string 14.

[0067] It is to be understood that the various embodiments of the present disclosure described herein may be utilized in various orientations, such as inclined, inverted, horizontal, vertical, etc., and in various configurations, without departing from the principles of the present disclosure. The embodiments are described merely as examples of useful applications of the principles of the disclosure, which is not limited to any specific details of these embodiments.

[0068] Of course, a person skilled in the art would, upon a careful consideration of the above description of representative embodiments of the disclosure, readily appreciate that many modifications, additions, substitutions, deletions, and other changes may be made to the specific embodiments, and such changes are contemplated by the principles of the present disclosure. Accordingly, the foregoing detailed description is to be clearly understood as being given by way of illustration and example only, the spirit and scope of the present invention being limited solely by the appended claims and their equivalents.

What is claimed is:

1. A method of steering a drill bit while drilling a wellbore, the method comprising:
   periodically increasing a rotational speed of the drill bit while drilling the wellbore; and
   the rotational speed of the drill bit being increased when an axis of the drill bit is oriented in a desired azimuthal direction relative to an axis of a drill string.

2. The method of claim 1, wherein the rotational speed of the drill bit is decreased when the drill bit axis is oriented away from the desired azimuthal direction.

3. The method of claim 1, wherein the drill bit axis rotates about the drill string axis while the rotational speed of the drill bit varies.
4. The method of claim 1, wherein the rotational speed of the drill bit is increased only when the drill bit axis is oriented in the desired azimuthal direction relative to the drill string axis.

5. The method of claim 1, wherein the rotational speed of the drill bit is increased when the drill bit axis is oriented within a selected range of the desired azimuthal direction relative to the drill string axis.

6. The method of claim 1, further comprising periodically delivering an impact to the drill bit as the drill bit is rotated.

7. The method of claim 6, wherein the impact is delivered by an impact tool interconnected in the drill string.

8. The method of claim 6, wherein the impact is delivered to the drill bit when the axis of the drill bit is oriented in the desired azimuthal direction relative to the axis of the drill string.

9. The method of claim 1, further comprising changing the desired azimuthal direction of the drill bit axis from a remote location.

10. The method of claim 9, wherein changing the desired azimuthal direction is performed in part by transmitting a command from the remote location via a telemetry signal.

11. A directional drilling system, comprising:
   a drill string having a bend interconnected therein;
   a drill bit; and
   a controller which selectively increases a rotational speed of the drill bit when an axis of the drill bit is oriented in a desired azimuthal direction relative to an axis of the drill string above the bend.

12. The system of claim 11, wherein the controller selectively decreases the rotational speed of the drill bit when the axis of the drill bit is oriented away from the desired azimuthal direction.

13. The system of claim 12, wherein the controller selectively decreases the rotational speed of the drill bit by selectively increasing a braking force applied to the drill string.

14. The system of claim 12, wherein the controller selectively increases the rotational speed of the drill bit when the axis of the drill bit is oriented within a selected range of the desired azimuthal direction.

15. The system of claim 11, wherein the controller selectively increases the rotational speed of the drill bit by selectively decreasing a braking force applied to the drill string.

16. The system of claim 11, further comprising an impact tool which delivers an impact to the drill bit.

17. The system of claim 16, wherein the impact tool delivers the impact to the drill bit when the axis of the drill bit is oriented in the desired azimuthal direction.

18. The system of claim 16, wherein at least one sensor interconnected in the drill string senses the azimuthal direction of the axis of the drill bit relative to the axis of the drill string above the bend.

19. The system of claim 11, wherein the desired azimuthal direction is changeable from a remote location.

20. The system of claim 19, wherein the desired azimuthal direction is changeable in part by transmission of a command from a remote location to the controller via a telemetry signal.

21. A method of steering a drill bit while drilling a wellbore, the method comprising:
   interconnecting a brake in a drill string; and
   periodically decreasing a braking force of the brake as the drill bit is rotated.

22. The method of claim 21, wherein the braking force is decreased when an axis of the drill bit is oriented in a desired azimuthal direction relative to an axis of the drill string.

23. The method of claim 22, further comprising changing the desired azimuthal direction from a remote location.

24. The method of claim 23, wherein changing the desired azimuthal direction is performed in part by transmitting a command from the remote location via a telemetry signal.

25. The method of claim 21, wherein a rotational speed of the drill bit is increased as a result of decreasing the braking force.

26. The method of claim 25, wherein the rotational speed of the drill bit is increased while an axis of the drill bit is oriented in a desired azimuthal direction relative to an axis of the drill string.

27. The method of claim 26, wherein the rotational speed of the drill bit is increased while an axis of the drill bit is oriented within a selected range of the desired azimuthal direction.

28. The method of claim 21, further comprising periodically delivering an impact to the drill bit as the drill bit is rotated.

29. The method of claim 28, wherein the impact is delivered by an impact tool interconnected in the drill string.

30. The method of claim 28, wherein the impact is delivered to the drill bit when an axis of the drill bit is oriented in a desired azimuthal direction relative to an axis of the drill string.

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