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(54) Title: ROTATING CONTROL DEVICE HAVING SEAL RESPONSIVE TO OUTER DIAMETER CHANGES

(57) Abstract: A rotating control device for sealing about a drill string having a change in outer diameter can include a seal which rotates with the drill string, the seal including at least two chambers connected by a passage, and a fluid which flows between the chambers via the passage in response to displacement of the outer diameter change through the seal. A method of sealing can include forming at least two chambers in a resilient material of a seal, displacing the outer diameter change into the seal, thereby transferring fluid from a first chamber to a second chamber, and displacing the outer diameter change out of the seal, thereby transferring the fluid from the first chamber to the second chamber. One of the chambers can increase in volume while the other of the chambers decreases in volume.
Declarations under Rule 4.17:

— as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(H))

Published:

— with international search report (Art. 21(3))
This disclosure relates generally to equipment utilized and operations performed in conjunction with a subterranean well and, in one example described below, more particularly provides a rotating control device with a seal which is responsive to outer diameter changes of a drill string.

BACKGROUND

Rotating control devices generally include one or more seals for sealing about drill pipe while the drill pipe rotates therein. These seals can be damaged by repeated displacement of drill pipe connections (e.g., collars or tool joints) or other outer diameter changes through the seals. One reason is that the seals deform to allow the drill pipe diameter changes to pass through them.

The seals are already compressed against the drill pipe (in order to seal), so further compression of the seals when diameter changes pass through them further strains the seals. In addition, drill pipe connections are typically not
perfectly smooth, so the seals can also be scraped, cut, abraded, etc., when the connections pass through the already-strained seals.

Therefore, it will be appreciated that improvements are continually needed in rotating control devices and the seals therein.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a representative partially cross-sectional view of a well drilling system and associated method which can embody principles of this disclosure.

FIG. 2 is a representative enlarged scale partially cross-sectional view of a rotating control device which may be used in the system and method of FIG. 1, and which can embody the principles of this disclosure.

FIG. 3 is a representative further enlarged scale cross-sectional view of a seal which may be used in the rotating control device of FIG. 2, and which can embody the principles of this disclosure.

FIG. 4 is a representative cross-sectional view of the seal, with an outer diameter change of a drill string being inserted into the seal.

FIG. 5 is a representative cross-sectional view of the seal, with the outer diameter change being displaced in the seal.

FIG. 6 is a representative cross-sectional view of the seal, with the outer diameter change being displaced out of the seal.
DETAILED DESCRIPTION

Representatively illustrated in FIG. 1 is a system 10 for use with a subterranean well, and an associated method, which system and method can embody principles of this disclosure. However, it should be clearly understood that the system 10 and method are merely one example of an application of the principles of this disclosure in practice, and a wide variety of other examples are possible. Therefore, the scope of this disclosure is not limited at all to the details of the system 10 and method described herein and/or depicted in the drawings.

In the FIG. 1 example, a wellbore 12 is drilled by rotating a drill pipe 14, such as, by utilizing a drilling rig (not shown) at or near the earth's surface. The drill pipe 14 can be rotated by any means, e.g., a rotary table, a top drive, a positive displacement or turbine drilling motor, etc. Thus, it should be understood that the scope of this disclosure is not limited to any particular way of rotating the drill pipe 14.

The drill pipe 14 is part of an overall drill string 16, which can include a variety of different components. Preferably, a drill bit 18 is connected at a distal end of the drill string 16, so that the drill bit cuts into the earth when the drill string rotates and weight is applied to the drill bit.

An annulus 20 is formed radially between the drill string 16 and the wellbore 12. A drilling fluid 22 (commonly known as "mud," although other fluids, such as brine water, may be used) is circulated downward through the drill string 16, exits the drill bit 18, and flows back to the surface via the annulus 20.
The drilling fluid 22 serves several purposes, including cooling and lubricating the drill bit 18, removing cuttings, maintaining a desired balance of pressures between the wellbore 12 and the surrounding earth, etc. In some situations (e.g., in managed pressure drilling or underbalanced drilling, or even in conventional overbalanced drilling), it may be desirable to seal off the annulus 20 at or near the earth's surface (for example, at a land or sea-based drilling rig, a subsea facility, a jack-up rig, etc.), so that communication between the annulus 20 and the earth's atmosphere or sea is prevented.

