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(54) SELF-STABILIZED AND ANTI-WHIRL DRILL BITS AND BOTTOM-HOLE ASSEMBLIES AND SYSTEMS FOR USING THE SAME

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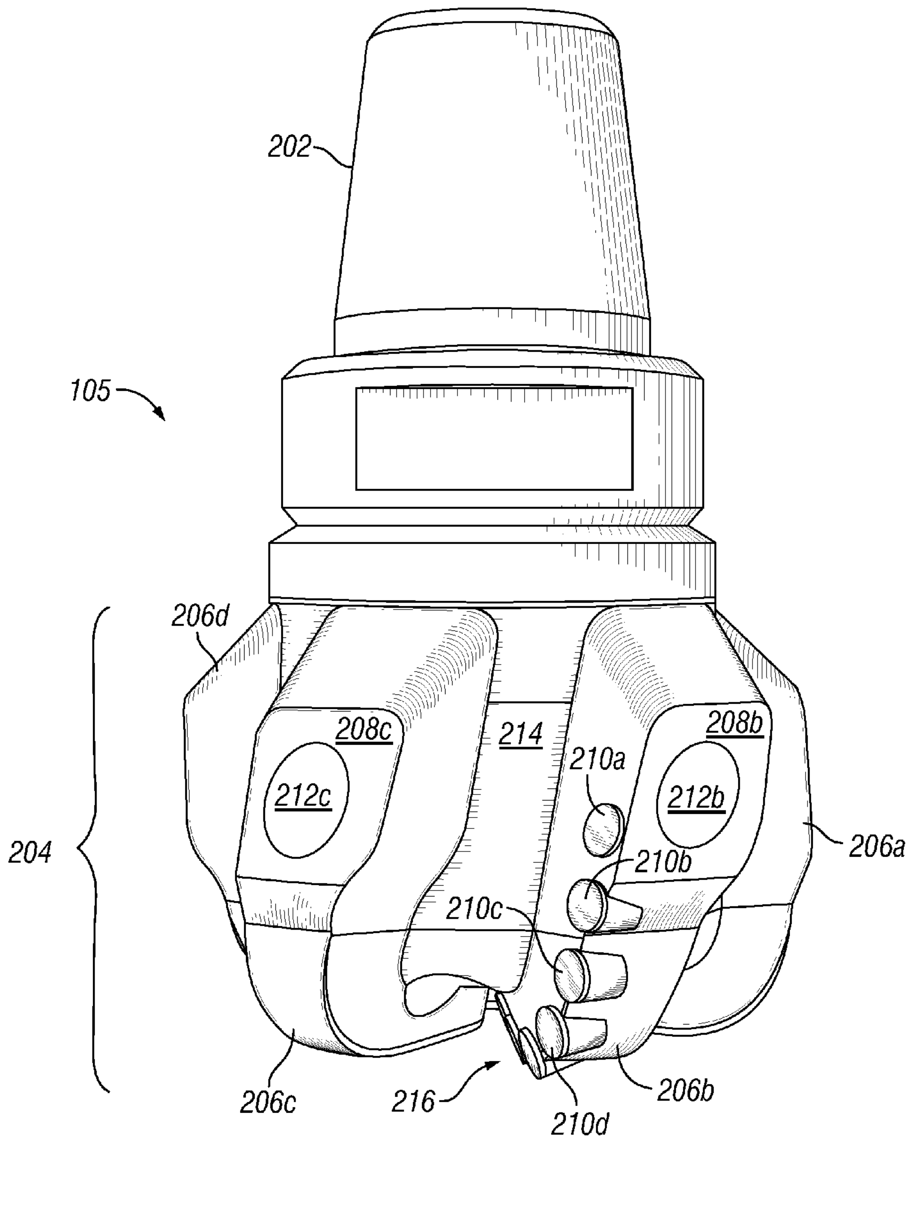
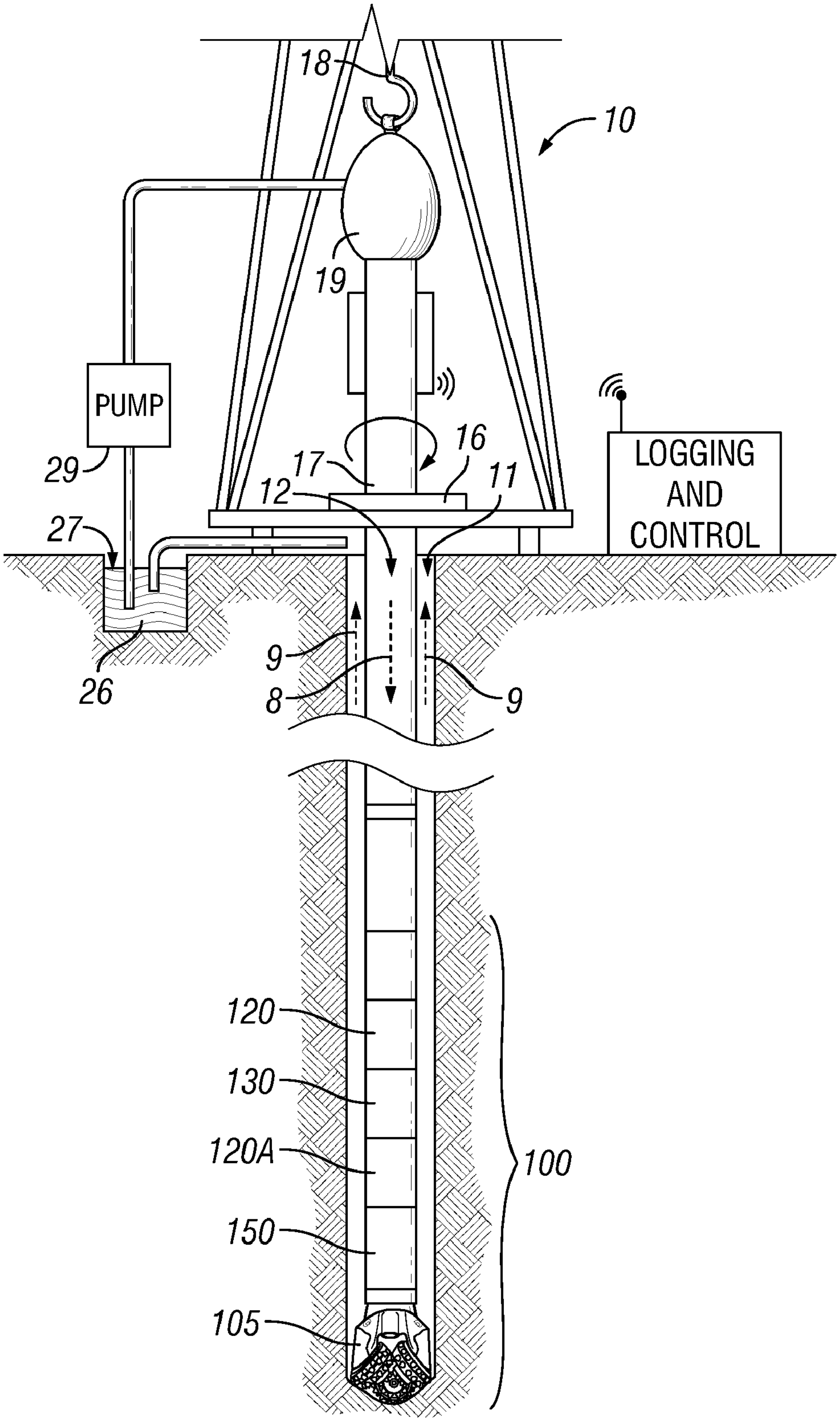
(57) ABSTRACT

