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**Abstract:** A drilling apparatus including a first cylindrical layer including a plurality of cylindrical members, and a second cylindrical layer including a plurality of elongate members, the plurality of cylindrical members and the plurality of elongate members arranged to form a plurality of spaces between an outer diameter of the first cylindrical layer and an inner diameter of the second cylindrical layer.
before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))
LINER DRILLING USING TEMPORARILY SEALED LINER

CROSS-REFERENCE TO RELATED APPLICATIONS


FIELD OF DISCLOSURE

[0002] The present disclosure relates generally to the field of drilling and processing of wells. More particularly, one or more embodiments relate to oil and gas well drilling while simultaneously installing a liner in the well bore.

BACKGROUND

[0003] Oil and gas wells are conventionally drilled with drill pipe to a certain depth, then casing is run and cemented in the well. The operator may then drill the well to a greater depth with drill pipe and cement another string of casing. In this type of system, each string of casing extends to the surface wellhead assembly.

[0004] In some well completions, an operator may install a liner rather than another string of casing. The liner is made up of joints of pipe in the same manner as casing. Also, the liner is normally cemented into the well. However, the liner does not extend back to the wellhead assembly at the surface. Instead, it is secured by a liner hanger to the last string of casing just above the lower end of the casing. The operator may later install a tieback string of casing that extends from the wellhead downward into engagement with the liner hanger assembly.

[0005] When installing a liner, in most cases, the operator drills the well to the desired depth, retrieves the drill string, then assembles and lowers the liner into the well. A liner top packer may also be incorporated with the liner hanger. A cement shoe with a check valve will normally be secured to the lower end of the liner as the liner is made up. When the desired length of liner is reached, the operator attaches a
liner hanger to the upper end of the liner, and attaches a running tool to the liner hanger. The operator then runs the liner into the wellbore on a string of drill pipe attached to the running tool. The operator sets the liner hanger and pumps cement through the drill pipe, down the liner and back up an annulus surrounding the liner. The cement shoe prevents backflow of cement back into the liner. The running tool may dispense a wiper plug following the cement to wipe cement from the interior of the liner at the conclusion of the cement pumping. The operator then sets the liner top packer, if used, releases the running tool from the liner hanger, and retrieves the drill pipe.

SUMMARY

[0006] According to one aspect of the disclosure, there is provided a drilling apparatus including a first cylindrical layer including a plurality of cylindrical members, and a second cylindrical layer including a plurality of elongate members, the plurality of cylindrical members and the plurality of elongate members arranged to form a plurality of spaces between an outer diameter of the first cylindrical layer and an inner diameter of the second cylindrical layer.

[0007] According to another aspect of the disclosure, there is provided a drilling system including a drilling liner having a first cylindrical layer formed from a plurality of cylindrical members coupled in parallel, a second cylindrical layer formed from a plurality of elongate members coupled in parallel, the plurality of cylindrical members and the plurality of elongate members arranged to form a plurality of spaces between an outer diameter of the first cylindrical layer and an inner diameter of the second cylindrical layer, and a removable material impregnated in the plurality of spaces formed between the first cylindrical layer and the second cylindrical layer, and a drill bit coupled to the drilling liner.

[0008] According to another aspect of the disclosure, there is provided a method of manufacturing a drilling liner apparatus, the method including forming a first cylindrical layer having a first plurality of perforations formed therethrough, forming a second cylindrical layer having a second plurality of perforations formed
therethrough, in which the second plurality of perforations are in fluid communication
with the first plurality of perforations, and impregnating one or more of the first plurality of perforations and the second plurality of perforations with a removable material.

[0009] According to yet another aspect of the disclosure, there is provided a method of drilling including drilling a well bore to a pre-determined depth with a drill bit coupled to a drilling liner, the drilling liner having a plurality of perforations formed therethrough and a removable material impregnated in one or more of the plurality of perforations, removing the removable material impregnated in the plurality of perforations, and producing a production fluid, wherein the production fluid passes through the drilling liner.

[0010] Other aspects and advantages of the invention will be apparent from the following description and the appended claims. The various characteristics described above, as well as other features, will be readily apparent to those skilled in the art upon reading the following detailed description, and by referring to the accompanying drawings.

BRIEF DESCRIPTION OF DRAWINGS

[0011] FIG. 1 is a partial top view of a slotted liner in accordance with embodiments disclosed herein.

[0012] FIG. 2 is a perspective view of a plurality of elongate members in accordance with embodiments disclosed herein.

[0013] FIG. 3A is a partial top view of a slotted liner in accordance with embodiments disclosed herein.

[0014] FIG. 3B is a cross-sectional view of section A-B of the slotted liner of FIG. 3A.

[0015] FIG. 4A is a partial cross-sectional view of a first cylindrical layer of a slotted liner without a removable material impregnated in gaps formed therein in accordance with embodiments disclosed herein.
FIG. 4B is a partial cross-sectional view of a first cylindrical layer and a second cylindrical layer of a slotted liner with a removable material impregnated in gaps formed therein in accordance with embodiments disclosed herein.

DETAILED DESCRIPTION

It is now recognized that there exists a need for improved and different systems and methods for oil and gas well drilling. Accordingly, one or more embodiments of the present disclosure are directed to drilling apparatuses, methods, and systems for oil and gas well drilling while simultaneously installing a slotted liner in the well bore. Specifically, aspects of the present disclosure are directed to drilling apparatuses, methods, and systems to allow an oil and gas well to be drilled with a slotted liner such that the slotted liner does not need to be installed separately after the well bore is drilled.

The following is directed to various exemplary embodiments of the disclosure. Although one or more of these embodiments may be preferred, the embodiments disclosed should not be interpreted, or otherwise used, as limiting the scope of the disclosure, including the claims. In addition, those having ordinary skill in the art will appreciate that the following description has broad application, and the discussion of any embodiment is meant only to be exemplary of that embodiment, and not intended to suggest that the scope of the disclosure, including the claims, is limited to that embodiment.

Certain terms are used throughout the following description and claims that refer to particular features or components. As those having ordinary skill in the art will appreciate, different persons may refer to the same feature or component by different names. This document does not intend to distinguish between components or features that differ in name but not function. The figures are not necessarily to scale. Certain features and components herein may be shown exaggerated in scale or in somewhat schematic form and some details of conventional elements may not be shown in interest of clarity and conciseness.