For this purpose, a rotating control device 24 can be used to seal about the drill string 16 during a drilling operation. In the example depicted in FIG. 1, the rotating control device 24 is connected to a blowout preventer stack 26 on a wellhead 28, but in other examples the rotating control device could be positioned in or on a riser string, in a subsea wellhead, in a wellbore, etc. The scope of this disclosure is not limited to any particular location of the rotating control device 24.

Referring additionally now to FIG. 2, an enlarged scale partially cross-sectional view of one example of the rotating control device 24 is representatively illustrated. In this view, it may be clearly seen that the rotating control device 24 includes two annular seals 30, 32 which seal against an exterior surface of the drill pipe 14 as the drill pipe rotates within an outer housing assembly 34 of the rotating control device. The FIG. 2 rotating control device 24 may be used with the system 10 and method of FIG. 1, or it may be used with other systems and methods.

In the FIG. 2 example, the outer housing assembly 34 is provided with a flange 36 at a lower end thereof for
connection to the blowout preventer stack 26. However, in other examples, the outer housing assembly 34 could be provided with suitable connectors for installing the rotating control device 24 in or on a riser string, to a subsea wellhead, or at any other location.

As depicted in FIG. 2, the lower seal 30 is positioned in the outer housing assembly 34, whereas the upper seal 32 is positioned in an upper "pot" or enclosure 38. In other examples, either or both of the seals 30, 32 could be positioned inside or outside of the outer housing assembly 34, and other numbers of seals (including one) may be used. The scope of this disclosure is not limited to any particular number or positions of seals.

The seals 30, 32 are in one sense "passive," in that they sealingly engage the drill pipe 14 whenever the drill pipe is positioned in the rotating control device 24, without any need of actuating the seals to effect such sealing. However, the seals 30, 32 can also be considered "active" seals, because they are responsive to change their sealing characteristics when acted upon by a stimulus, as described more fully below.

In the FIG. 2 example, the seals 30, 32 are mounted to a bearing assembly 40, which is secured to the outer housing assembly 34 by a clamp 42. The bearing assembly 40 includes bearings 44, which permit an inner generally tubular mandrel 46 to rotate relative to the outer housing assembly 34.

In other examples, a latch mechanism or other device could be used in place of the clamp 42. The bearing assembly 40 and both seals 30, 32 could be positioned entirely within the outer housing assembly 34. Thus, the scope of this disclosure is not limited to any particular arrangement or
configuration of the various components of the rotating control device 24.

Note that, as depicted in FIG. 2, the seals 30, 32 rotate with the enclosure 38 and mandrel 46 relative to the outer housing assembly 34 when the drill pipe 14 rotates in the rotating control device 24. Preferably, the drill pipe 14 is both sealingly and grippingly engaged by the seals 30, 32.

Referring additionally now to FIG. 3, the seal 30 is representatively illustrated apart from the remainder of the rotating control device 24. The seal 30 may be used in the FIG. 2 rotating control device 24, or it may be used in other types of rotating control devices, in keeping with the principles of this disclosure.

In the FIG. 3 example, the drill string 16 includes an outer diameter change 48. The outer diameter change 48 may be in the form of a tool joint, a collar, another type of drill pipe connection, a drilling tool, etc. Any type of outer diameter change can be included in the drill string 16, within the scope of this disclosure.

In this example, the outer diameter change 48 comprises an increased outer diameter of the drill pipe 14. It is desired for the seal 30 to continue sealing against the outer diameter change 48 and the adjacent drill pipe 14 as the outer diameter change passes through the seal, without incurring any damage to the seal, shortening its useful life, etc.

For this purpose, the seal 30 includes fluid-filled chambers 50, 52 in a resilient material 54 of the seal. The material 54 may comprise, for example, an elastomer (such as, a nitrile, fluoro-elastomer, EPDM, etc.).
The chambers 50, 52 are preferably formed by molding them into the seal 30 when the seal is fabricated. However, the scope of this disclosure is not limited to any particular method of forming the chambers 50, 52.

An annular-shaped passage 56 connects the chambers 50, 52. The passage 56 may also be formed in resilient material 54, or it may be formed in a rigid or other non-resilient material if desired.

It will be appreciated that fluid 58 can flow between the chambers 50, 52 via the passage 56. Thus, if one of the chambers 50, 52 is compressed or reduced in volume, the fluid 58 can flow to the other chamber via the passage, thereby enlarging a volume of the other chamber.

The fluid 58 is preferably a compressible fluid (e.g., a liquid or gas, such as, silicone fluid, nitrogen gas, etc.). In this manner, compression of the fluid 58 will function to resiliently bias the seal 30 into sealing contact with the drill pipe 14 and any outer diameter change 48.