A wellsite system includes a drill string suspended within a borehole, and a bottom hole assembly with a drill bit at its lower end, where the drill bit is a self stabilized and anti-whirl drill bit. The drill bit includes an interior cavity in fluid communication with the drill string, and a plurality of gauge pads located on the exterior of the drill bit. One or more of the gauge pads include an orifice in communication with the interior cavity, where the orifice is arranged at an angle relative to cutters fixed to the drill bit. The drill bit is configured such that a fluid continuously flows from each of the orifices.




18
10
19
PUMP
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26
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120A
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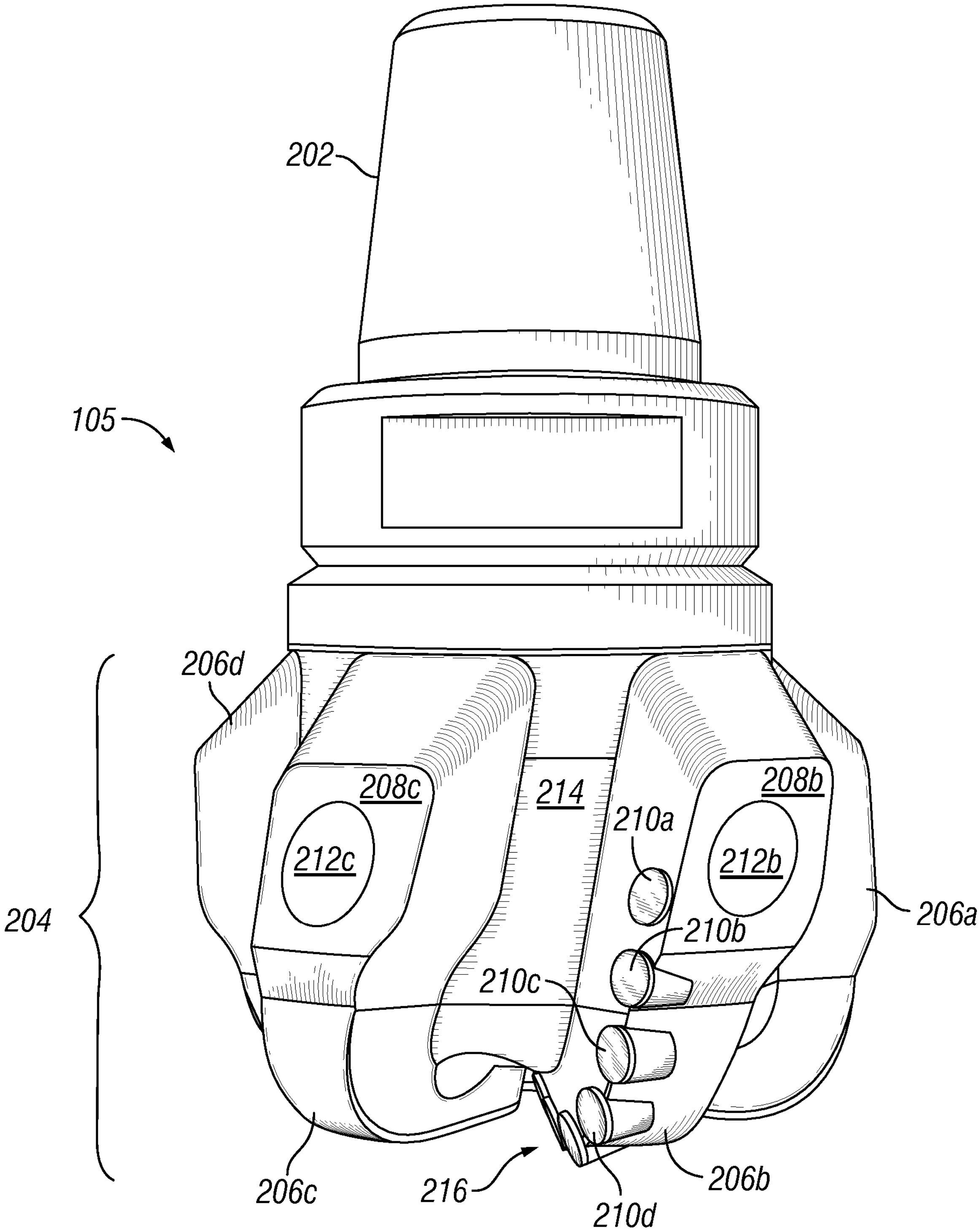
150
105

