

TOE CASING

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority from and the benefit of U.S. Provisional Application Serial No. 62/455,216, entitled “*Toe Casing*,” filed February 6, 2017, which is hereby incorporated by reference in its entirety.

BACKGROUND

[0002] The invention relates generally to wells, such as those used to access subsurface formations containing minerals, such as oil and gas.

[0003] Technologies used in exploration and production of subterranean deposits have been greatly refined over past decades. All equipment used for wells in such applications involve tubular products which can traverse water depths, subterranean formations, and that ultimately access subterranean horizons of interest. These horizons may include locations where products are found that have commercial value, such as oil and gas deposits. In conventional systems, tubular products such as drillpipe, casing, and so forth are assembled at the Earth's surface or on a floating vessel or platform, and run into a well. In most cases, these tubular products are made of steel that is produced and utilized in standard lengths with standard coupling ends that can be readily threaded together to form an extended tubular string.

[0004] One important phase of the drilling and completions process involves setting casing in the producing zone. This prevents the open hole from collapsing, reinforces the hole for completions operations, and allows a long term conduit for producing. . Depending upon the horizons traversed by the well, different techniques may be needed, such as to prevent degradation of the well bore, collapse of the rock, sand, mud or other materials comprising the well bore, and to access the horizons of commercial interest. Conventional casing techniques often include running a tubular casing string into the well

following drilling. Such casing strings are typically made of steel and perform adequately in most applications, in some cases, however, it may be difficult or impossible, or economically infeasible to case extended sections of the well. This is particularly true of off-horizontal sections of a well (e.g., resulting from directional drilling), where forces on the casing string are influenced both by the formations and the resistance to advancement of the casing (e.g., due to its weight and any deviations or tortuosity of the hole that may exist in the wellbore).

[0005] In some cases, reamers, tools, shoes, guides, and other structures have been used or proposed to aid in deploying rigid casing in sections of wells. Some of these may be designed to be drilled through. Others act as guides for the actual casing, but do not, and are not intended to themselves form any permanent part of the well casing. Indeed, given their construction, dimensions, and placement, they may be wholly unsuitable for use as actual casing.

[0006] There is a need, therefore, for improved approaches to casing extended sections of wells, and particularly in extents that cannot be reached by conventional casing running methods.

BRIEF DESCRIPTION

[0007] In accordance with one aspect of the disclosure, a system comprises a tubular casing section comprising a first material and extending through a first section of a subterranean well, and a toe casing section coupled to the lower end of the tubular casing section and extending into the furthest section of open hole of the well, the toe casing section comprising a second material different from the first material, wherein both the tubular casing section and the toe casing section comprise production casing once the well is completed for the production of hydrocarbons from the well.

[0008] The disclosure also provides a system comprising a tubular casing section comprising a first material and extending through a generally vertical section of a subterranean well and into a portion of an off-vertical section of the subterranean well

continuous with the vertical section, and a toe casing section coupled to the distal end of the tubular casing section and extending into the furthest section of open-hole , the toe casing section comprising a second material different from the first material, wherein both the tubular casing section and the toe casing section comprise production casing once the well is completed for the production of hydrocarbons from the well.

[0009] Furthermore, the disclosure provides a method comprising assembling a toe casing section comprising a toe casing material, deploying the toe casing section into a well, assembling a casing section comprising a casing material different from the toe casing material, the toe casing section being secured to an upper section of casing, and deploying the whole casing into the well to set the toe casing section into the end of the open-hole section of the well, wherein both the tubular casing section and the toe casing section comprise production casing once the well is completed for the production of hydrocarbons from the well.

DRAWINGS

[0010] These and other features, aspects, and advantages of the present invention will become better understood when the following detailed description is read with reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

[0011] FIG. 1 is a diagrammatical representation of an example installation for drilling, completing, or servicing a well in accordance with the present techniques;

[0012] FIG. 2 is a diagrammatical representation of a sections of a tubular string extending into a well and including the toe casing section;

[0013] FIG. 3 is a diagrammatical representation of a toe casing section inserted into a section of a well; and

[0014] FIG. 4 is a flow chart illustrating example operations for deploying a toe casing section into a well.