In the following discussion and in the claims, the terms "including" and "comprising" are used in an open-ended fashion, and thus should be interpreted to mean "including, but not limited to ...." Also, the term "couple" or "couples" is
intended to mean either an indirect or direct connection. Thus, if a first component is coupled to a second component, that connection may be through a direct connection, or through an indirect connection via other components, devices, and connections. Further, the terms "axial" and "axially" generally mean along or parallel to a central or longitudinal axis, while the terms "radial" and "radially" generally mean perpendicular to a central longitudinal axis.

Additionally, directional terms, such as "above," "below," "upper," "lower," etc., are used for convenience in referring to the accompanying drawings. In general, "above," "upper," "upward," and similar terms refer to a direction toward the earth's surface from below the surface along a borehole, and "below," "lower," "downward," and similar terms refer to a direction away from the surface along the borehole, \textit{i.e.}, into the borehole, but is meant for illustrative purposes only, and the terms are not meant to limit the disclosure.

One or more embodiments of the present disclosure are directed to a drilling apparatus having a cylindrical layer, the cylindrical layer having a plurality of perforations formed therethrough, which may be referred to as a slotted liner. The plurality of perforations may be any openings, gaps, or spaces formed through the cylindrical layer such that a fluid may pass from an outer surface of the cylindrical layer through the cylindrical layer to an inner surface of the cylindrical layer, and vice versa. For example, the plurality of perforations may be holes or slots formed through the cylindrical layer or gaps or spaces formed between adjacent cylindrical layers.

Further, the drilling apparatus may include a removable material impregnated in one or more of the plurality of perforations; in some embodiments, the removable material may be impregnated in each of the plurality of perforations. In one or more embodiments, the removable material may be stable when exposed to, or in combination with, drilling fluid or pills that may be used. For example, the removable material may be chemically stable during drilling, thermally stable at drilling conditions, resilient with respect to frictional forces and other forces that may be encountered while drilling. The frictional forces and other forces that may be encountered while drilling may be caused by the formation, particles in drilling fluid, and rotational forces/bending forces of the downhole tool. Furthermore, the
removable material may be of high enough viscosity so as to not flow significantly under such expected downhole conditions.

[0024] Once drilling and emplacement of the liner is completed, it would then be necessary to remove the removable material. Thus, the removable material may also be dissolvable, depolymerizable, degradable or otherwise capable of being broken down and removed from the perforations or gaps when desired. For example, in one or more embodiments, the removable material may be a dissolvable polymer impregnated in the plurality of perforations. In one or more embodiments, the dissolvable polymer may be one of a water-stable polymer and an oil-stable polymer. In other words, the dissolvable polymer may be a polymer that does not break down or dissolve when exposed to water or oil based drilling fluids. For example, the removable material may be a water-stable, oil soluble polymer; after drilling with a water-based mud, an oil-based mud or solvent may be used to remove the removable material. In other embodiments, the dissolvable polymer according to embodiments disclosed herein may be a dissolvable polymer that does not break down or dissolve when exposed to either a water-based drilling mud or an oil-based drilling mud, but may be removed by other means, such as contact or exposure to select organic solvents, inorganic solvents, or other means of dissolving, depolymerizing, softening, or degrading of the polymer. As such, the removable material according to embodiments herein may include polymers, gels, or other chemical or physical networks that are water soluble, hydrocarbon soluble, thermally degradable, thermally unstable, photo-degradable and/or U/N degradable. For example, the removable material may include a cross-linked cellulosic network, an acid soluble polyamide, and other materials as may be readily envisioned based on the above description.

[0025] Furthermore, those having ordinary skill in the art will appreciate that the removable material of the present disclosure may be any material that is removable by way of exposure to a specific material or substance. For example, the removable material of the present disclosure may be a material removable by exposure to a specific removal material. In one or more embodiments, the removable material may be able to sustain high temperature and high pressure downhole conditions without breaking down or dissolving, while still being able to dissolve when exposed to a specific removal material, such as a solvent.
In one or more embodiments, the cylindrical layer may be a first cylindrical layer and the drilling apparatus may include a second cylindrical layer, which may be disposed within the first cylindrical layer. For example, in one or more embodiments, an outer diameter of the second cylindrical layer may be substantially equal to or smaller than an inner diameter of the first cylindrical layer. In other words, the second cylindrical layer may be configured to be disposed within the first cylindrical layer, or vice versa.

In one or more embodiments, the first cylindrical layer may be formed from a plurality of cylindrical members coupled in parallel having a first plurality of perforations formed therethrough. The cylindrical members may be of any cross-sectional shape, such as triangular, semi-circular, etc., as described later, formed to have an overall circular or helical structure having a height and a diameter. For example, the first cylindrical members may be rings formed from triangular wire, where multiple rings may be arranged to form a cylindrical structure, the first cylindrical layer. Further, in one or more embodiments, the first plurality of perforations may include gaps formed between each of the plurality of cylindrical members. In one or more embodiments, the plurality of cylindrical members may be coupled by way of spot welding. For example, the plurality of cylindrical members may be spot welded together to form the first cylindrical layer such that each of the elongate members extends in a direction that is parallel to one another, while leaving gaps between some or each of the plurality of elongate members such that fluid may pass between some or each of the plurality of elongate members. In one or more embodiments, gaps may not necessarily be formed between each and every elongate member of the first cylindrical layer. However, in one or more embodiments, gaps may be formed between each and every elongate member of the first cylindrical layer.

As discussed above, in one or more embodiments, the drilling apparatus may include a second cylindrical layer. In one or more embodiments, the second cylindrical layer may include a second plurality of perforations formed therethrough. Further, in one or more embodiments, the second cylindrical layer may be formed from a plurality of elongate members coupled in parallel having a second plurality of perforations formed therethrough. In one or more embodiments, the plurality of elongate members may be substantially similar to the plurality of cylindrical
members. For example, a cross-section of the plurality of cylindrical members may be substantially identical to a cross-section of the plurality of elongate members. Further, in one or more embodiments, the plurality of cylindrical members may be formed from substantially the same material as the plurality of elongate members. However, those having ordinary skill in the art will appreciate that the plurality of cylindrical members is not limited to being substantially similar to the plurality of elongate members. For example, while the cross-section of each of the first and the plurality of elongate members may be substantially identical, a length of each of the first and the plurality of elongate members may not necessarily be equivalent. Further, in one or more embodiments, the cross-section of each of the first and the plurality of elongate members may not necessarily be identical.