FIG. 1


202
105
206d
204
208c
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214
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206a
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210c
206c
216
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206b

FIG. 2

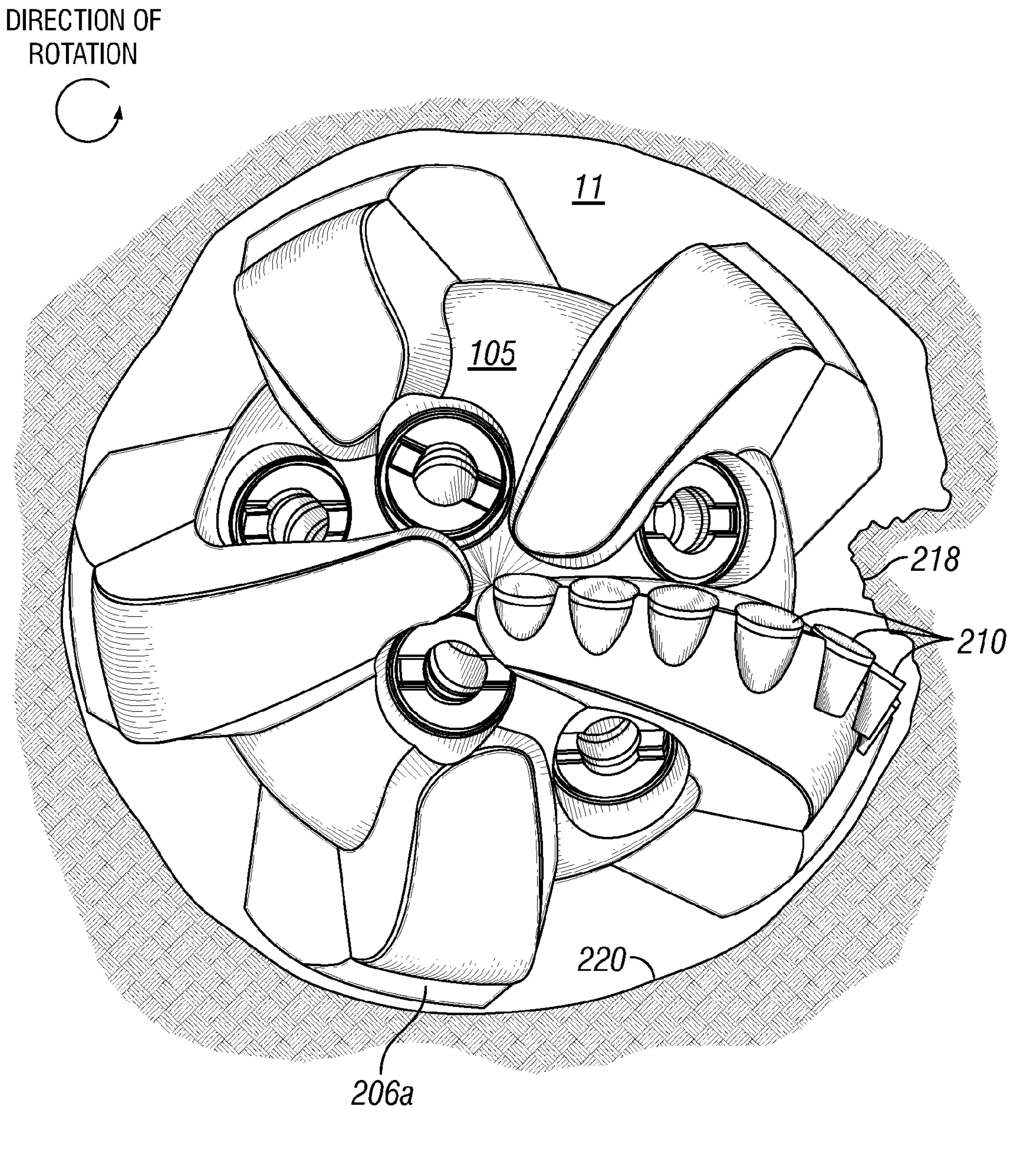

FIG. 2A

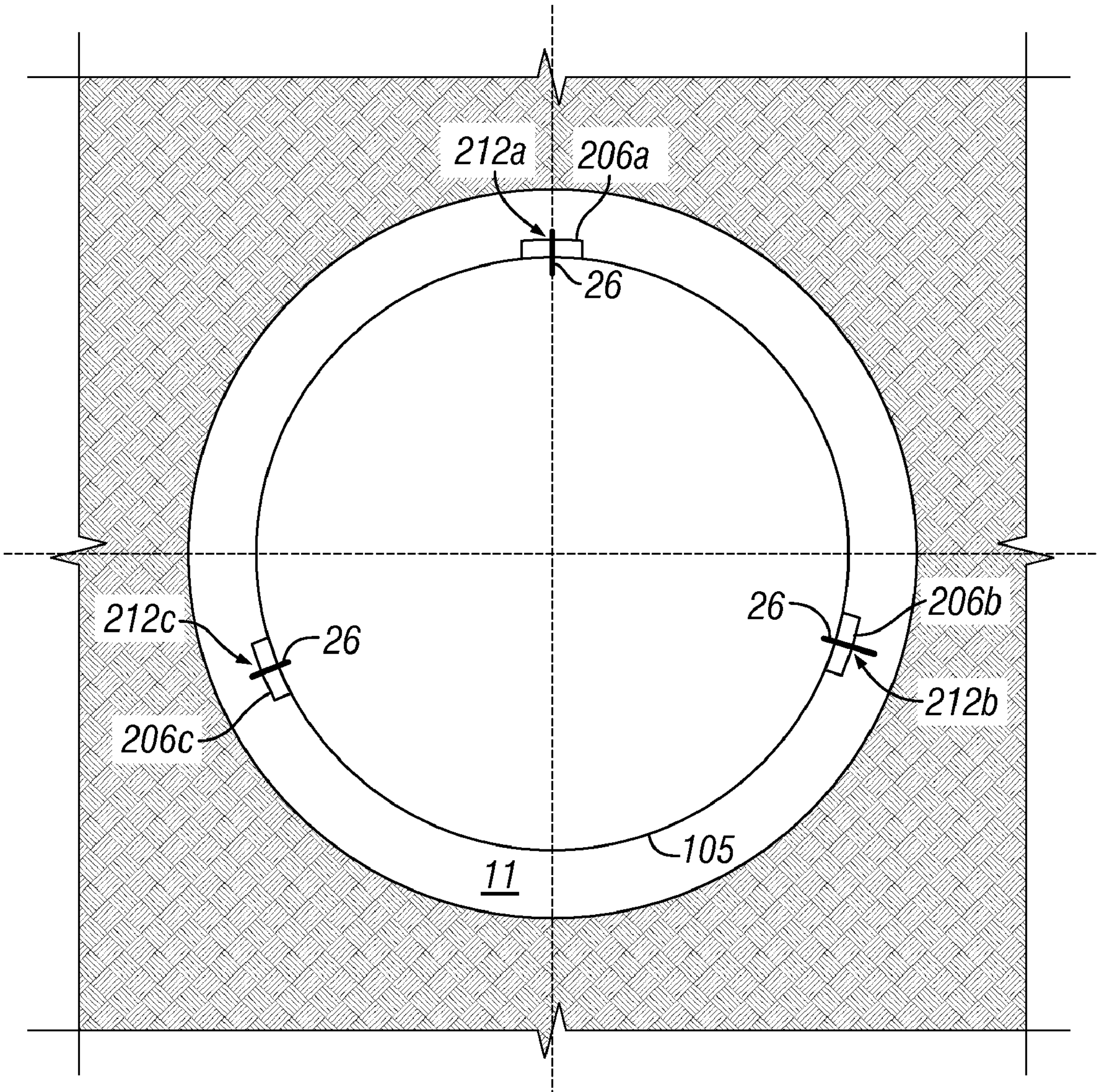

FIG. 3A

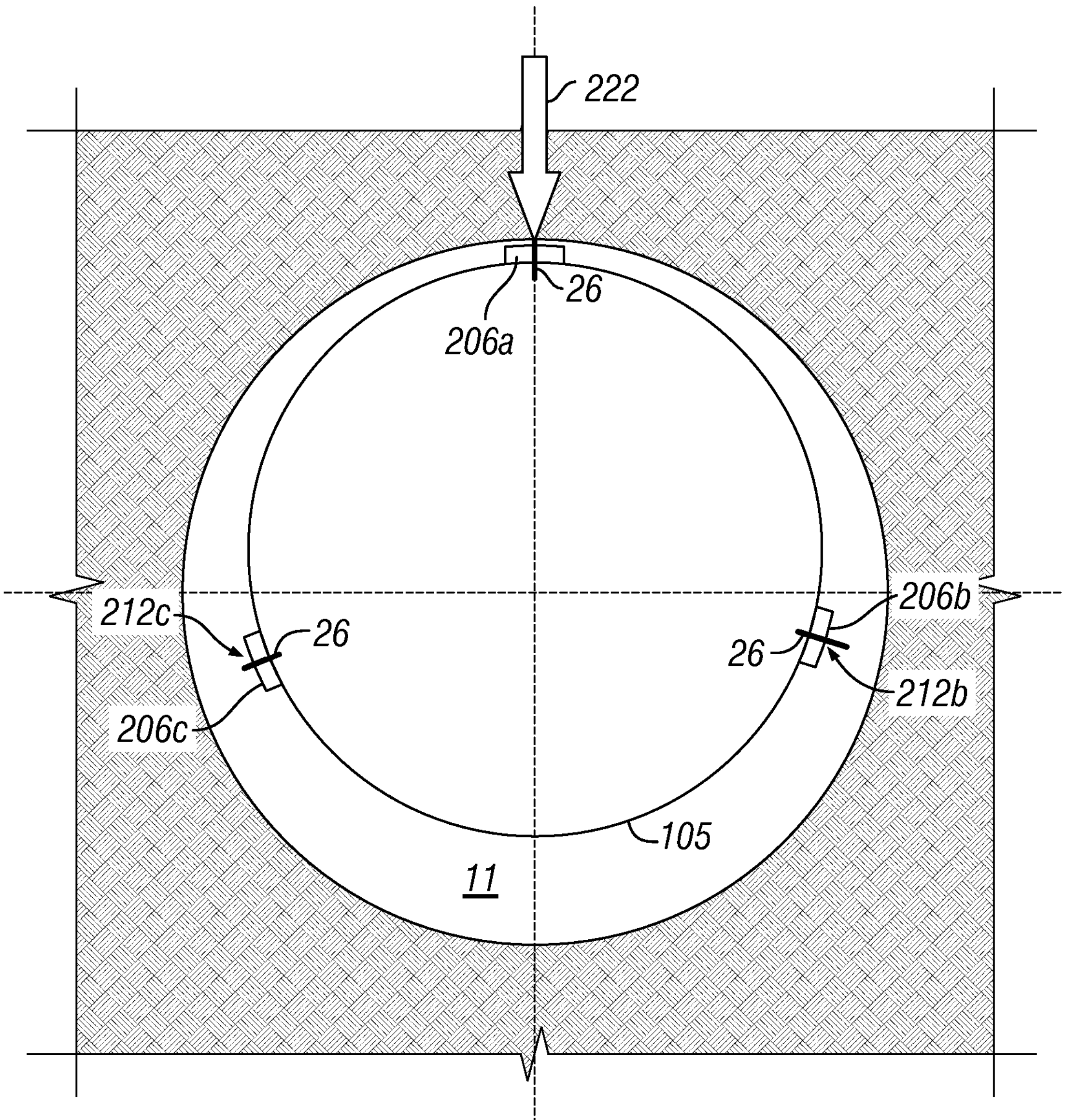

FIG. 3B

SELF-STABILIZED AND ANTI-WHIRL DRILL BITS AND BOTTOM-HOLE ASSEMBLIES AND SYSTEMS FOR USING THE SAME

FIELD OF THE INVENTION

[0001] The present invention relates to systems and methods for preventing whirl and other deviations of the drill bit and/or bottom-hole assembly while drilling within a wellbore.

BACKGROUND OF THE INVENTION

[0002] Drill bit whirl and deviations are a significant problem within the drilling industry. Oil, gas, water, and other natural resources are often located between 4,000 and 10,000 feet below ground. As a result, even a one-degree deviation of an well can result in a significant increase in drilling distance, time and cost.

[0003] In some application, the driller seeks a vertical wellbore. A smooth vertical wellbore facilitates running larger casing with minimal clearance and affords the possibility of using an extra string of casing at some later state in well construction operations. A wellbore that drifts away from and back into verticality can eliminate this option. Additionally, if multiple wellbore are drilled from a single platform, deviations can cause drill string collisions.