DETAILED DESCRIPTION

[0015] Turning now to the drawings, and referring first to FIG. 1, a well system is illustrated and designated generally by the reference numeral 10. The system is illustrated as an onshore operation located on the earth's surface 12 although the present techniques are not limited to such operations, but may be used in offshore applications, in which the drilling and service equipment and systems described would be located on a vessel or platform, and the well would be located below a body of water. In FIG. 1, the underlying ground or earth is illustrated below the surface such that well equipment is positioned near or over one or more wells. One or more subterranean horizons 16 are traversed by the well, which ultimately leads to one or more horizons of interest 18. The well and associated equipment permit, for example, accessing and extracting the hydrocarbons located in the hydrocarbon zones of interest, depending upon the purpose of the well. In many applications, the horizons will hold hydrocarbons that will ultimately be produced from the well, such as oil and/or gas. The well equipment may be used for any operation on the well, such as drilling, completion, workover, and so forth. In many operations the installation may be temporarily located at the well site, and additional components may be provided.

[0016] In the simplified illustration of FIG. 1, equipment is very generally shown, but it will be understood by those skilled in the art that this equipment is conventional and is found in some form in all such operations. For example, a derrick 14 allows for various tools, instruments and tubular strings to be assembled and lowered into the well, traversing both the horizons 16 and the particular horizons of interest 18. Well or surface equipment 20 will typically include draw works, a rotary table, generators, instrumentations, and so forth. Control and monitoring systems 22 allow for monitoring all aspects of drilling, completion, workover or any other operations performed, as well as well conditions, such as pressures, flow rates, depths, rates of penetration, and so forth.

[0017] In accordance with the present disclosure, many different tubular stocks may be provided and used by the operation, and these may be stored on any suitable racks or

other storage locations. In FIG. 1 a first of these is designated tubular 1 storage 24, and the second is designated tubular 2 storage 26. As will be appreciated by those skilled in the art, such tubular products may comprise lengths of pipe with connectors at each end to allow for extended strings to be assembled, typically by screwing one into the other, or two tubular products connected via a single coupling. Different tubular stocks are used here to allow the operation to balance the technical qualities and performance possibilities of each against their costs. That is, one material may be selected for its relative strength but lower cost (e.g., steel), while the other is selected based upon its superior ability, such as low density and modulus, to be inserted into extended portions of the well, although it may be more costly than the first material. In presently contemplated embodiments, this second tubular stock may comprise, aluminum alloys, for example, but possibly also certain titanium alloys, composite materials, or metal matrix alloys. As discussed below, the operation judiciously selected which material to use based upon the nature of the well, the well position and geology, and the relative need to extend tubular strings into portions of the well that may not be readily accessed by conventional casing sections.

[0018] In the illustration of FIG. 1, a well comprises a first, generally vertical section 28 that extends through the upper horizons 16, and an off-vertical section 30 that extends through at least a portion of the zone of interest 18. The vertical section is formed to access the horizon of interest, and may extend to any desired depth, such as 7,000 feet to 12,000 feet.. The off-vertical section may extend at any desired angle from the vertical section, which may be generally perpendicular to the vertical section, although other angles for this section may be used. In practice, a well or a well system may access a number of locations in one or more horizons of interest by directional drilling to create one or more such off-vertical sections. A casing 32 is illustrated as already deployed in the well. This casing may be at least partially surrounded by cement 34 after it is set, to fortify at least part of the well and to secure the casing in the zone of interest. As will be appreciated by those skilled in the art, the casing and cement sections may differ from

well to well depending upon such factors as the geology of the subterranean horizons, the sizes desired, the anticipated conditions (e.g., pressures and flow) and so forth.

[0019] Near the end of the well, which will typically be in the off-vertical section 30, an open hole section 36 extends into the horizon of interest. In some wells, as discussed below, although ideally the well has a straight, controlled topology, in practice, the hole through the zone of interest will rise and fall, “snaking” through the formation, often referred to as ‘tortuosity’. In the illustration of FIG. 1, the casing extends to an end or limit 38 beyond which it may be very difficult or impossible, or very expensive to move conventional casing further into the drilled open hole.

[0020] It should be noted that, unlike simple inserts or guides, as used here the term “casing” is intended to convey that tubular section(s) are inserted permanently into the wellbore, may be cemented in place, and serve for both booking of reserves and for production from the well, such as by extraction of hydrocarbons (e.g., by perforation of the toe casing section(s) in at least one location).