Referring additionally now to FIG. 4, the seal 30 is representatively illustrated after the diameter change 48 has entered an upper portion of the seal. The increased outer diameter of the drill pipe 14 has caused a volume of the upper chamber 50 to decrease, thereby forcing some or all of the fluid 58 in the chamber 50 to flow via the passage 56 to the other chamber 52.

The increased volume of fluid 58 in the lower chamber 52 is beneficial, in that it causes the lower portion of the seal 30 to be increasingly biased into sealing contact with the drill pipe 14 below the diameter change 48. This is due in part to the volume of the lower chamber 52 increasing as a result of the additional fluid 58 therein.
Referring additionally now to FIG. 5, the seal 30 is representatively illustrated after the diameter change 48 has been displaced further downward in the seal 30. The diameter change 48 in this view is now positioned opposite the lower chamber 52.

The lower chamber 52 is radially compressed by the presence of the diameter change 48 in the seal 30, thereby forcing the fluid 58 from the lower chamber to the upper chamber 50 via the passage 56. Thus, the volume of the lower chamber 52 decreases, while the volume of the upper chamber 50 increases.

The increased volume of fluid 58 in the upper chamber 50 is beneficial, in that it causes the upper portion of the seal 30 to be increasingly biased into sealing contact with the drill pipe 14 above the diameter change 48. This is due in part to the volume of the upper chamber 50 increasing as a result of the additional fluid 58 therein.

Referring additionally now to FIG. 6, the seal 30 is representatively illustrated after the diameter change 48 has been displaced downwardly out of the seal. The upper and lower chambers 50, 52 have now returned to their respective FIG. 3 volumes, with some of the fluid 58 having flowed from the upper chamber 50 back to the lower chamber 52.

The transfer of the fluid 58 between the chambers 50, 52 during the passage of the diameter change 48 through the seal 30 allows the seal to enlarge as needed, and where needed, to prevent over-straining the seal, as well as abrasions and cuts, due to the diameter change. However, instead of decreasing the sealing capability of the seal 30, the transfer of the fluid 58 to a particular chamber 50 or 52 allows a respective portion of the seal to be
increasingly biased into sealing contact with the drill pipe 14, thereby enhancing the sealing capability of the seal.

Note that these benefits can be obtained, even without applying any external pressure to the chambers 50, 52. Thus, it is preferably not necessary to connect any external pressure source (e.g., a pump, bottles of compressed gas, etc.) to the seal 30. This simplifies the construction and operation of the rotating control device 24, thereby reducing manufacturing, operating and maintenance costs, while enhancing the rotating control device's reliability and sealing capability. However, in some examples, an external pressure source could be connected to the seal 30.

Although the diameter change 48 is depicted in FIGS. 3-6 as displacing downwardly through the seal 30, similar benefits are obtained when the diameter change displaces upwardly through the seal. In that case, the fluid 58 would travel in opposite directions, and the chambers 50, 52 would expand and contract, in reverse order to that described above for FIGS. 3-6.

Although the diameter change 48 is depicted in FIGS. 3-6 as comprising a diameter increase, similar benefits can be obtained when the diameter change comprises a diameter decrease. In that case, the fluid 58 would travel in opposite directions, and the chambers 50, 52 would expand and contract, in reverse order to that described above for FIGS. 3-6.

The diameter change 48 could comprise a combination of diameter increases and decreases. Thus, the scope of this disclosure is not limited to any of the specific details of the diameter change 48, the seal 30 (or any other elements of the rotating control device 24) or the method described above and/or depicted in the drawings.
It may now be fully appreciated that an improved rotating control device 24 is provided to the art by the above disclosure. In one example described above, the rotating control device 24 seals about a drill string 16 having a change in outer diameter 48. The rotating control device 24 can comprise a seal 30 which rotates with the drill string 16. The seal 30 can include at least first and second chambers 50, 52 connected by at least one passage 56, and a fluid 58 which flows between the first and second chambers 50, 52 via the passage 56 in response to displacement of the outer diameter change 48 through the seal 30.

One of the first and second chambers 50, 52 can decrease in volume in response to an increase in volume of the other of the first and second chambers 50, 52. Each of the first and second chambers 50, 52 may increase in volume and decrease in volume in response to displacement of the diameter change 48 through the seal 30 in any direction.