[0029] Further, in one or more embodiments, the second plurality of perforations may be in fluid communication with the first plurality of perforations. In other words, in an embodiment in which the drilling apparatus, e.g., the slotted liner, includes the first cylindrical layer and the second cylindrical layer disposed within the first cylindrical layer, a fluid, e.g., a production fluid or a drilling fluid, may pass from an outer surface of the first cylindrical layer through the drilling apparatus to an inner surface of the second cylindrical layer, and vice versa. The gaps formed between the cylindrical members and the elongate members may define a flow path from the first plurality of perforations to the second plurality of perforations.

[0030] In one or more embodiments, the removable material may be impregnated in the gaps formed in both the first cylindrical layer and the second cylindrical layer such that a fluid, e.g., a production fluid or a drilling fluid, may not pass from an outer surface of the first cylindrical layer through the drilling apparatus to an inner surface of the second cylindrical layer, and vice versa. For example, in one or more embodiments, the removable material may be impregnated in the gaps formed between each of the plurality of cylindrical members and the plurality of elongate members such that a fluid may not pass from an outer surface of the first cylindrical layer through the drilling apparatus to an inner surface of the second cylindrical layer, and vice versa.
As used herein, the term "perforations" may refer to openings formed through a drilling apparatus, e.g., a slotted liner. For example, a slotted liner formed from two cylindrical layers having perforations formed therethrough refers to openings formed through both the first cylindrical layer and the second cylindrical layer. Each of the first cylindrical layer and the second cylindrical layer may include "gaps" formed therein, e.g. formed between a plurality of cylindrical members and between a plurality of elongate members. As used herein, the "gaps" formed in each of the first cylindrical layer and the second cylindrical layer may form the "perforations" formed through the slotted liner. Further, in one or more embodiments, "spaces" may be formed between the first cylindrical layer and the second cylindrical layer. These "spaces" may be in fluid communication with the "gaps" formed in each of the first cylindrical layer and the second cylindrical layer may also form the "perforations" formed through the slotted liner.

Referring to FIG. 1, a partial top view of a slotted liner 100 according to embodiments disclosed herein is shown. As shown, the slotted liner 100 includes a first cylindrical layer 101 and a second cylindrical layer 102. As discussed above, the first cylindrical layer 101 may be formed from a plurality of cylindrical members 103 and the second cylindrical layer 102 may be formed from a plurality of elongate members 104. In some embodiments, the first cylindrical layer 101 may be formed of a continuous structure, such as a triangular wire, helically wrapped around the elongate members 104 of the second cylindrical layer 102 (thus, the cylindrical members 103 may be considered as a portion of the helix for the purposes of the additional discussions herein).

The plurality of cylindrical members 103 and the plurality of elongate members 104 may be coupled, such as by spot welding. For example, the plurality of cylindrical members 103 may be spot welded together to form the first cylindrical layer 101 such that each of the plurality of cylindrical members 103 extends in a direction that is parallel to one another, while leaving gaps (not shown) between some or each of the plurality of cylindrical members 103 such that fluid, e.g., a production fluid or a drilling fluid, may pass between some or each of the plurality of cylindrical members 103. Alternatively, in one or more embodiments, the first cylindrical layer 101 may be formed by casting. As such, the first cylindrical layer 101 of the present
Disclosure is not limited to being formed from coupling a plurality of cylindrical members 103, as the first cylindrical layer 101, which may include the plurality of cylindrical members 103, may be formed together, e.g., by way of a casting process.

Similarly, the plurality of elongate members 104 may be coupled together to form the second cylindrical layer 102 such that each of the plurality of elongate members 104 extends in a direction that is parallel to one another, while leaving gaps 106 between some or each of the plurality of elongate members 104 such that fluid, e.g., a production fluid or a drilling fluid, may pass between some or each of the plurality of cylindrical members 104. As discussed above, gaps may not necessarily be formed between each and every elongate member of the first cylindrical layer 101 and/or the second cylindrical layer 102. However, in one or more embodiments, gaps may be formed between each and every elongate member of the first cylindrical layer 101 and the second cylindrical layer 102. Alternatively, in one or more embodiments, the second cylindrical layer 102 may be formed by casting. As such, the second cylindrical layer 102 of the present disclosure is not limited to being formed from coupling a plurality of elongate members 104, as the first cylindrical layer 102, which may include the plurality of cylindrical members 104, may be formed together, e.g., by way of a casting process.

Each of the plurality of cylindrical members 103 and the plurality of elongate members 104 may have a triangular cross section. In other words, the cross-section of each of the plurality of cylindrical members 103 and the plurality of elongate members 104 is substantially triangular in cross section. Having triangular elongate members form the first cylindrical layer 101 and/or the second cylindrical layer 102 may result in substantially wedge-shaped gaps or spaces, e.g., gaps 106, formed between one or more triangular elongate members. As will be discussed further below, wedge-shaped spaces formed between the plurality of elongate members of the first cylindrical layer 101 and/or the second cylindrical layer 102 may prevent a removable material (not shown) from inadvertently escaping from the gaps or spaces formed between one or more triangular elongate members. However, those having ordinary skill in the art will appreciate that the cross-section of each of the plurality of cylindrical members and the plurality of elongate members, according to aspects described herein, is not limited to being triangular in shape. For example, the cross-
section of each of the plurality of cylindrical members and the plurality of elongate members may be circular, semi-circular, rectangular, pentagonal, hexagonal, octagonal, or any other shape.