[0021] In this illustrated embodiment, the casing 32 extends a length 40 through the vertical section 28 of the well and through a portion of the off-vertical section 30 to the limit 38. The casing comprises a tubular string that is run into the well following drilling. Such strings may comprise any suitable length of tubular products, and these will depend upon a number of factors, but typically the location of the horizon of interest (e.g., its depth and the length of the off-vertical section, the distance to a location of interest), the depth of the water, if offshore, and so forth. In the illustration of FIG. 1, the tubular casing extends into the open hole section 36 and includes a toe casing section 44. The casing may include a casing shoe 46 to help navigate the casing through the open hole section. A heel 48 in the tubular string will be formed where the build section transitions into the horizontal section.

[0022] The tubular string defined by the casing 32 and the toe casing 44 will typically be assembled by the well equipment, drawing from the tubular materials stored as discussed

above. That is, once the well is drilled, the casing sections may be assembled by taking the casing sections from the storage, threading them end-to-end, and deploying them progressively into the well. Once the desired length of toe casing is assembled, the upper casing is added to the toe casing by accessing the other tubular material and assembling sections of it end-to-end in a similar manner. In presently contemplated embodiments, for example, the toe casing 44 may be made of aluminum alloy, or another material that enables the casing to be more easily run into the open-hole section of the well, by decreasing frictional forces on the casing, and increasing hook load (e.g., titanium alloy, composite material, metal matrix alloys). The upper casing 32 may be made of conventional materials, such as steel. The tubular sections assembled in this way may comprise, for example, multiple sections of standard length (e.g., 40 foot sections) each having industry standard end connectors to facilitate their assembly. By way of example only, while the vertical section of the well may extend as much as 7,000 to 12,000 or more feet vertically into the earth (note that the “vertical” section need not be strictly vertical, but may be inclined in at least a part of the well), the off-horizon section may extend another 5,000 to 20,000 feet. The toe casing section thus will be set in the furthest portion of the open-hole section. It is presently contemplated that the toe casing section 44 may be from 100 to 1,000 feet in length, although any suitable length may be used.

[0023] FIG. 2 represents a section of toe casing as it might be deployed in a well. As shown, the toe casing section 44 will have a casing shoe 46 at an end to assist in advancing the casing through the open hole. Here again, the total length 52 of the toe casing may vary depending upon the well profile and the length of the open-hole section.

[0024] FIG. 3 illustrates the toe casing 44 deployed in the open-hole section of the well. As will be appreciated by those skilled in the art, although the well bore may be represented as a generally straight shaft, this will rarely be the case. In many wells, the well will have side walls 54 that undulate or wind through the horizon due to many factors, particularly the geology of the surrounding formations and drilling practices and equipment used. Variability in the wellbore walls, indicated generally by reference

numeral 56, may cause serious challenges in advancing conventional casing. In conventional approaches, special costly tools and techniques may be employed to rotate the casing, although these ultimately reach a limit beyond which further advancement is not cost effective. The toe casing made of a material such as an aluminum alloy, a titanium alloy, or a composite material, metal matrix alloy, on the other hand, may be more easily advanced into extended sections of open hole by the flexibility and lighter weight of the material of the toe casing, as indicated generally by reference numeral 58 in FIG. 3. It should be noted that while FIG. 3 illustrates some space between the toe casing and the well bore for clarity, in actual wells there is minimal clearance, and the toe casing may be tightly surrounded by the local formation, following its contour and topology through the extent of the open-hole section. In presently contemplated embodiments, the toe casing may have an outer diameter of between about 3" and 18" and wall thickness between .25" and 1.5". Other or multiple dimensions may, of course, be used.

[0025] It is contemplated that the toe casing made of the materials disclosed may realize advantages for a number of reasons. Although the tubulars made of such materials may be more costly than conventional casing, they may reduce or eliminate the need for special tooling and techniques for forcing and turning the casing. Moreover, the toe casing may produce a buoyant effect by which the casing may be lifted somewhat in the hole, reducing drag and friction by virtue of its lighter weight. Further, such materials will have a lower modulus of elasticity and density, allowing some degree of flexibility to follow more tortuous contours of the well bore. Finally, the ability to case the well along extended sections of open-hole may allow operators to produce oil and gas that would otherwise be inaccessible if the casing did not reach total depth.

[0026] Suitable materials for the toe casing may include, for example 2000 and 7000 series aluminum alloys, titanium alloys, and metal matrix composites. By way of further example, the toe casing section(s) may be made of materials that have significantly different material properties than the conventional casing used in the rest of the well application. In the case of conventional steel casing, for example, expected or

example densities may be on the order of 0.283 lb /in³ (+/- 8%), with a modulus of elasticity on the order of 29.5 x 10⁶ psi (+/- 10%). Presently contemplated materials for the toe casing section(s) (e.g., aluminum and aluminum alloys, titanium and titanium alloys, metal and other composites) may have densities on the order of 0.070 - .180 lb / in³, with a modulus of elasticity on the order of 4 x 10⁶ – 19 x 10⁶ psi. It is believed that the combination of these two material properties, that is, the density and the modulus of elasticity, combined, offer the greatest advantage in terms of the ability to adapt and conform to the wellbore, and still serve as a true casing section in the completed well.