[0004] Even in controlled steering or directional drilling applications, it may be highly desirable to maintain the desired trajectory, for example when drilling to targets below faulted rocks, in steeply dipping beds, or in tectonically active areas.

[0005] Additionally, drill bit whirl, a condition wherein the bit's center of rotation shifts away from its geometric center, leads to several problems. These problems include non-cylindrical holes, wellbore deviation, and excessive bit wear.

[0006] Conventional anti-whirl drill bits attempt to reduce whirl by creating an imbalanced side force by cutter(s)-rock interaction. This imbalance force will only have a predictable magnitude and direction if the cutting action is smooth and continuous and the cutters are not worn or damaged. Neither of these conditions occur regularly as cutting action is often a discrete process rather than a continuous one (as when the cutters generate chips rather than continuous cuttings). When the rock is removed by a chipping action, the magnitude and direction is neither constant nor predictable.

[0007] Accordingly, there is a continued need for apparatus and methodology for preventing whirl and deviations.

SUMMARY OF THE INVENTION

[0008] This section will be added once the claims are finalized.

DESCRIPTION OF THE DRAWINGS

[0009] For a fuller understanding of the nature and desired objects of the present invention, reference is made to the following detailed description taken in conjunction with the accompanying drawing figures wherein like reference characters denote corresponding parts throughout the several views and wherein:

[0010] FIG. **1** illustrates a wellsite system in which the present invention can be employed.

[0011] FIG. **2** illustrates a drill bit according to the present inventions.

[0012] FIG. **2**A illustrates a drill bit according to the present inventions within a borehole.

[0013] FIG. **3**A illustrates a cross-section of a drill bit centered within a borehole.

[0014] FIG. **3**B illustrates a cross-section of a drill bit located off-center within a borehole.

DETAILED DESCRIPTION OF THE INVENTION

[0015] The present invention provides apparatus and methods for preventing whirl and other deviations of the drill bit and/or bottom-hole assembly while drilling within a wellbore.

[0016] The inventions provide herein are adapted for use in a range of drilling operations such as oil, gas, and water drilling. As such, the bit body is designed for incorporation in wellsite systems that are commonly used in the oil, gas, and water industries. An exemplary wellsite system is depicted in FIG. **1**.