[0036] The second cylindrical layer 102 may be disposed within the first cylindrical layer 101, and the second cylindrical layer 102 may be coupled to the first cylindrical layer 101. For example, the second cylindrical layer 102 may be coupled to the first cylindrical layer 101 by way of spot welding. At the interface of the first and second cylindrical layers, shown by the dotted circles in FIG. 1, the second cylindrical layer 102 may be coupled to the first cylindrical layer 101 by spot welding each of the plurality of elongate members 102, which form the second cylindrical layer 102, to one or more cylindrical members of the first cylindrical layer 101. However, those having ordinary skill in the art will appreciate that, in one or more embodiments, the first cylindrical layer 101 may be configured to be disposed in the second cylindrical layer 102, and the second cylindrical layer 102 may be coupled to the first cylindrical layer 101.

[0037] Referring to FIG. 2, a perspective view of a plurality of elongate members 204 according to embodiments disclosed herein is shown. As discussed above, each of the plurality of elongate members 204 may be a triangular elongate member. In other words, the cross-section of each of the plurality of elongate members 204 may be substantially triangular, which may result in wedge-shaped gaps formed between the elongate members 204. Further, the plurality of elongate members 204 may be arranged to form a cylindrical layer (not shown) such that each of the elongate members 204 extends in a direction that is parallel to one another, e.g., in the direction of axis 250, while leaving gaps, e.g., the gaps 106 from FIG. 1, between some or each of the plurality of elongate members 204 such that fluid, e.g., a production fluid or a drilling fluid, may pass between some or each of the plurality of elongate members 204. Furthermore, as discussed above, the plurality of elongate members 204 may be coupled together by way of spot welding.

[0038] In one or more embodiments, the cylindrical layer may be formed from a plurality of elongate members. For example, elongate members, such as elongate members 204, may be bent or curved to form the first cylindrical layer and/or the
second cylindrical layer. For example, in one or more embodiments, a plurality of elongate members may be bent or curved such that a length of the elongate members may substantially form a circumference of the first cylindrical layer, e.g., the first cylindrical layer 101 shown in FIG. 1. Alternatively, in one or more embodiments, elongate members may be truncated to be of even length, if necessary, and arranged to form the second cylindrical layer, e.g., the second cylindrical layer 102 shown in FIG. 1, such that the length of the elongate members substantially forms a height of the second cylindrical layer. Further, in one or more embodiments, the first cylindrical layer and/or the second cylindrical layer may be formed by way of a casting process and may not necessarily be limited to arranging, bending or curving the elongate members forming the first and/or second cylindrical layers. In other words, in one or more embodiments, each of the first cylindrical layer and the second cylindrical layer may be manufactured or formed as cylindrical layers.

[0039] Those having ordinary skill in the art will appreciate that the first and second cylindrical layers, the cylindrical members 203 and the elongate members 204, may be formed from any substantially rigid material known in the art. For example, in one or more embodiments, the cylindrical and elongate members may be formed from steel or any other substantially rigid material capable of withstanding high pressure, high temperature downhole conditions as well as the torque and other forces that may be encountered during the drilling process.

[0040] Referring to FIG. 3A, a partial top view of a slotted liner 300 according to embodiments disclosed herein is shown. As shown, the slotted liner 300 includes a first cylindrical layer 301 and a second cylindrical layer 302. In one or more embodiments, the first cylindrical layer 301 may be formed from a plurality of cylindrical members 303 and the second cylindrical layer 302 may be formed from a plurality of elongate members 304.

[0041] The plurality of cylindrical members 303 and the plurality of elongate members 304 may be coupled, such as by spot welding. For example, the plurality of cylindrical members 303 may be arranged to form the first cylindrical layer 301 such that each of the plurality of cylindrical members 303 extends in a direction that is parallel to one another, while leaving gaps (not shown) between some or each of the
plurality of cylindrical members 303 such that fluid, e.g., a production fluid or a drilling fluid, may pass between some or each of the plurality of cylindrical members 303. Similarly, the plurality of elongate members 304 may be arranged to form the second cylindrical layer 302 such that each of the plurality of elongate members 304 extends in a direction that is parallel to one another, while leaving gaps 306 between some or each of the plurality of elongate members 304 such that fluid, e.g., a production fluid or a drilling fluid, may pass between some or each of the plurality of cylindrical members 304. The members of the first and/or second cylindrical layers may then be coupled together, such as by spot welding, to form a cylindrical structure.

[0042] For example, the second cylindrical layer 302 may be coupled to the first cylindrical layer 301 by way of spot welding. As shown by the dotted circle in FIG. 3A, the second cylindrical layer 302 may be coupled to the first cylindrical layer 301 by spot welding each of the plurality of elongate members 302, which form the second cylindrical layer 302, to the first cylindrical layer 301. In one or more embodiments, the welding may be continuous welding and may be accomplished by resistivity welding.

[0043] As will be discussed further below, each of the gaps (not shown) formed in the first cylindrical layer and the gaps 306 formed in the second cylindrical layer may be impregnated with a removable material (not shown). The impregnated removable material may prevent fluid, e.g., a production fluid or a drilling fluid, from passing through the first cylindrical layer 301 and the second cylindrical layer 302. For example, a fluid, e.g., a drilling fluid, may be prevented from flowing from within the slotted liner 300, i.e., in an outward radial direction indicated by arrow 351, by the impregnated removable material. Further, a fluid, e.g., a production fluid, may be prevented from flowing into the slotted liner 300 from outside the slotted liner 300, i.e., in an inward radial direction indicated by arrow 352, by the impregnated removable material. Further, as will be discussed further below, the wedge-shaped geometry and orientation of each of the gaps may help retain the impregnated removable material within each of the gaps when the impregnated removable material is under fluid pressure in both the inward radial direction and the outward radial direction.
Referring to FIG. 3B, a cross-sectional view of section A-B of the slotted liner 300 of FIG. 3A is shown. As discussed above, in one or more embodiments, the plurality of cylindrical members 303 and/or the plurality of elongate members 304 may be bent or curved to form the first cylindrical layer 301 and the second cylindrical layer 302, respectively.

For example, as shown, a plurality of cylindrical members 303 forms a circumference of the first cylindrical layer 301. Further, as shown, the plurality of elongate members 304 may be arranged to form the second cylindrical layer 302 such that the length of each of the plurality of elongate members 304 substantially forms a height of the second cylindrical layer 302. In other words, as shown, the plurality of cylindrical members 303 extend in a first direction, and the plurality of elongate members 304 extend in a second direction, in which the first direction is substantially perpendicular to the second direction, although other angles of orientation between the first and second directions may be used.