[0027] Example operations for use of the disclosed toe casing are summarized in FIG. 4. The process 60 will typically begin with drilling or otherwise accessing a well, such as during a workover operation. In general, these initial operations, including drilling, casing and cementing surface and intermediate sections of the well are indicated by reference numeral 62. Sections of the well may then be drilled to access one or more target zones, as indicated by operation 64. Production casing may then be run into the well, including assembly and running in of the toe casing as discussed above, and as indicated by operation 66. Again, this may entail assembling a number of sections of tubular sections made of the toe casing material. As the toe casing is then lowered into the well, upper sections of casing, made of a conventional material and assembled in a conventional manner, extend the casing through the well. As discussed above, this operation may comprise progressively deploying the toe casing and the upper casing sections in the well to partially or fully case the open-hole section. Thereafter, other applicable completion operations and eventual production may be performed, as indicated by reference numeral 68.

[0028] While only certain features of the invention have been illustrated and described herein, many modifications and changes will occur to those skilled in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the invention.

CLAIMS:

1. A system comprising:
a tubular casing section comprising a first material and extending through a first section of a subterranean well; and
a toe casing section coupled to a lower end of the tubular casing section and extending into an open-hole section of the subterranean well, the toe casing section comprising a second material different from the first material,
wherein both the tubular casing section and the toe casing section comprise production casing once the well is completed for the production of hydrocarbons from the well.
2. The system of claim 1, wherein the first material comprises steel, and the second material comprises an aluminum alloy.
3. The system of claim 1, wherein the toe casing section has a nominal length of 20 feet.
4. The system of claim 2, wherein the toe casing section has a length sufficient to assist the whole casing string to reach desired depth.
5. The system of claim 1, wherein the toe casing section comprises a plurality of modular sections having a nominal length of 10 to 45 feet.
6. The system of claim 1, wherein the toe casing section has an outer diameter of at least about 3 inches to 36 inches.
7. The system of claim 5, wherein the toe casing section has a wall thickness of between about 0.25 inches to 1.5 inches.

8. The system of claim 1, wherein the toe casing section comprises a casing shoe.

9. The system of claim 1, wherein the open-hole section is off-vertical and the toe casing section extends at least 5,000 to 20,000 feet into the off-vertical open-hole section.

10. A system comprising:

a tubular casing section comprising a first material and extending through a generally vertical section of a subterranean well and into a portion of an off-vertical section of the subterranean well continuous with the vertical section; and

a toe casing section coupled to a distal end of the tubular casing section and extending into an open-hole section of the off-vertical section beyond a limit of the casing section, the toe casing section comprising a second material different from the first material,

wherein both the tubular casing section and the toe casing section comprise production casing once the well is completed for the production of hydrocarbons from the well.

11. The system of claim 10, wherein the first material comprises steel, and the second material comprises an aluminum alloy.

12. The system of claim 10, wherein the toe casing section has a nominal length of 20 feet.

13. The system of claim 10, wherein the toe casing section has an outer diameter of at least about 3 inches to 36 inches.

14. The system of claim 13, wherein the toe casing section has a wall thickness of between about 0.25 inches to 1.5 inches.

15. The system of claim 10, wherein the toe casing section comprises at least one casing shoe.

16. The system of claim 10, wherein the toe casing section extends at least 5,000 to 20,000 feet into the off-vertical open-hole section.

17. A method comprising:
assembling a toe casing section comprising a toe casing material;
deploying the toe casing section into a well;
assembling a casing section comprising a casing material different from the toe casing material, a lower end of the casing section being secured to an upper end of the toe casing section;
deploying the casing section into the well to set the toe casing section into an open-hole section of the well,
wherein both the tubular casing section and the toe casing section comprise production casing once the well is completed for the production of hydrocarbons from the well.

18. The method of claim 17, wherein the open-hole section is generally off-vertical.

19. The method of claim 17, wherein the toe casing section comprises at least one casing shoe.

20. The method of claim 17, wherein the toe casing material comprises an aluminum alloy and the casing material comprises steel.