[0017] FIG. **1** illustrates a wellsite system in which the present invention can be employed. The wellsite can be onshore or offshore. In this exemplary system, a borehole **11** is formed in subsurface formations by rotary drilling in a manner that is well known. Embodiments of the invention can also use directional drilling, as will be described hereinafter.

[0018] A drill string **12** is suspended within the borehole **11** and has a bottom hole assembly **100** which includes a drill bit **105** at its lower end. The surface system includes platform and derrick assembly **10** positioned over the borehole **11**, the assembly **10** including a rotary table **16**, kelly **17**, hook **18** and rotary swivel **19**. The drill string **12** is rotated by the rotary table **16**, energized by means not shown, which engages the kelly **17** at the upper end of the drill string. The drill string **12** is suspended from a hook **18**, attached to a traveling block (also not shown), through the kelly **17** and a rotary swivel **19** which permits rotation of the drill string relative to the hook. As is well known, a top drive system could alternatively be used.

[0019] In the example of this embodiment, the surface system further includes drilling fluid or mud **26** stored in a pit **27** formed at the well site. A pump **29** delivers the drilling fluid **26** to the interior of the drill string **12** via a port in the swivel **19**, causing the drilling fluid to flow downwardly through the drill string **12** as indicated by the directional arrow **8**. The drilling fluid exits the drill string **12** via ports in the drill bit **105**, and then circulates upwardly through the annulus region between the outside of the drill string and the wall of the borehole, as indicated by the directional arrows **9**. In this well known manner, the drilling fluid lubricates the drill bit **105** and carries formation cuttings up to the surface as it is returned to the pit **27** for recirculation.

[0020] The bottom hole assembly **100** of the illustrated embodiment includes a logging-while-drilling (LWD) module **120**, a measuring-while-drilling (MWD) module **130**, a roto-steerable system and motor, and drill bit **105**.

[0021] The LWD module **120** is housed in a special type of drill collar, as is known in the art, and can contain one or a plurality of known types of logging tools. It will also be understood that more than one LWD and/or MWD module can be employed, e.g. as represented at **120**A. (References, throughout, to a module at the position of **120** can alternatively mean a module at the position of **120**A as well.) The LWD module includes capabilities for measuring, processing, and storing information, as well as for communicating with the surface equipment. In the present embodiment, the LWD module includes a pressure measuring device.

[0022] The MWD module **130** is also housed in a special type of drill collar, as is known in the art, and can contain one or more devices for measuring characteristics of the drill string and drill bit. The MWD tool further includes an apparatus (not shown) for generating electrical power to the downhole system. This may typically include a mud turbine generator powered by the flow of the drilling fluid, it being understood that other power and/or battery systems may be employed. In the present embodiment, the MWD module includes one or more of the following types of measuring devices: a weight-on-bit measuring device, a torque measuring device, a vibration measuring device, a shock measuring device, a stick slip measuring device, a direction measuring device, and an inclination measuring device.

[0023] A particularly advantageous use of the system hereof is in conjunction with controlled steering or "directional drilling." In this embodiment, a roto-steerable subsystem **150** (FIG. **1**) is provided. Directional drilling is the intentional deviation of the wellbore from the path it would naturally take. In other words, directional drilling is the steering of the drill string so that it travels in a desired direction.

[0024] Directional drilling is, for example, advantageous in offshore drilling because it enables many wells to be drilled from a single platform. Directional drilling also enables horizontal drilling through a reservoir. Horizontal drilling enables a longer length of the wellbore to traverse the reservoir, which increases the production rate from the well.

[0025] A directional drilling system may also be used in vertical drilling operation as well. Often the drill bit will veer off of a planned drilling trajectory because of the unpredictable nature of the formations being penetrated or the varying forces that the drill bit experiences. When such a deviation occurs, a directional drilling system may be used to put the drill bit back on course.

[0026] A known method of directional drilling includes the use of a rotary steerable system ("RSS"). In an RSS, the drill string is rotated from the surface, and downhole devices cause the drill bit to drill in the desired direction. Rotating the drill string greatly reduces the occurrences of the drill string getting hung up or stuck during drilling. Rotary steerable drilling systems for drilling deviated boreholes into the earth may be generally classified as either "point-the-bit" systems or "push-the-bit" systems.

[0027] In the point-the-bit system, the axis of rotation of the drill bit is deviated from the local axis of the bottom hole assembly in the general direction of the new hole. The hole is propagated in accordance with the customary three point geometry defined by upper and lower stabilizer touch points and the drill bit. The angle of deviation of the drill bit axis coupled with a finite distance between the drill bit and lower stabilizer results in the non-collinear condition required for a curve to be generated. There are many ways in which this may be achieved including a fixed bend at a point in the bottom hole assembly close to the lower stabilizer or a flexure of the drill bit drive shaft distributed between the upper and lower stabilizer. In its idealized form, the drill bit is not required to cut sideways because the bit axis is continually rotated in the direction of the curved hole. Examples of point-the-bit type rotary steerable systems, and how they operate are described in U.S. Patent Application Publication Nos. 2002/0011359; 2001/0052428 and U.S. Pat. Nos. 6,394,193; 6,364,034; 6,244,361; 6,158,529; 6,092,610; and 5,113,953 all herein incorporated by reference.