As shown, each of the plurality of cylindrical members 303 and the plurality of elongate members 304 has a triangular cross section. In other words, the cross-section of each of the plurality of cylindrical members 303 and the plurality of elongate members 304 is substantially triangular. As discussed above, having triangular elongate members form the first cylindrical layer 301 and/or the second cylindrical layer 302 may result in substantially wedge-shaped gaps or spaces, e.g., gaps 305 and 306, formed between the first plurality of triangular elongate members 303 and the second plurality of triangular elongate members 304, respectively. In one or more embodiments, the wedge-shaped gaps formed between the cylindrical members and elongate members may prevent a removable material (not shown) from inadvertently escaping from the gaps or spaces 305, 306 formed between the cylindrical members 303 and the elongate members 304, respectively.

For example, as shown, the gaps 305 formed between each of the plurality of cylindrical members 303 are substantially wedge-shaped, in which an apex of each of the wedge-shaped gaps 305 is oriented near an outer diameter of the first cylindrical layer 301. In one or more embodiments, the apex of each of the wedge-shaped gaps 305 of the first cylindrical layer 301 may be considered the point of the wedge-shaped
gap 305, e.g., the corner of the triangle, which is most proximate to the outer diameter of the first cylindrical layer 301. Similarly, the gaps 306 formed between each of the plurality of elongate members 304 are substantially wedge-shaped, in which an apex of each of the wedge-shaped gaps 306 is oriented near an inner diameter of the second cylindrical layer 302. In one or more embodiments, the apex of each of the wedge-shaped gaps 306 of the second cylindrical layer 302 may be considered to be the point of the wedge-shaped gap 306, e.g., the corner of the triangle, which is most proximate to the inner diameter of the second cylindrical layer 302.

[0048] The wedge-shaped nature and orientation of the gaps 305 formed in the first cylindrical layer 301 may prevent a removable material (not shown) that may be impregnated in each of the gaps 305 formed in the first cylindrical layer 301 from escaping through the gaps 305 toward the outer diameter of the first cylindrical layer 301 such as due to pressure and/or friction as a result of drilling fluid circulation, formation fluids, or contact with the formation itself. In one or more embodiments, the normal force provided by the wedge structure may help contain the removable material within the gaps 305. For example, if the removable material is impregnated in each of the gaps 305 formed in the first cylindrical layer 301, a fluid, e.g., a drilling fluid, may not be able to escape from within the slotted liner 300 because the removable material may block fluid flow therethrough. In other words, the wedge-shaped nature and orientation of the gaps 305 of the first cylindrical layer 301 may help contain a fluid within the slotted liner 300 with the impregnated removable material, which may allow the slotted liner to function as a non-perforated liner or casing, i.e., by allowing mud to flow through the slotted liner 300 without fluid escaping through the gaps 305.

[0049] Similarly, the wedge-shaped nature and orientation of the gaps 306 formed in the second cylindrical layer 302 may prevent the removable material (not shown), which may also be impregnated in each of the gaps 306 formed in the second cylindrical layer 302, from escaping through the gaps 306 toward the inner diameter of the second cylindrical layer. In one or more embodiments, the normal force provided by the wedge structure may help contain the removable material within the gaps 306. For example, if the removable material is impregnated in each of the gaps 306 formed in the second cylindrical layer 302, a fluid, e.g., a production fluid, may
not be able to enter the slotted liner 300 from outside of the slotted liner 300 because the removable material may block fluid flow therethrough. In other words, the wedge-shaped nature and orientation of the gaps 306 of the first cylindrical layer 302 may help prevent a fluid from entering the slotted liner 300 with the impregnated removable material, which may allow the slotted liner to function as a non-perforated liner or casing, *i.e.*, by preventing fluids from entering the slotted liner 300 through the gaps 306 and flowing up through the slotted liner 300 to the surface.

[0050] However, those having ordinary skill in the art will appreciate that the gaps 305, 306 formed in the first cylindrical layer 301 and the second cylindrical layer 302, respectively, are not limited to being wedge-shaped. In one or more embodiments, the gaps 305, 306 may be tapered and may include a narrowing flow region which may be configured to help retain a removable material within the gaps 305, 306. For example, in one or more embodiments, the plurality of cylindrical members 303 of the first cylindrical layer 301 and/or the plurality of elongate members of the second cylindrical layer 302 may have a circular or semi-circular cross-section. These circular or semi-circular cross-sections may be arranged to form a tapered, narrowing flow region between adjacent elongate members in each of the cylindrical layers 302, 303, which may help retain the removable material within the gaps 305, 306.

[0051] In one or more embodiments, the impregnated removable material may be selectively dissolved or removed by way of exposure to a specific removal material or solvent. As such, in one or more embodiments, the impregnated removable material may be dissolved from within each of the gaps 305 and 306, which may then allow the slotted liner 300 to function as a slotted liner, *i.e.*, allow fluid to pass from an outer surface of the slotted liner 300 to an inner surface of the slotted liner 300, and vice versa. This may save valuable time in producing production fluids after drilling a well bore by using the slotted liner 300 to drill the well bore and being able to position the slotted liner 300 within the well bore while drilling the well bore instead of separately installing a slotted liner after the well bore is drilled.

[0052] Referring to FIG. 4A, a partial cross-sectional view of a first cylindrical layer 401 of a slotted liner 400 without a removable material (not shown) impregnated in gaps 405 formed therein according to embodiments disclosed herein is shown. As
shown, the first cylindrical layer 401 includes a first plurality of triangular elongate members 403 having wedge-shaped gaps 405 formed therebetween. Because no polymer is impregnated in the gaps 405, fluid is free to pass through the slotted liner 400, e.g., in the direction of arrows 410. Those having ordinary skill in the art will appreciate that fluid may also be free to pass through the slotted liner 400 in a direction that is substantially opposite to the direction of arrows 410. In other words, the gaps 405 may allow fluid to pass from an outer surface of the slotted liner 400 to an inner surface of the slotted liner 400, and vice versa.