The first and second chambers 50, 52 are preferably free of any connection to an external pressure source. The fluid 58 may comprise a compressible fluid.

Each of the first and second chambers 50, 52 may be formed in a resilient material 54 of the seal 30, although non-resilient materials may be used, if desired. The passage 56 may comprise an annular space formed in a resilient material 54 of the seal 30. The passage 56 in other examples could be formed in a rigid or other non-resilient material, and is not necessarily annular in shape (for example, holes of various shapes could be used).

A method of sealing about a drill string 16 having an outer diameter change 48 is also described above. In one example, the method comprises: forming at least first and
second chambers 50, 52 in a resilient material 54 of a seal 30; displacing the outer diameter change 48 into the seal 30, thereby transferring fluid 58 from the first chamber 50 to the second chamber 52; and displacing the outer diameter change 48 out of the seal 30, thereby transferring the fluid 58 from the first chamber 50 to the second chamber 52.

Displacing the outer diameter change 48 into the seal 30 can include flowing the fluid 58 through at least one passage 56 which connects the first and second chambers 50, 52, and/or increasing a volume of the second chamber 52. Displacing the outer diameter change 48 into the seal 30 may be performed without either of the first and second chambers 50, 52 being connected to an external pressure source.

The method can include forming the passage 56 in the resilient material 54.

Displacing the outer diameter change 48 out of the seal 30 can include flowing the fluid 58 from the second chamber 52 to the first chamber 50 via the passage 56, and/or increasing a volume of the first chamber 50.

The passage 56 can comprise an annular space.

The method can include displacing the outer diameter change 48 within the seal 30, thereby displacing the fluid 58 from the second chamber 52 to the first chamber 50.

Also described above is a seal 30 for sealing about a drill string 16 in a rotating control device 24, the drill string 16 having an outer diameter change 48. In one example, the seal 30 can include at least first and second chambers 50, 52. One of the first and second chambers 50, 52 increases in volume while the other of the first and second chambers 50, 52 decreases in volume.
The first one of the first and second chambers 50, 52 decreases in volume in response to an increase in volume of the other of the first and second chambers 50, 52.

Each of the first and second chambers 50, 52 increases in volume and decreases in volume in response to displacement of the outer diameter change 48 through the seal 30. This displacement may be in any direction. The diameter change 48 may be an increase and/or a decrease in diameter.

The first and second chambers 50, 52 may be free of any connection to an external pressure source. Each of the first and second chambers 50, 52 may be formed in a resilient material 54 of the seal 30.

The first and second chambers 50, 52 are preferably connected by at least one passage 56. The passage 56 may comprise an annular space formed in a resilient material 54 of the seal 30.

The seal 30 can include a fluid 58 which flows between the first and second chambers 50, 52 via the passage 56 in response to displacement of the diameter change 48 through the seal 30. The fluid 58 may comprise a compressible fluid, although compressible fluid(s) may be used in addition to, or in place of, compressible fluid.

Although various examples have been described above, with each example having certain features, it should be understood that it is not necessary for a particular feature of one example to be used exclusively with that example. Instead, any of the features described above and/or depicted in the drawings can be combined with any of the examples, in addition to or in substitution for any of the other features of those examples. One example's features are not mutually exclusive to another example's features. Instead, the scope
of this disclosure encompasses any combination of any of the features.

Although each example described above includes a certain combination of features, it should be understood that it is not necessary for all features of an example to be used. Instead, any of the features described above can be used, without any other particular feature or features also being used.

It should be understood that the various embodiments 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 this 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.

In the above description of the representative examples, directional terms (such as "above," "below," "upper," "lower," etc.) are used for convenience in referring to the accompanying drawings. However, it should be clearly understood that the scope of this disclosure is not limited to any particular directions described herein.

The terms "including," "includes," "comprising," "comprises," and similar terms are used in a non-limiting sense in this specification. For example, if a system, method, apparatus, device, etc., is described as "including" a certain feature or element, the system, method, apparatus, device, etc., can include that feature or element, and can also include other features or elements. Similarly, the term "comprises" is considered to mean "comprises, but is not limited to."
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 this disclosure. For example, structures disclosed as being separately formed can, in other examples, be integrally formed and vice versa.

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 invention being limited solely by the appended claims and their equivalents.
WHAT IS CLAIMED IS:

1. A rotating control device for sealing about a drill string having a change in outer diameter, the rotating control device comprising:
   a seal which rotates with the drill string, the seal including at least first and second chambers connected by at least one passage, and a fluid which flows between the first and second chambers via the passage in response to displacement of the outer diameter change through the seal.