[0028] In the push-the-bit rotary steerable system there is usually no specially identified mechanism to deviate the bit axis from the local bottom hole assembly axis; instead, the requisite non-collinear condition is achieved by causing either or both of the upper or lower stabilizers to apply an eccentric force or displacement in a direction that is preferentially orientated with respect to the direction of hole propagation. Again, there are many ways in which this may be achieved, including non-rotating (with respect to the hole) eccentric stabilizers (displacement based approaches) and eccentric actuators that apply force to the drill bit in the desired steering direction. Again, steering is achieved by creating non co-linearity between the drill bit and at least two other touch points. In its idealized form the drill bit is required to cut side ways in order to generate a curved hole. Examples of push-the-bit type rotary steerable systems, and how they operate are described in U.S. Pat. Nos. 5,265,682; 5,553,678; 5,803,185; 6,089,332; 5,695,015; 5,685,379; 5,706,905; 5,553,679; 5,673,763; 5,520,255; 5,603,385; 5,582,259; 5,778,992; 5,971,085 all herein incorporated by reference.

[0029] Particular embodiments of the inventions described herein provide drill bits **105** and bottom-hole assemblies **100** for reducing whirl and/or deviations.

Anti-Whirl Bits

[0030] FIG. **2** depicts a drill bit **105**. Drill bit **105** includes a trailing end **202** and a cutting portion **204**. Trailing end **202** is adapted for direct or indirect connection with drill string **12**. Cutting portion **204** includes one or more ribs **206***a*, **206***b*, **206***c*, **206***d*. Ribs **206** include gauge sections **208**, which contact the walls of the borehole that has been drilled by cutters **210**. Although cutters **210** are only depicted on rib **206***b*, cutters **210** can be configured on a plurality or all of ribs **206** as advantageous for particular drilling situations.

[0031] In embodiments of the present invention, one or more orifices **212** are located on the exterior of drill bit **105**. Orifices **212** can be located on gauge sections **208** or in valleys **214** between ribs **206**. The orifices **212** allow fluid **26** from the interior of drill string **12** to exit the drill bit to achieve stability and reduce whirl. Additional orifices can be located on drill bit **105**, for example, on the leading end **216** for lubrication and removal of cuttings as is known in the art.

[0032] In some embodiments, drill bit **105** contains a single orifice **212**. Drill fluid **26** flows from orifice **212**, and contacts the wall of borehole **11**, creating a side force substantially perpendicular to the orientation of orifice **212** and gauge section **208**. This force, creates an anti-whirl effect.

[0033] In some embodiments, the orifice **212** is positioned substantially opposite from the majority of cutters **210**. For example, if the cutters **210** are located longitudinally along the drill bit **105**, the orifice **212** can be located about 180° from the cutters **210**. In such an embodiment, drill fluid released from the orifice **212** creates a side force that pushes the bit in the direction of the cutters **210**. This embodiment (1) causes in increased contact between cutters **210** and the wall of borehole **11**, and/or (2) neutralizes side forces resulting from contact between the cutters **210** and the borehole wall.

[0034] In other embodiments, the orifice **212** is positioned approximately 90° behind the majority of the cutters **210**. As illustration of this principle, consider the situation depicted in FIG. **2**A. Drill bit **105** is rotating counter-clockwise in borehole **11**. Cutters **210** are about to impact a protuberance **218** from borehole wall **220**. If protuberance **218** is particularly strong material, protuberance will remain intact at least momentarily when first contacted by cutters **210**. The rotational force on drill bit **105** will cause drill bit **105** to move in the negative y direction until gauge pad **206***a* contacts borehole wall **220**. However, if orifice **212** is located on gauge pad **206***a*, the drilling fluid **26** will generate a force in the positive y direction, counteracting the tendency of the drill bit **105** to move off center. Moreover, the positive y force moves the entire bit **105**, thereby providing additional force to cutters **210** and assisting in borehole propagation.

[0035] Other cutter **210** and orifice **212** configurations are within the scope of these inventions. For example, the aggregate force vector generated by the rotation of the drill bit **105** and contact with a plurality of cutters **210** can be calculated using known equations and technology. The orifice **212** can be configured to counteract the most probable force vectors.

[0036] By utilizing the hydraulic force of drilling fluid **26** from orifice **212**, drill bits **105** produce a more predictable and constant imbalance force to reduce and/or prevent bit whirl. The direction of the imbalance force is known given the position of the port. The magnitude of the imbalance force is a function of the distance between the orifice **212** and borehole wall **220**, the differential pressure between the drilling fluid **26** in the borehole and the drilling fluid **26** in the drill string **12**, and the geometry (e.g. shape and size) of the orifice **212**. Furthermore, wear and damage to the cutters **210** should not affect the amplitude and direction of the side force.

[0037] In some embodiments, the exterior of orifice **212** is surrounding by a raised annulus or other geometric feature in order to form greater hydraulic pressure as drilling fluid **26** exits orifice **212**. Such a feature and/or the entire gauge section **206** can be coated with or fabricated entirely from a wear resistant or hardfaced material such as polycrystalline diamond (PCD).

Self-Stabilized Bits and Bottom Hole Assemblies

[0038] Another embodiment of the invention utilizes one or more orifices **212** to stabilize a drill bit **105** and/or bottom hole assembly (BHA) within a borehole.

[0039] FIG. **3**A depicts a cross-section of a drill bit **105** with three gauge pads **206***a*, **206***b*, **206***c* generally spaced (e.g. **1200** on center) around the circumference of the drill bit **105**, each having an orifice **212***a*, **212***b*, **212***c*, respectively. Drilling fluid **26** (represented by the thick lines) flows from inside the drill bit **105** through orifices **212***a*, **212***b*, **212***c*.