[0053] Referring to FIG. 4B, a partial cross-sectional view of a first cylindrical layer 401 and a second cylindrical layer 402 of a slotted liner 400 with a removable material 420 impregnated in gaps 405, 406 formed therein according to embodiments disclosed herein is shown. As shown, the first cylindrical layer 401 is formed from a first plurality of members 403 having a triangular cross section, and the second cylindrical layer 402 is formed from a second plurality members 404 having a triangular cross section. Further, as shown, the gaps 405 are formed in the first cylindrical layer 401 between the plurality of members 403, and the gap 406 is formed in the second cylindrical layer 402 between the plurality elongate members 404.

[0054] In one or more embodiments, a removable material is disposed in one or more of the gaps 405, 406; in each of the gaps 405, 406 in other embodiments. The removable material 420 impregnated in each of the gaps 405, 406 may be a dissolvable polymer. Further, in one or more embodiments, the removable material 420 may be stable when exposed to, or in combination with, drilling fluid or pills that may be used. For example, the removable material 420 may be chemically stable during drilling, thermally stable at drilling conditions, resilient with respect to frictional forces and other forces that may be encountered while drilling. The frictional forces and other forces that may be encountered while drilling may be caused by the formation, particles in drilling fluid, and rotational forces/bending forces of the downhole tool. Furthermore, the removable material 420 may be of high enough viscosity so as to not flow significantly under such expected downhole conditions.
Once drilling and emplacement of the liner is completed, it would then be necessary to remove the removable material. Thus, the removable material 420 may also be dissolvable, depolymerizable, degradable or otherwise capable of being broken down and removed from the perforations or gaps when desired. For example, in one or more embodiments, the removable material 420 may be a dissolvable polymer impregnated in each of the plurality of perforations. In one or more embodiments, the dissolvable polymer may be one of a water-stable polymer and an oil-stable polymer. In other words, the dissolvable polymer may be a polymer that does not break down or dissolve when exposed to water or oil-based drilling fluids. For example, the removable material may be a water-stable, oil soluble polymer; after drilling with a water-based mud, an oil-based mud or solvent may be used to remove the removable material. In other embodiments, the dissolvable polymer according to embodiments disclosed herein may be a dissolvable polymer that does not break down or dissolve when exposed to either a water-based drilling mud or an oil-based drilling mud, but may be removed by other means, such as contact or exposure to select organic solvents, inorganic solvents, or other means of dissolving, depolymerizing, softening, or degrading of the polymer. As such, the removable material according to embodiments herein may include polymers, gels, or other chemical or physical networks that are water soluble, hydrocarbon soluble, thermally degradable, thermally unstable, photo-degradable and/or unsoluble. For example, the removable material may include a cross-linked cellulosic network, an acid soluble polyamide, and other materials as may be readily envisioned based on the above description.

Furthermore, those having ordinary skill in the art will appreciate that the removable material 420 may be any material that is removable by way of exposure to a specific material or substance. For example, the removable material 420 may be a polymer dissolvable by exposure to a specific solvent. In one or more embodiments, the dissolvable polymer may be able to sustain high temperature and high pressure downhole conditions without breaking down or dissolving, while still being able to dissolve when exposed to a specific solvent.

As shown, fluid flow is prevented from an outer surface of the slotted liner 400 to an inner surface of the slotted liner 400, and vice versa. As discussed above,
the wedge-shaped geometry and orientation of the gaps 405, 406 may help retain the impregnated removable material 420 within each of the gaps 405, 406 when the impregnated removable material 420 is under pressure in both the inward radial direction and the outward radial direction.

[0058] According to another aspect of the present disclosure, there is provided a drilling system. The drilling system may include a drilling liner having a first cylindrical layer formed from a plurality of cylindrical members coupled in parallel, the first cylindrical layer having gaps formed between each of the plurality of cylindrical members, and a removable material impregnated in the gaps formed between each of the plurality of cylindrical members of the first cylindrical layer, and a drill bit coupled, directly or indirectly, to the drilling liner.

[0059] Referring back to FIG. 4A, the slotted liner 400 includes a first cylindrical layer 401 formed from a plurality of cylindrical members 403 coupled in parallel. As shown, the first cylindrical layer 401 includes gaps 405 formed between each of the plurality of cylindrical members 403. In one or more embodiments, a removable material (not shown) may be impregnated in the gaps 405 formed between each of the plurality of cylindrical members 403 of the first cylindrical layer 401.

[0060] In one or more embodiments, the slotted liner 400 may be coupled to a drill bit (not shown). As such, the drill bit may be used to drill well bore, while also allowing the slotted liner 400 to be positioned while drilling. This may eliminate the need to separately install a slotted liner after a well bore is drilled because the slotted liner 400 may be coupled to the drill bit and may be set while drilling the well bore. Alternatively, in one or more embodiments, the slotted liner 400 may be coupled to a bottom hole-assembly (BHA), which may be used to drill the well bore. Moreover, in one or more embodiments, a drill bit or a BHA may be coupled to a drill string and may be disposed through the slotted liner 400.

[0061] Further, the drilling system may include a second cylindrical layer formed from a plurality of elongate members coupled in parallel, the second cylindrical layer having gaps formed between each of the plurality of elongate members, in which the second cylindrical layer is disposed within the first cylindrical layer, the second cylindrical layer is coupled to the first cylindrical layer, and the removable material is
also impregnated in the gaps formed between each of the plurality of elongate members.

[0062] Referring back to FIG. 4B, the slotted liner 400 also includes the second cylindrical layer 402 formed from the plurality of elongate members 404 coupled in parallel. As shown, the second cylindrical layer 402 includes gaps 406 formed between each of the plurality of elongate members 404. In one or more embodiments, a removable material 402 is impregnated in the gaps 405, 406 formed between each of the plurality of cylindrical members 403 of the first cylindrical layer 401 and between each of the plurality of elongate members 404 of the second cylindrical layer 402, respectively.

[0063] According to another aspect of the disclosure, there is provided a method of manufacturing a drilling liner apparatus. The method of manufacturing may include forming a first cylindrical layer having a first plurality of perforations formed therethrough, and impregnating each of the first plurality of perforations with a removable material.