2. The rotating control device of claim 1, wherein one of the first and second chambers decreases in volume in response to an increase in volume of the other of the first and second chambers.

3. The rotating control device of claim 1, wherein each of the first and second chambers increases in volume and decreases in volume in response to displacement of the diameter change through the seal.

4. The rotating control device of claim 1, wherein the first and second chambers are free of any connection to an external pressure source.

5. The rotating control device of claim 1, wherein the fluid comprises a compressible fluid.
6. The rotating control device of claim 1, wherein each of the first and second chambers is formed in a resilient material of the seal.

7. The rotating control device of claim 1, wherein the passage comprises an annular space formed in a resilient material of the seal.
8. A method of sealing about a drill string having an outer diameter change, the method comprising:

forming at least first and second chambers in a resilient material of a seal;

displacing the outer diameter change into the seal, thereby transferring fluid from the first chamber to the second chamber; and

displacing the outer diameter change out of the seal, thereby transferring the fluid from the first chamber to the second chamber.

9. The method of claim 8, wherein displacing the outer diameter change into the seal further comprises flowing the fluid through at least one passage which connects the first and second chambers.

10. The method of claim 9, further comprising forming the passage in the resilient material.

11. The method of claim 9, wherein displacing the outer diameter change out of the seal further comprises flowing the fluid from the second chamber to the first chamber via the passage.

12. The method of claim 9, wherein the passage comprises an annular space.
13. The method of claim 8, wherein displacing the outer diameter change into the seal further comprises increasing a volume of the second chamber.

14. The method of claim 13, wherein displacing the outer diameter change out of the seal further comprises increasing a volume of the first chamber.

15. The method of claim 8, wherein displacing the outer diameter change into the seal is performed without either of the first and second chambers being connected to an external pressure source.

16. The method of claim 8, further comprising displacing the outer diameter change within the seal, thereby displacing the fluid from the second chamber to the first chamber.
17. A seal for sealing about a drill string in a rotating control device, the drill string having an outer diameter change, the seal comprising:

   at least first and second chambers, and

   wherein one of the first and second chambers increases in volume while the other of the first and second chambers decreases in volume.

18. The seal of claim 17, wherein the one of the first and second chambers decreases in volume in response to an increase in volume of the other of the first and second chambers.

19. The seal of claim 17, wherein each of the first and second chambers increases in volume and decreases in volume in response to displacement of the outer diameter change through the seal.

20. The seal of claim 17, wherein the first and second chambers are free of any connection to an external pressure source.

21. The seal of claim 17, wherein each of the first and second chambers is formed in a resilient material of the seal.

22. The seal of claim 17, wherein the first and second chambers are connected by at least one passage.
23. The seal of claim 22, wherein the passage comprises an annular space formed in a resilient material of the seal.

24. The seal of claim 22, further comprising a fluid which flows between the first and second chambers via the passage in response to displacement of the diameter change through the seal.

25. The seal of claim 24, wherein the fluid comprises a compressible fluid.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

E21B 33/126(2006.01)i, E21B 33/122(2006.01)1, F16J 15/40(2006.01)1

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)

IPC: E21B33/126; E21B33/12; E21B19/00; F16J15/10; F16K25/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean Utility Models and applications for Utility Models

Japanese Utility Models and applications for Utility Models

Electronic database consulted during the international search (name of database and, where practicable, search terms used)

eKOMPASS (KIPO internal) & Keywords: rotating control device, seal, drill string, fluid, channel, chamber, change, outer diameter, drill, string and similar terms

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<td>US20100307772 A1 (BAILEY, THOMAS R. et al.) 09 December 2010</td>
<td>1-3,6-14,16-19,21-24</td>
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<td>See abstract, paragraphs [0034]-[0036], and figures 2-4</td>
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<td>US5580068 A (GUNDY, WILLIAM F.) 03 December 1996</td>
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<td>See abstract, column 3 lines 59-67, column 4 line 60 - column 5 line 10, and</td>
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<td>US20120118559 A1 (LI, YAMMEI et al.) 17 May 2012</td>
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<td>See abstract, paragraphs [0041],[0042],[0047]-[0049] and figures 6,8</td>
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Further documents are listed in the continuation of Box C. ✗ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search
18 FEBRUARY 2013 (18.02.2013)

Date of mailing of the international search report
19 FEBRUARY 2013 (19.02.2013)

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<table>
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