[0040] The drill bit **105** depicted in FIG. **3**A is generally centered within borehole **11**. Accordingly, any hydraulic forces created by the drilling fluid will cancel each other. However, if drill bit **105** moves off center as depicted in FIG. **3**B, the amplitude of the force vector generated by drilling fluid **26** from orifice **212***a* will increase as the space between orifice **212***a* and borehole wall **220** decrease. Concurrently, any force vector generated by orifices **212***b* and **212***c* will decrease, resulting in a net force vector (represented by arrow **222**) pushing the bit away from the wall **220**.

[0041] In some embodiments, fluid flow to the one or more orifices is limited by one or more valve (e.g. choke valves). A single valve may be connected to each orifice by tubing or other means. More preferably, each orifice is independently regulated by a separate valve. Independent regulation ensures that the volume of drilling fluid **26** flowing to a particular orifice **212** does not increase beyond a desired threshold so as to deprive other orifices **212** or other ports (e.g. ports located on the leading edge **216** of drill bit **105**).

[0042] While the embodiment in FIGS. **3**A and **3**B depicts a drill bit **105** with three orifices **212**, the inventions described herein encompass the use of fluid with any number of orifices **212** for the stabilization of a drill bit **105** or bottom hole assembly. For example, a drill bit **105** with a single orifice would produce a similar effect as a drill bit **105** with three orifices. As the drill bit **105** rotated, the force generated by the single orifice would increase in amplitude as the orifice passed through regions in which the drill bit **105** was closer to the borehole wall **220**. This increased force would urge the drill bit **105** back center. Furthermore, drill bits and bottom hole assemblies having two, three, four, five, or six orifices, and the like are within the scope of the invention.

[0043] The principles described herein can be applied to stabilization pads located along the exterior of bottom hole assembly **100** and other portions of the drill string **12**. Stabilization pads act similarly to gauge pads to minimize movement of the bottom hole assembly and drill string. In such an embodiment, one or more orifices are added to one or more stabilization pads to allow drilling fluid **26** to act as described herein.

Combination Anti-Whirl and Self-Stabilized Bits

[0044] The principles of anti-whirl and self-stabilized bits described herein can be combined to produce a bit **105** that produces net imbalanced side force to reduce whirl while still providing one or more orifices to correct a drift from center of the borehole **11**. In such an embodiment, one of a plurality of orifices **212** is larger in cross-sectional area to produce an imbalance side force.

[0045] The foregoing specification and the drawings forming part hereof are illustrative in nature and demonstrate certain preferred embodiments of the invention. It should be recognized and understood, however, that the description is not to be construed as limiting of the invention because many changes, modifications and variations may be made therein by those of skill in the art without departing from the essential scope, spirit or intention of the invention.

1. A drill bit, comprising:

an interior cavity in fluid communication with a drill string;

a plurality of gauge pads located on the exterior of the drill bit, at least one of the gauge pads being formed with a plurality of cutters; and

one or more of the gauge pads having an orifice in communication with the interior cavity, the orifice being positioned at an angle of approximately 90° relative to the plurality of cutters arranged on the respective gauge pad,

wherein the drill bit is configured such that a fluid continuously flows from each of the orifices to provide a net stabilizing effect.

2. The drill bit of claim **1**, wherein the fluid flow is sufficient to urge the drill bit away from a wall of a borehole.

3. The drill bit of claim **1**, wherein the drill bit comprises the plurality of gauge pads each having an orifice in communication with the interior cavity.

4. The drill bit of claim **3**, wherein the drill bit comprises three gauge pads each having an orifice in communication with the interior cavity.

5. The drill bit of claim **4**, wherein the orifices are spaced about 120° on center around the exterior of the drill bit.

6-**8**. (canceled)

9. A bottom hole assembly, comprising:

an interior cavity in fluid communication with a drill string;

a plurality of stabilization pads located on the exterior of the bottom hole assembly, at least one of the stabilization pads being formed with a plurality of cutters; and

one or more of the stabilization pads having an orifice in communication with the interior cavity to provide a net stabilizing force to the bottom hole assembly,

wherein the orifice is positioned at an angle of approximately 90° relative to the plurality of cutters arranged on the respective stabilization pad.

10. The bottom hole assembly of claim **9**, wherein the bottom hole assembly is configured such that a fluid continuously flows from each of the one or more orifices.

11. The bottom hole assembly of claim **10**, wherein the fluid flow is sufficient to urge the drill bit away from a wall of a borehole thereby stabilizing said drill bit in the borehole.

12. The bottom hole assembly of claim **9**, wherein the bottom hole assembly comprises the plurality of stabilization pads each having an orifice in communication with the interior cavity.

13. The bottom hole assembly of claim **12**, wherein the bottom hole assembly comprises three stabilization pads each having an orifice in communication with the interior cavity.

14. The bottom hole assembly of claim **13**, wherein the orifices are spaced about 120° on center around the exterior of the bottom hole assembly.

15-16. (canceled)

17. A wellsite system comprising:

a drill string;

a kelly coupled to the drill string; and

a drill bit comprising:

an interior cavity in fluid communication with the drill string;

a plurality of gauge pads located on the exterior of the drill bit, at least one of the gauge pads being formed with a plurality of cutters; and

one or more of the gauge pads having an orifice in communication with the interior cavity, the orifice being positioned at an angle of approximately 90° relative to the plurality of cutters arranged on the respective gauge pad,

wherein the drill bit is configured such that a fluid continuously flows from at least one of said orifices to provide a net stabilizing effect on the wellsite system.

* * * * *