[0064] The method of manufacturing may include, in other embodiments, forming a first cylindrical layer having a first plurality of perforations formed therethrough, forming a second cylindrical layer having a second plurality of perforations formed therethrough, in which the second plurality of perforations are in fluid communication with the first plurality of perforations. The method may also include impregnating one or more of the first and second plurality of perforations with the removable material so as to prevent or retard flow from the first to the second plurality of perforations or vice versa.

[0065] For example, in one or more embodiments, a first cylindrical layer may be formed from a substantially rigid material, e.g., steel, by way of forging, casting, injection-molding, or any other method. Further, perforations may be formed through the first cylindrical layer by way of cutting, punching, or drilling. Alternatively, in one or more embodiments, the first cylindrical layer may be formed with perforations already formed therethrough by way of molding or casting. Subsequently, a removable material, e.g., a dissolvable polymer 420 shown in FIG. 4B, may be impregnated into each of the plurality of perforations formed in the first cylindrical
layer. In one or more embodiments, the impregnation of the perforations may be
accomplished by submerging the first cylindrical layer into the dissolvable polymer,
by way of injection molding the dissolvable polymer into each of the plurality of
perforations, or any other method.

Further, according to one or more aspects of the method of manufacturing,
forming the first cylindrical layer may also include forming a plurality of cylindrical
members, coupling the plurality of cylindrical members in parallel to form a cylinder,
in which gaps are formed between each of the plurality of cylindrical members and in
which impregnating each of the first plurality of perforations includes impregnating
the gaps formed between each of the plurality of cylindrical members with the
dissolvable polymer. Furthermore, according to one or more aspects of the method of
manufacturing, forming the second cylindrical layer may also include forming a
plurality of elongate members, coupling the plurality of elongate members in parallel
to form a cylinder, in which gaps are formed between each of the plurality of elongate
members, disposing the second cylindrical layer within the first cylindrical layer,
coupling the first cylindrical layer to the second cylindrical layer, in which
impregnating each of the second plurality of perforations includes impregnating the
gaps formed between each of the plurality of elongate members with the dissolvable
polymer.

In one or more embodiments, forming the plurality of cylindrical members and
the plurality of elongate members may be accomplished by way of forging, casting,
injection-molding, or any other method. Further, as discussed above, coupling each
of the plurality of cylindrical members and the plurality of elongate members may be
accomplished by spot welding or by way of continuous welding, such as with
resistivity welding. Furthermore, as discussed above, in one or more embodiments,
the impregnation of the plurality of perforations may be accomplished by submerging
the first cylindrical layer and the second cylindrical layer into the dissolvable
polymer, by way of injection molding the dissolvable polymer into each of the
plurality of perforations, or any other method.

According to another aspect of the present disclosure, there is provided a
method of drilling. The method of drilling may include drilling a well bore to a pre-
determined depth with a drill bit coupled, either directly or indirectly, to a drilling liner, the drilling liner having a plurality of perforations formed therethrough and a removable material impregnated in each of the plurality of perforations, removing the removable material impregnated in each of the plurality of perforations, and producing a production fluid, in which the production fluid passes through the perforations of the drilling liner. In one or more embodiments, removing the removable material may include pumping a solvent configured to dissolve the removable material impregnated in each of the plurality of perforations.

[0069] As discussed above in reference to FIG. 4B, the slotted liner 400 may be coupled, either directly or indirectly, to a drill bit (not shown). As such, the drill bit may be used to drill well bore, while also allowing the slotted liner 400 to be positioned while drilling. As such, this eliminates the need to separately install a slotted liner after a well bore is drilled because the slotted liner 400 may be coupled to the drill bit and may be set while drilling the well bore. Alternatively, in one or more embodiments, the slotted liner 400 may be coupled to a bottom hole-assembly (BHA), which may be used to drill the well bore. Moreover, in one or more embodiments, a drill bit or a BHA may be coupled to a drill string and may be disposed through the slotted liner 400.

[0070] Embodiments disclosed herein may allow the slotted liner 400 to be used as both a non-perforated liner, which may be used to pump mud to the drill bit/BHA, and a perforated liner, which may be used to filter debris from production fluid. For example, while drilling, the perforations of the slotted liner 400 may be impregnated with the dissolvable polymer 420 such that drilling mud may be pumped through the slotted liner 400 to the drill bit/BHA without escaping through the perforations, which may be accomplished with assistance from the wedge-shaped geometry and orientation of the gaps formed in the slotted liner 400, as discussed above, in which the design of the gap, which may be perpendicular gaps, retains the removable material within the liner. In other words, by impregnating the perforations of the slotted liner 400 with the dissolvable polymer 420, the slotted liner 400 may function as a non-perforated liner or casing during the drilling process. Allowing mud to be pumped through the throughbore of the slotted liner 400 may help straighten the slotted liner 400 and may also prevent drill cuttings from u-tubing into the annulus
between the liner and the drill string/BHA. Once the slotted liner 400 is desirably positioned downhole, the specific solvent may be pumped through the slotted liner 400 to dissolve the impregnated dissolvable polymer 420. In one or more embodiments, the removal of the impregnated dissolvable polymer 420 by way of exposure to the specific solvent may soften, dilute, or acidize the dissolvable polymer 420 and may allow the dissolvable polymer 420 to circulate out of the perforations of the slotted liner 400.

[0071] Instead of taking the time to separately install a slotted liner after a well bore is drilled, a specific solvent may be pumped through the slotted liner 400, which may dissolve the dissolvable polymer impregnated in each of the plurality of perforations. This may allow the slotted liner 400 to be used to allow production fluid to pass into the interior of the slotted liner 400 and flow up toward the surface while debris, such as sand, gravel, etc., is be filtered by the slotted liner 400.

[0072] Although only a few example embodiments have been described in detail above, those skilled in the art will readily appreciate that many modifications are possible in the example embodiments without materially departing from this disclosure. Accordingly, all such modifications are intended to be included within the scope of this disclosure. In the claims, means-plus-function clauses are intended to cover the structures described herein as performing the recited function and not only structural equivalents, but also equivalent structures. Thus, although a nail and a screw may not be structural equivalents in that a nail employs a cylindrical surface to secure wooden parts together, whereas a screw employs a helical surface, in the environment of fastening wooden parts, a nail and a screw may be equivalent structures. It is the express intention of the applicant not to invoke 35 U.S.C. § 112, paragraph 6 for any limitations of any of the claims herein, except for those in which the claim expressly uses the words 'means for' together with an associated function.
What is claimed is:

1. A drilling apparatus comprising:
   a first cylindrical layer including a plurality of cylindrical members; and
   a second cylindrical layer including a plurality of elongate members, the plurality of
cylindrical members and the plurality of elongate members arranged to form a
plurality of gaps between an outer diameter of the first cylindrical layer and an
inner diameter of the second cylindrical layer.

2. The apparatus of claim 1, further comprising:
   a removable material impregnated in one or more of the plurality of gaps formed
between the outer diameter of the first cylindrical layer and the inner diameter
of the second cylindrical layer,
   wherein the plurality of cylindrical members and the plurality of elongate members
are arranged to retain the removable material in the plurality of gaps formed
between the outer diameter of the first cylindrical layer and the inner diameter
of the second cylindrical layer.

3. The apparatus of claim 2, wherein the removable material is one of a water-stable polymer
   and an oil-stable polymer.

4. The apparatus of claim 1, wherein the first cylindrical layer is formed from the plurality of
cylindrical members coupled in parallel and defining gaps formed between one or more of the
plurality of cylindrical members, and a removable material is impregnated in one or more of
the gaps formed between one or more of the plurality of cylindrical members of the first
cylindrical layer.

5. The apparatus of claim 4, wherein a cross-section of the plurality of cylindrical members is
   triangular.

6. The apparatus of claim 4, wherein the gaps formed between the plurality of cylindrical
   members are substantially wedge-shaped, wherein an apex of the wedge-shaped gaps is
oriented near an outer diameter of the first cylindrical layer.
7. The apparatus of claim 1, wherein the second cylindrical layer is formed from a plurality of elongate members coupled in parallel having gaps formed between one or more of the plurality of elongate members.

8. The apparatus of claim 7, wherein a cross-section of the plurality of elongate members is triangular.

9. The apparatus of claim 8, wherein the gaps formed between one or more of the plurality of elongate members are substantially wedge-shaped, wherein an apex of the wedge-shaped gaps is oriented near an inner diameter of the second cylindrical layer.

10. The apparatus of claim 7, wherein the second cylindrical layer is disposed within the first cylindrical layer, the second cylindrical layer is coupled to the first cylindrical layer.

11. The apparatus of claim 7, wherein the plurality of cylindrical members extend in a first direction, and the plurality of elongate members extend in a second direction, wherein the first direction is substantially perpendicular to the second direction.

12. A drilling system comprising:
   a drilling liner having a first cylindrical layer formed from a plurality of cylindrical members coupled in parallel, a second cylindrical layer formed from a plurality of elongate members coupled in parallel, the plurality of cylindrical members and the plurality of elongate members arranged to form a plurality of gaps between an outer diameter of the first cylindrical layer and an inner diameter of the second cylindrical layer, and a removable material impregnated in the plurality of gaps formed between the first cylindrical layer and the second cylindrical layer; and
   a drill bit coupled to the drilling liner.

13. The system of claim 12, wherein the removable material is a dissolvable polymer configured to dissolve through contact with a specific solvent.
14. A method of manufacturing a drilling liner apparatus, the method comprising:
   forming a first cylindrical layer having a first plurality of perforations formed therethrough;
   forming a second cylindrical layer having a second plurality of perforations formed therethrough, wherein the second plurality of perforations are in fluid communication with the first plurality of perforations; and
   impregnating one or more of the first plurality of perforations and the second plurality of perforations with a removable material.

15. The method of claim 14, wherein forming the first cylindrical layer comprises:
   forming a plurality of cylindrical members; and
   disposing a plurality of cylindrical members in parallel to form a cylinder,
   wherein impregnating one or more of the first plurality of perforations includes impregnating gaps formed between one or more of the plurality of cylindrical members with the removable material.

16. The method of claim 14, wherein forming the second cylindrical layer comprises:
   forming a plurality of elongate members; and
   disposing a plurality of elongate members in parallel to form a cylinder,
   wherein impregnating one or more of the second plurality of perforations includes impregnating gaps formed between one or more of the plurality of elongate members with the removable material.

17. The method of claim 14, further comprising:
   disposing the first cylindrical layer within the second cylindrical layer; and
   coupling the first cylindrical layer to the second cylindrical layer,
   wherein gaps are formed between one or more of the cylindrical members and between one or more of the plurality of elongate members.

18. The method of claim 14, wherein impregnating one or more of the first plurality of perforations includes one of submerging the first cylindrical layer into the removable material and molding the removable material into one or more of the first plurality of perforations.
19. A method of drilling comprising:

- drilling a well bore to a pre-determined depth with a drill bit coupled to a drilling liner, the drilling liner having a plurality of perforations formed therethrough and a removable material impregnated in one or more of the plurality of perforations;
- removing the removable material impregnated in one or more of the plurality of perforations; and
- producing a production fluid, wherein the production fluid passes through the drilling liner.

20. The method of claim 19, wherein the drilling liner includes a first cylindrical layer formed from a plurality of cylindrical members coupled in parallel, the first cylindrical layer having gaps formed between one or more of the plurality of cylindrical members, and the removable material impregnated in the gaps formed between one or more of the plurality of cylindrical members of the first cylindrical layer.
**INTERNATIONAL SEARCH REPORT**

**International application No.**
PCT/US2012/069815

**A. CLASSIFICATION OF SUBJECT MATTER**

**E21B 33/14(2006.01)i, E21B 17/01(2006.01)i**

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: E03B 3/18; E21B 33/14; E21B 43/08; E21B 43/10; E21B 43/11; E21B 43/24

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 data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & keywords: liner drilling, cylindrical, layer, elongate, gap, and removal material

**c. DOCUMENTS CONSIDERED TO BE RELEVANT**

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<th>Category*</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
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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
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Date of the actual completion of the international search
17 April 2013 (17.04.2013)

Date of mailing of the international search report
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Name and mailing address of the ISA/KR
Korean Intellectual Property Office
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Facsimile No. 82-42-472-7140

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LEE, Jong Kyung

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**Information on patent family members**

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